Runliang Dou *Editor*

Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation (IEMI2012)

EXTRA
MATERIALS
springerlink.com

Springer

Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)

Runliang Dou
Editor

Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation (IEMI2012)

Springer

Editor
Runliang Dou
College of Management and Economics
Tianjin University
Tianjin, China, People's Republic

Additional material to this book can be downloaded from http://extras.springer.com

ISBN 978-3-642-33011-7 ISBN 978-3-642-33012-4 (eBook)
DOI 10.1007/978-3-642-33012-4
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013930170

Printed on acid-free paper

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

Contents

Part II Assistive Technology of Industrial Engineering

Part I
Core Areas of Industrial Engineering

Chapter 1
Heavy Assembly Line Logistics System Based on RFID Applications

Jie Feng, Hai-ping Zhu, Fei He, and Yong-yi Wu

Abstract Based on the production logistics in one heavy industry enterprise, this paper describes the logistics operation mode of the assembly process, analyses and designs the operation mode. By taking the advantage of RFID technology in the secondary sorting process of materials, the automatic sorting method is proposed, which improves the sorting speed and accuracy.

Keywords Assembly line • Heavy industry • Intra logistics • Mode of operation • RFID

Introduction

Heavy manufacturing industry is a complex manufacturing industry which has its own characteristics as follows: discrete manufacturing; Multi-species and small quantities production; numerous material suppliers; frequent production change; lots of uncertainties affecting the production; high quality requirements and so on (Liling Jiang 2008). These characteristics of heavy industry make the intra logistics

J. Feng (✉) • Y.-y. Wu
Department of Industrial Engineering, Huazhong University of Science and Technology, Wuhan, Hubei 430074, China
e-mail: hbszfendjic@gmail.com

H.-p. Zhu
State Key Lab of Digital Manufacturing Equipment and Technology, Wuhan, Hubei 430074, China

HUST-SANY Joint Laboratory of Advanced Manufacturing Technology Key, Changsha, Hunan 410079, China

F. He
State Key Lab of Digital Manufacturing Equipment and Technology, Wuhan, Hubei 430074, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_1,

quite complicate. With the advancement of technology and development of economic, the completion between different industries becomes more and more fierce. In order to improve the competitiveness of enterprises, the intra logistics becomes a problem that can't be ignored (Chen Chenghe 2007).

This paper describes the logistics of a company truck production line. In order to meet the rapid growth of market demand, the heavy enterprise expands its production capacity, builds new logistics system in the production factory, and introduces automatic logistics equipment (Cochran and Kaylani 2008; Cochran and Kim 1998a, b). Combining with the advancing management method, the logistics efficiency and accuracy are greatly improved. By using proper logistics operation mode, the objectives of waving off the shelf, online sorting, single-station distribution and real time sending are achieved.

Intra Logistics Mode of Operation

There are two main mode of intra logistics operation, which are Push-type system and Pull-type system.

The push-type system can be described as a top-down planning system because all production quantity decisions are derived from forecasted demand in the master production schedule. The system produces as many parts as previously forecasted. The parts are released to the next station as quickly as possible to avoid starvation at the downstream stations (Cochran and Kim 1998b; Flapper et al. 1991). This characteristic enables the system to reduce delivery leadtime since many semi-finished or finished products are available. Medium to large variation of demand may not cause any chaos because semi-finished products are kept at each station. The push-type system is better for planning and controlling production activities. However, it causes high volume of work-in-process(WIP), both in the form of semi-finished and finished products (Beamon and Bermudo 2000). As a result, the system suffers from high inventory holding cost.

The pull-type system drives productions based upon customer demand (as opposed to forecasted demand). Each station can be viewed as an isolated station with its own supplier (the upstream station) and its own customer (the downstream station). When a customer order is placed, it will be fulfilled from the finished product inventory (Bushée and Svestka 1999). As soon as the finished product is pulled from this inventory, a signal (or kanban) is generated to trigger production of the upstream station in order to replenish the finished product inventory (Rafaelpast 2000; Lee 1993). Similar procedures take place until the first station, where it pulls raw material from the raw material storage. The pull-type system can reduce WIP significantly. However, the system may not work well in an environment with medium to large demand variation because there is not enough semi-finished inventory kept. This in turn may result in a significant backorder. In addition, the pull-type system often has longer delivery leadtime than that of the push-type system, thus higher delivery late penalty costs.

Introduction of Intra Logistics in a Corporate

Lean Logistics Strategy

The logistics department of an enterprise uses the MM(Material Management) module in the SAP system to achieve material management currently. It's prepared to re-development the materials management module to realize the standardization and accuracy of logistics.

The new factory plans to enhance the management of the logistics process on the basis of existing materials management, including logistics scheduling and vehicle scheduling. In order to enhance the timeliness and transparency of the material delivery process, the new factory will carry out sophisticated management. Currently, the logistics model which the department of enterprise is applying is procuring, stocking and distribution according to plan order, which almost utilize push mode.

In order to let the production logistics be leaner, in-time and more transparent, we proposed the following push-pull distribution mode (Fig. 1.1)

As shown above, materials that require sending to the line we can sample divide into three categories. The first one: according to the division's master production schedule, the suppliers distribute the materials to the space of secondary sorting, and then sent to the side of production line after sorted. The second one: according to the division's master production schedule, the suppliers distribute the materials to warehouse, and on the basis of planning to put the materials off from the shelf, and then sent to the side of production line when the materials are needed. The third one: the suppliers send the materials to the side of production line directly when the materials is needed.

In order to be a good combination, Push distribution and pull distribution is also need a system to support. The figure below shows how to allocate push and pull distribution task (Fig. 1.2).

Push logistics:

MRP logic. Accordance with the ERP of the next day plan, starting with BOM, dispatchers pick materials to the production line or sorting area In advance (Olhager and Ostlund 1990).

The above is generally used for: (1) Materials supply and consumption are relatively stable situation. (2) The situation of less dosage or special order.

With the standardization of production logistics, the first case can be gradually replaced by the JIT.

Pull logistics:

JIT logic. According to the actually order of sending materials to the production line in the MES, dispatchers can real-time ration materials to the side of the production line or sorting area (Spearman and Zazamis 1992; Takahashi and Nakamura 2004).

It is generally used for the materials of configuration differences and frequently used.

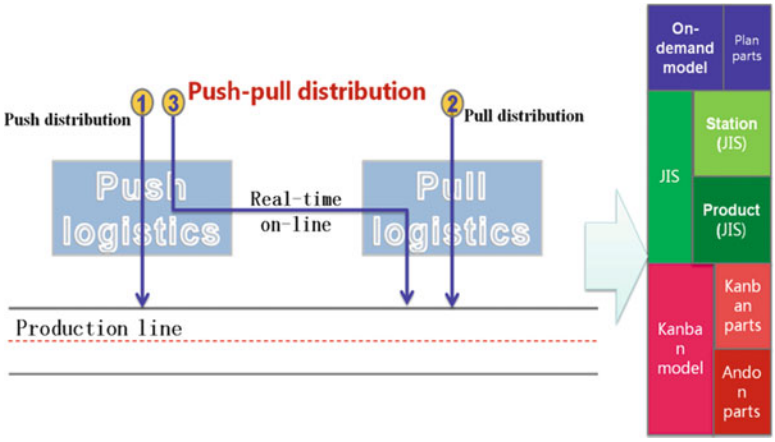


Fig. 1.1 Push-pull distribution

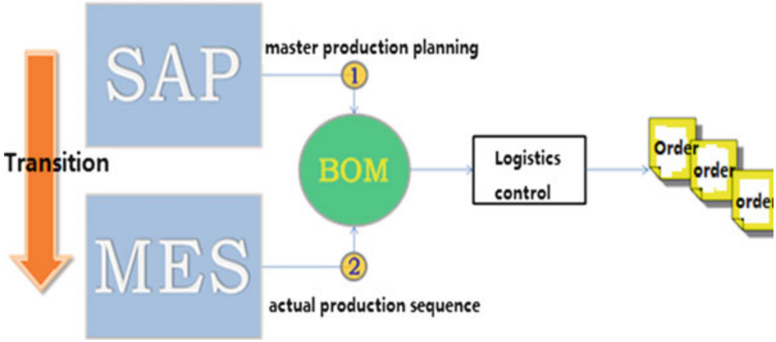


Fig. 1.2 Allocate push and pull distribution task

Intra Logistics Distribution Model

All logistics way in the 18th plant of the division are as shown below (Fig. 1.3):

1. According to production plan generated by the APS , LES will automatically generate the picking list, and then deliver to the various storages.
2. According to the picking list, the pickers start to picking.
3. The materials which need not secondary sorting from the stereoscopic warehouse is sent to conveyor by forklift truck, and then to production line by AGV.
4. The materials which need secondary sorting from the stereoscopic warehouse is sent to secondary sorting area by forklift truck, and then grouped with the other materials from other storage. After grouping, sent to conveyor by forklift truck, then sent to production line by AGV.

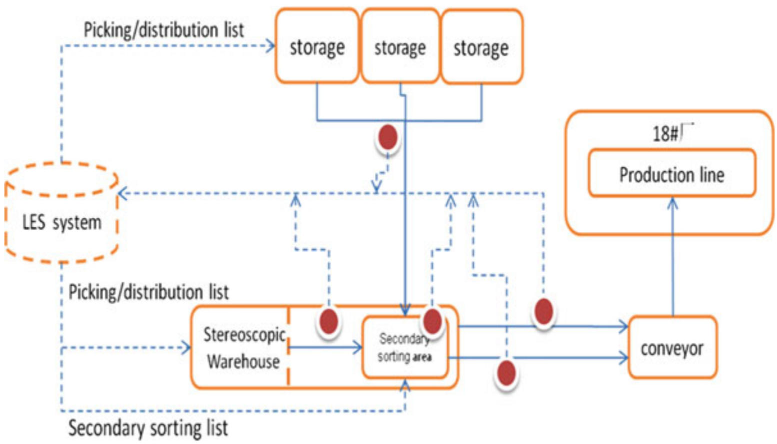


Fig. 1.3 Logistics way in the 18th plant of the division

5. The forklift smart distribution module of LES and the AGV system achieve the automated collaborative distribution throughout the whole distribution process.

The Difficulty of the Logistics Process

The most difficult in the whole logistics process is the material of the secondary sorting. The secondary sorting area is mainly used to group materials from the stereoscopic warehouse, other warehouses and suppliers direct supply materials.

However, secondary sorting area space is limited. There is no place to store the materials from the stereoscopic warehouse, which need group with the materials from other storage. The regional distribution of the secondary sorting area is as shown below (Fig. 1.4).

Materials of Group Based on RFID Applications

Introduction of RFID System

The Fig. 1.5 shows the process that RFID readers to write material information to the RFID tag.

1. The system will send the information of materials which is prepared to sort to the RFID reader.
2. RFID reader send the information to the RFID tags on the sorting small cart, through the wireless.

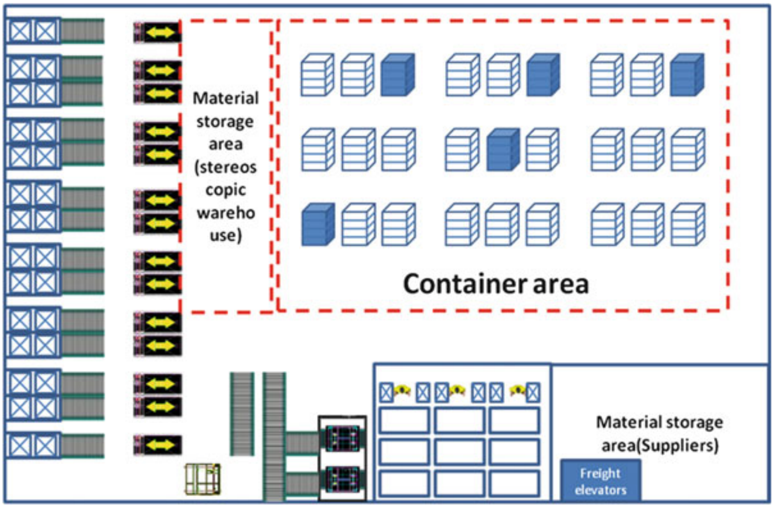


Fig. 1.4 The regional distribution of the secondary sorting area

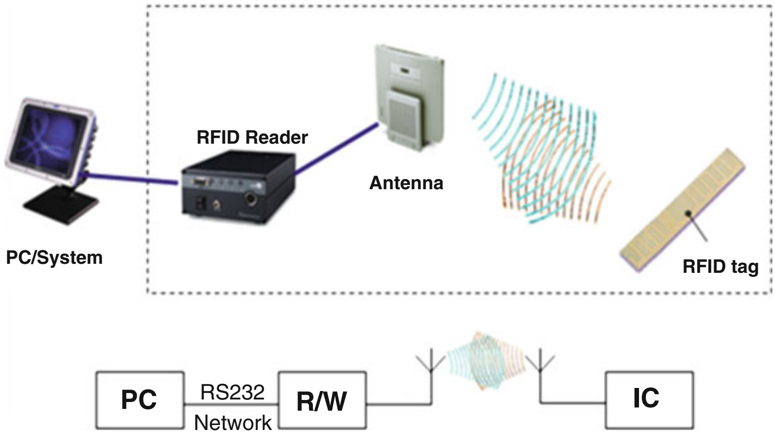


Fig. 1.5 The structure of RFID system

Group Process Based on the RFID Application

There is only one tray on a shelf in stereoscopic warehouse, materials place on the tray. One tray could be put one or more kinds of material, and each type of material does not have mark. The material from the stereoscopic warehouse need carry out a sorting, which let the material into the sorting cart and write material information into the RFID tags on the sorting cart (Fig. 1.6).

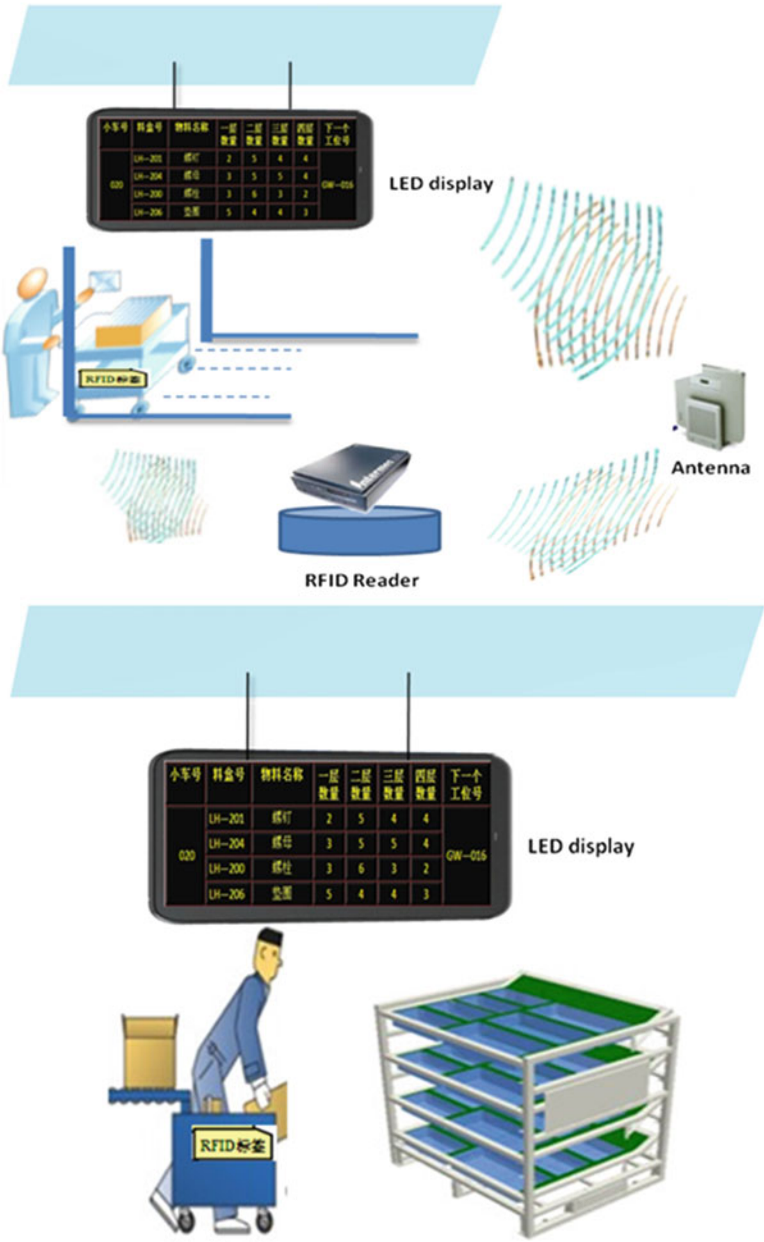


Fig. 1.6 The group process

The group process:

1. Sorting workers push the transport cart which carried full of materials to the entrance of group area.
2. When the sorting workers passed the entrance, the RFID reader at the entrance would read the information from the RFID tags on the cart.
3. After disposing by the background, the LED display at the entrance would show the group location where the sorting workers should to go. Then the works will go where the LED wanting him to go.
4. When the worker arrived the designated locations, the LED display at the designated location would show the sorting information.
5. After complete the sorting, the worker would press the LED control terminal to tell the system you have done.
6. The information showed by the LED display would be changed to next place the work should to go.
7. When the materials on the cart were all throw in the container, the LED display would show nothing.

Conclusion

The 18th plant of the division take the full use of push-pull distribution logistics, stereoscopic warehouse, AGV, RFID and so on, which greatly improve the logistics efficiency and make the materials stacked better beside the line.

In the material sorting process, the use of RFID technology make the material identification become more accuracy, and the identification distance become more flexible since its advantage of reading information without barrier. Combining the LED display, the secondary sorting speed is improved and the problem of insufficient sorting space is also solved.

Acknowledgments The authors greatly acknowledge the financial supports from the National Basic Research Program of China with the Grant number 2012AA040909, and the National Natural Science Foundation of China (NSFC) with the Grant number 51105157.

References

Beamon BM, Bermudo JM (2000) A hybrid push/pull control algorithm for multi-stage, multi-line production systems. Prod Plan Control 11(4):349–356

Bushée DC, Svestka JA (1999) A bi-directional scheduling approach for job shops. Int J Prod Res 37(16):3823–3837

Chen Chenghe (2007) Research on line balancing problem of manufacturing enterprises based on simulation optimization [D]. Poly technical University of Hefei, Hefei

Cochran JK, Kaylani HA (2008) Optimal design of a hybrid push/pull serial manufacturing system with multiple part types. Int J Prod Res 46(4):949–965

Cochran JK, Kim SS (1998a) Optimizing a serially combined push and pull manufacturing system by simulated annealing. In: Proceedings of the second international conference on engineering design and automation, session WA3B paper 5 on CD-ROM, Mani, HI, 9–12 Aug 1988, 5 p
Cochran JK, Kim S-S (1998b) Optimum junction point location and inventory levels in serial hybrid push/pull production systems. Int J Prod Res 36(4):1141–1155
Flapper SD, Miltenburg GJ, Wijngaard J (1991) Embedding JIT into MRP. Int J Prod Res 29 (2):329–341
Lee CY (1993) A recent development of the integrated manufacturing system: a hybrid of MRP and JIT. Int J Oper Prod Manag 13(4):3–17
Liling Jiang (2008) The research on the network planning of shipway assembly line and its simulation. Master's thesis[M], Shanghai Jiao Tong University
Olhager J, Ostlund B (1990) An integrated push/pull manufacturing strategy. Eur J Oper Res 45:135–142
Rafaelpast AC (2000) Assembly line balancing with work zone and station load time windows constrains[C]. In: Proceedings of the 2000 IEEE, International conference on robotics and automation, San Francisco, CA, Apr 2000, pp 2404–2409
Spearman ML, Zazamis MA (1992) Push and pull production systems: issues and comparisons. Oper Res 40(3):521–532
Takahashi K, Nakamura N (2004) Push pull, or hybrid control in supply chain management. Int J Comput Integr Manuf 17(2):126–140

Chapter 2
An Improved Variable M/T Method Based on Speed Estimation for Optical Incremental Encoders

Hui Wang and Jian-tao Pu

Abstract Optical incremental encoders are widely used for the speed measurements in motor servo systems due to low cost and high performance. But it is difficult to use the encoders when wide speed range, high accuracy and extremely short responding time are required at the same time in high performance servo systems. In this paper, an improved variable M/T method is introduced. In this method, both encoder pulse and high frequency clock pulse are counted in a variable interval which ensures the high measurement accuracy in both high speed and low speed. By speed estimation algorithm, the rapid response can be obtained even at very low speed.

Keywords Optical incremental encoder • Motor servo system • Speed measurement • Variable M/T method

Introduction

Optical incremental encoders are widely used as speed sensors on closed-loop speed control systems. With high noise immunity, low maintenance, and low cost, they are the preferred method for obtaining motor velocity information and are generally considered to be superior to direct current tachometers (Ekekwe et al. 2008). Optical incremental encoders produce two sequences of pulses with a 90° phase shift, which are called quadrature encoded pulses. As the motor rotating, the direction can be determined by detecting which of the two sequences is the leading sequence and the

H. Wang
Institute of Automation, Chinese Academy of Sciences, Beijing, China

Beijing Information Science & Technology University, Beijing, China

J.-t. Pu (✉)
College of Automation, Beijing Union University, Beijing, China
e-mail: pu.jiantao@hotmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_2, © Springer-Verlag Berlin Heidelberg 2013

speed can be determined by the pulse frequency. The speed accuracy is limited by the quantized speed measurement of the encoder, i.e. it is limited by the number of slits on the encoder disk (Merry et al. 2010). But higher resolution is limited by the manufacturing capacity and cost. Therefore a quadrupler is usually used to improve the encoder resolution which generates a decoded clock with four times frequency of each input sequence.

Counting the decoded clock during a constant sampling period can get the pulse frequency. However this method is not applicable at low speed since the pulses are not frequently produced and no pulse will be detected in some sampling periods (Lilit Kovudhikulrungsri and Takafumi Koseki 2006; Takafumi Koseki et al. 2010). An alternative way is to measure the time interval between two consecutive pulses (Lilit Kovudhikulrungsri and Takafumi Koseki 2006). The approach has high resolution at low speed but low resolution at high speed. Combination of these methods is proposed by Ohmae et al. in (1982). This method combines the advantages of each method with high accuracy in wide speed range. But it still can't solve the problem of long time delay at low speed even though the resolution at low speed is raised. In reference (Bonert 1983, 1989), the constant elapsed time (CET) method is proposed which measures the elapsed time between k successive pulses, and dynamically adjusts the value of k to obtain a near constant response time. E. Galvan et al. improve the aforementioned method by several adaptive techniques to maintain the accuracy of the results while preserving the short system response time (Hagiwara et al. 1992; Galvan et al. 1994, 1996; Bhatti and Hannaford 1997). In literature, kinds of microcontroller and ASIC are used to implement these techniques (Rull et al. 1999; Lygouras 2000; Sisinni et al. 2002; Tsai and Chen 2002). But the CET method uses a variable sampling interval so as to adapt accordingly to the motor speed each time which brings new problems in the design of the closed-loop controllers.

In this paper, a new approach of speed measurement is proposed for high accuracy in wide speed range. This approach is based on a speed estimation which takes account of the speed reference change during the speed measurement period. Therefore the accuracy maintains high in wide speed range with rapid response at the same time. It is particularly suitable for the advanced numerical control system or servo system in industry robots which have strictly rapid response and wide speed range requirements.

This paper is organized as follows: speed measurement techniques are introduced in section "Introduction". A new speed measurement approach is presented in details in section "Speed Measurement Techniques". Section "An Improved Variable M/T Method" shows the discussions, while section "Conclusion" gives the final conclusions.

Speed Measurement Techniques

The types of speed measurement techniques basically fall into four categories: M method counting with fixed sampling interval (clock-driven); T method counting in time between two consecutive encoder decoded clock pulses (encoder driven); M/T

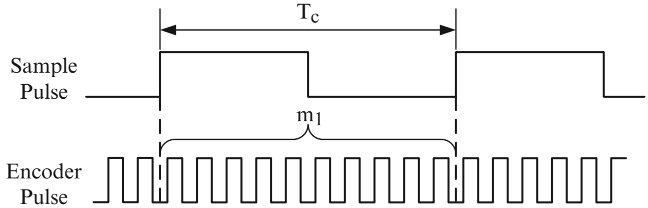


Fig. 2.1 Scheme of M method

method which is the combination of the two methods with fixed sampling interval; variable M/T method with a variable counting interval.

M Method

This method, shown in Fig. 2.1, is implemented by counting the encoder pulses m_1 produced in a fixed counting period – Tc (usually the system sampling period) and dividing by the counting period.

Setting the number of encoder pulse as Z per revolution, the motor speed is given by

$$n = \frac{60m_1}{ZT_c}. \tag{2.1}$$

As Z and Tc are constant, the motor speed n is proportional to the value of m_1, so called as M method. Obviously the maximum error will be one encoder pulse. The relative error is defined as the division of the absolute error by the true value and can be written as

$$\delta_{\max} = \frac{1}{m_1} \times 100\,\%. \tag{2.2}$$

Encoder pulse frequency is proportional to the motor speed, thus bigger value of m_1, i.e. lower relative error, will be gotten at high speed during a certain sampling period. So the M method is more applicable at medium and high speeds rather than at low speed, where the encoder pulses cannot be detected at every control period, as a result the accuracy will remarkably decline.

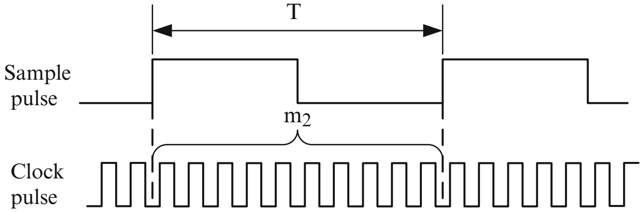


Fig. 2.2 Scheme of T method

T Method

Motor speed can be obtained by measure the time interval of the encoder cycle. That is to count pulses of a high-frequency clock between successive pulses of the encoder as shown in Fig. 2.2. This method involves measuring the encoder cycle T, so called as T method.

If f_0 is clock frequency, Z has the same significance as in M method and counter final value is m_2 as denoted in Fig. 2.2, the velocity can be expressed as

$$n = \frac{60 f_0}{Zm_2}. \tag{2.3}$$

Higher count value m_2 means longer T of encoder cycle, i.e. lower motor speed. The maximum error will be one clock pulse, so the relative error is given by

$$\delta_{\max} = \frac{1}{m_2 - 1} \times 100\,\%. \tag{2.4}$$

Equation (2.4) indicates that the bigger m_2, the lower error. The motor speed is inversely proportional to m_2. Therefore T method is preferred at low speed, but has unacceptable error at high speed.

M/T Method

Obviously in wide speed range neither M method nor T method is suitable, that is why M/T method is proposed. This method maintains the resolution by combining the advantages of each method. It measures not only encoder pulse but also the clock pulse in fixed sampling periods, as shown in Fig. 2.3.

Substituting $Tc = m_2/f_0$ for Tc in Eq. (2.1) gives the motor speed

$$n = \frac{60 f_0 m_1}{Zm_2}. \tag{2.5}$$

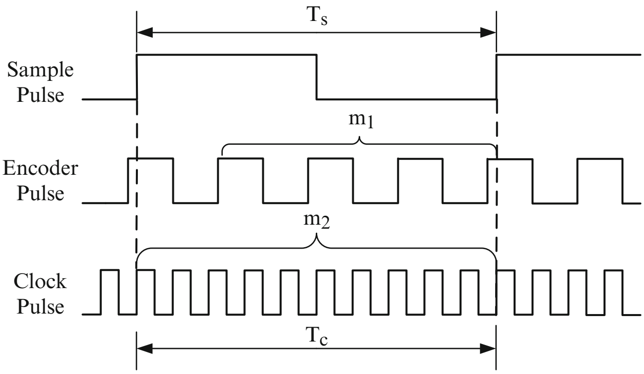


Fig. 2.3 Scheme of M/T method

M/T method greatly improves the accuracy at low speed and can be easily implemented by QEP unit of DSP. However it still can't deal with the problem of low encoder pulse frequency at very low speed and the system performance will deteriorate by intermittent speed feedback. To overcome this shortcoming, the variable M/T method comes into being.

Variable M/T Method

The difference between M/T method and variable M/T method lies in the counting time. For variable M/T method, counting time begins at the first rising edge of the encoder pulse in sampling period and finishes at the end of a whole encoder cycle in the current sampling period, as shown in Fig. 2.4.

In this method, the motor speed is given by the same equation as Eq. (2.5) of the M/T method. Attention to the trigger time of counting time Tc delaying the sampling time Ts at the rising edge of the encoder pulse following the current sampling period. This can bring two advantages. First, the number m_2 is counted in the period of m_1 complete encoder cycles. The error will be one clock pulse which is much shorter than encoder pulse. It can decrease the counting error effectively. Second, it unifies M method and T method in one method. At high speed shown in Fig. 2.4a, encoder frequency is larger than sampling frequency, Tc approximates Ts. In this case, variable M/T method has the same effect with M/T method and the relative error is nearly the same. As speed decreasing to a very low value that encoder cycle is much longer than sampling period, variable M/T method turns to be T method when m_1 equals to one. At that time variable M/T method has the same relative error with T method. Concisely variable M/T method can gain a high accuracy in quite wide speed range.

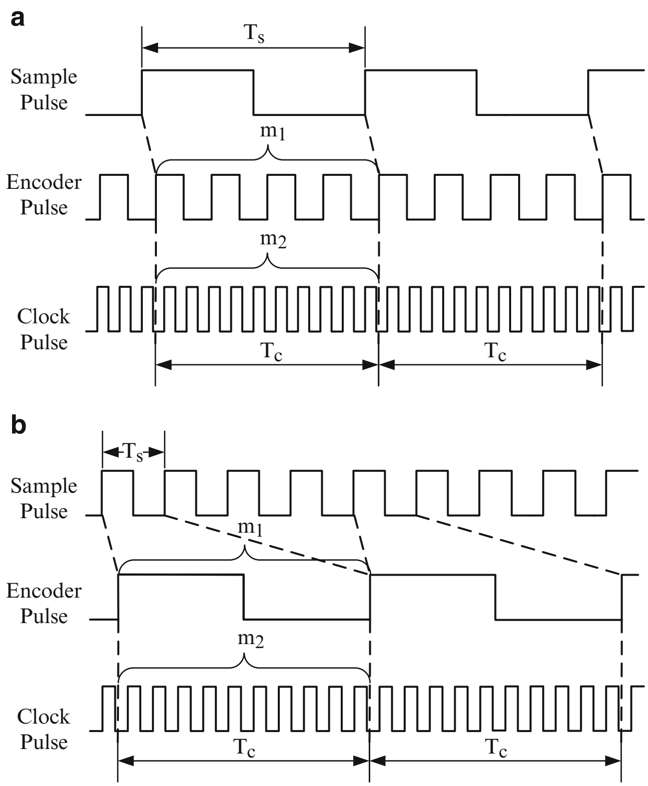


Fig. 2.4 Scheme of variable M/T method (**a**) At high speed (**b**) At low speed

An Improved Variable M/T Method

As T method, time delay is unavoidable in variable M/T method at low speed, since the counting time is much longer than sampling period and the calculated speed is the average value of the previous interval. There is not any information about speed during the counting interval. Using a zero-order holder or one-order holder is an easy solution to the problem. Bu it is not suitable for the applications with rapid changing references such as advanced numerical control machines and industry robots, since this speed measurement value of the previous counting interval has no information about the change of the speed reference during the current sampling period. The delay of the speed feedback will be unacceptable and will cause the system vibration.

An improved variable M/T method based on speed estimation will bring good performance which takes account of the speed reference change during the speed measurement period. The speed control loop scheme is shown in Fig. 2.5. Speed

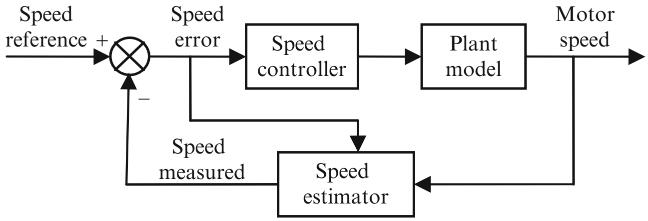


Fig. 2.5 Speed measurement using speed estimator

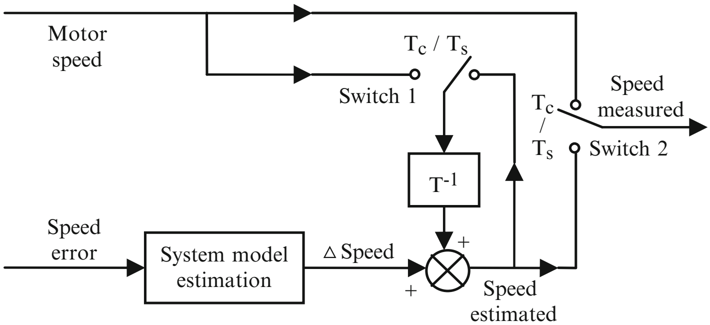


Fig. 2.6 Speed estimator framework

feedback comes form speed estimator which has two inputs, motor speed and speed error. The structure of speed estimator is shown in Fig. 2.6. If the counting period Tc just ends in the current sampling period, the counting Motor speed will be sent immediately to the estimator output with switch 2 connected up. At the same time switch 1 turns left to store the newest motor speed. Otherwise switch 2 connects down and the estimator output is speed estimated signal which is the sum of delta speed from the system model estimation and the previous motor speed by switch 1 turns to right. By this way the speed estimation will get to the controller during every sampling period between the counting periods. Therefore the accuracy maintains high in wide speed range with rapid response at the same time.

Conclusion

In this paper, an incremental encoder-based motor speed measurement has been described. It is based on variable M/T method which provides an alternative counting period between the system sampling period at high speed and encoder cycle at low speed, so that it can gain high accuracy for a wide speed range. At low speed it can obtain a higher accuracy, but the long counting time brings the sluggish system response. While the improved method with speed estimator can give the more accurate speed feedback and improve the performance at very low speed. For the advanced numerical control system or servo system in industry robots which have strictly rapid response and wide speed range requirements, improved variable M/T method is particularly suitable.

References

Bhatti P, Hannaford B (1997) Single-chip velocity measurement system for incremental optical encoders. IEEE Trans Control Syst Technol 5(6):654–661

Bonert R (1983) Digital tachometer with fast dynamic response implemented by a microprocessor. IEEE Trans Ind Appl IA-19(6):1052–1056

Bonert R (1989) Design of a high performance digital tachometer with a microcontroller. IEEE Trans Instrum Meas 38(6):1104–1108

Ekekwe N, Etienne-Cummings R, Kazanzides P (2008) A wide speed range and high precision position and velocity measurements chip with serial peripheral interface. Integr VLSI J 41 (2):297–305

Galvan E, Torralba A, Franquelo LG (1994) A simple digital tachometer with high precision in a wide speed range. Ind Electron Control Instrum 2:920–923

Galvan E, Torralba A, Franquelo LG (1996) ASIC implementation of a digital tachometer with high precision in a wide speed range. IEEE Trans Ind Electron 43(6):655–660

Hagiwara N, Suzuki Y, Murase H (1992) A method of improving the resolution and accuracy of rotary encoders using a code compensation technique. IEEE Trans Instrum Meas 41(1):98–101

Lilit Kovudhikulrungsri, Takafumi Koseki (2006) Precise speed estimation from a low-resolution encoder by dual-sampling-rate observer. IEEE/ASME Trans Mechatron 11(6):661–670

Lygouras JN (2000) Accurate velocity evaluation using adaptive sampling interval. Microprocess Microsyst 24(5):269–275

Merry RJE, van de Molengraft MJG, Steinbuch M (2010) Velocity and acceleration estimation for optical incremental encoders. Mechatronics 20:20–26

Ohmae T, Matsuda T, Kamiyama K, Tachikawa M (1982) A microprocessor-controlled high-accuracy wide-range speed regulator for motor drives. IEEE Trans Ind Electron IE-29 (3):207–221

Rull J, Sudria A, Bergas J, Galceran S (1999) Programmable logic design for an encoder-based velocity sensor in a DSP-controlled motion system. IEEE Int Conf Emerg Technol Fact Autom 2:1243–1247

Sisinni E, Flammini A, Marioli D, Taroni A (2002) A PLD based encoder interface with accurate position and velocity estimation. IEEE Int Symp Ind Electron 2:606–611

Takafumi Koseki, Takeomi Suzuki, Lilit Kovudhikurlungsri (2010) Dual sampling-rate observer-based state feedback control of motor drive systems- estimation from coarse position signal with dead time. www.koseki.t.u-tokyo.ac.jp

Tsai M-F, Chen C-P (2002) Design of a quadrature decoder/counter interface IC for motor control using CPLD. IEEE Int Conf Ind Electron Soc 3:1936–1944

Chapter 3
The Empirical Evaluation of Guangxi New Manufacturing Industry

Lu Ma, Dong-li Zhao, and Xin Zhu

Abstract Confronting with many problems from environment, population and resource, new manufacturing industry is the hope for further economic development. However, for now, there is not an agreed evaluation system of new manufacturing industry. At the meantime, it is inadequate to empirical research in this domain. After researching some scholars' last research and analyzing actual manufacturing situation of Guangxi, the authors propose an evaluation system of new manufacturing industry. It is a four-dimensional evaluation system (Economy Benefit, R&D Capability, Energy-saving Efficiency and Environmental Protection Ability) and includes 19 secondary indexes. To guide further research, taking Guangxi as an empirical subject, this article evaluates Guangxi new manufacturing industry from different aspects and draws some conclusions by Using SPSS16.0 software to make principal component analysis. The contribution of this study is not only making an evaluation system but also providing reference to the Guangxi new manufacturing industry development path.

Keywords Evaluation • New manufacturing industry • R&D ability • Energy energy-saving efficiency • Environmental protection

Introduction

The rapid development of manufacturing has greatly contributed for GDP in China. The new industrialization is the road that every manufacturing industry will go in the future. With the world's economy development, manufacturing has become the leading economic department to achieve modernization,

Supported by Key project of Department of Education in Guangxi (201012MS121)

L. Ma (✉) • D.-l. Zhao • X. Zhu
Department of Management, Guangxi University of Technology, Liuzhou, China
e-mail: malu6655@163.com; dongli0224@163.com; zhuxinjupiter@hotmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_3,

industrialization, informationization and urbanization in one country. However, Chinese manufacturing industry of rapid development is facing unprecedented challenges containing environment and resources. In order to cope with the multiple constraint factors, the future manufacturing industry must rely on scientific and technological innovation, lower energy consumption, and reduce environmental pollution, increasing employment, to realize the dual ascension of economic benefit and competitive ability, and have to go a "new manufacturing industry" development path, which is a kind of people-oriented, positive developing, resource-recycling and protecting environmental way, to adapt the situation of China (Lianshui Li and Zhanyuan Du 2005).

Guangxi has achieved the rapid economic development since the reform and opening. According to comparable calculation, GDP grew from 7.585 billion RMB in 1978 to 717.158 billion RMB in 2008, it grew by about 94 times in a short span of 30 years, and its average annual growth rate was 16.37% which was higher than the average annual growth rate of the nation. In 2009, growth rate of Guangxi GDP ranked national fifth and the GDP was 775.916 billion RMB.

New Manufacturing Industry

New industrialization road will have to become one of the main growth modes of intensive way with economic growth mode which has gradually been changing from extensive mode to intensive. New industrialization is a way that high-technology, good economic returning, low consumption of resources, less contamination to environment, full-displaying of human resources' superiority (Bo Zeng et al. 2008). New manufacturing industry would adjust the industrial structure and promote industrial upgrading.

Industry is one of the most important forces to drive economic development of Guangxi, and it has a great contribution to GDP every year. Manufacturing is vital part of the industrial development, but manufacturing's contribution to Guangxi GDP was less than 30% in 2009. This seriously affected Guangxi economic development. Worse, the development of most Guangxi manufacturing will be hindered in the greatest degree by its high-cost and high-pollution. Therefore, it is very urgent that we should in-depth analyze and comprehensively evaluate every industry of Guangxi manufacturing to find good economic returning, well R&D capability, high-efficiency and good environmental protecting new industries.

The Evaluation System of New Manufacturing Industry

New manufacturing industry is a new concept following new industrialization that proposed by Li Lianshui and Wang Huaiming etc. in recent years. However, the evaluation system is not taken notice by scholar until Wang Huaiming put forward a four-dimensional index system including four first-class indexes and 21 second-class indexes in 2010 (Huaiming Wang 2010)· This paper refers this four-dimensional index system, analyzes the actual condition of Guangxi and finally constructs a new four-dimensional index system including 19 second-class indexes. And then, these indexes are explained in detail.

Economy Benefit

Economic benefit is an important aspect to measure the degree of new manufacturing industry. So, I use four indexes (the ratio of industrial added value to total industrial output value (A1), the proportion of liquid assets to total assets (A2), sales profit margin (A3), and overall labor productivity (A4)) to reflect the economic benefit of Guangxi manufacturing. One index (the ratio of industrial quantity of employment to total industrial output value (A5)) shows how much contribution of the manufacturing industries of Guangxi to employment situation and the share of manufacturing industries' labor force in total labor force. The index, ratio of dependence on foreign trade (A6), evaluates the new manufacturing industry degree from the angle of foreign trade market (Shichun Li 2007).

R&D Ability

R&D ability is a leading index to measure the degree of Guangxi new manufacturing industry. Two of the second-class indexes, the ratio of R&D expenditure to total industrial output value (B1), the proportion of R&D quantity of employment to quantity of industrial employment (B2), show R&D funds and talents investment. The other indexes, the ratio of quantity of science and technology employment to quantity of industrial employment (B3), the proportion of science and technology activity expenditure to total industrial output value (B4), totally reflect the amount of science and technology investment.

Energy-Saving Efficiency

Sustainable development is how every industry can be always young. The index of energy-saving efficiency mainly shows energy utilization efficiency and energy consumption. Amount of energy consumed for every unit of economic output (C1) and amount of electricity consumed for every unit of economic output (C2), these two indexes reflects Guangxi manufacturing industries energy-saving intensity and efficiency. The other two indexes, the proportion of every manufacturing industry's energy consumption to total energy consumption in Guangxi (C3) and the proportion of every manufacturing industry's electricity consumption to total electricity consumption in Guangxi (C4), reveal the condition of Guangxi manufacturing industries energy consumption and could draw the energy dependence and dissipation contribution of Guangxi manufacturing industries.

Environmental Protection Ability

It is a decided way that creating stable & harmonious ecological environment if Guangxi manufacturing can develop enduringly and stably later (Yongquan Lv 2010). The attainment rate of the industrial waste water (D1), the attainment rate of the industrial SO2(D2), the attainment rate of soot (D3), the attainment rate of industrial dust(D4), and the rate of volume of industrial solid wastes utilized to volume of industrial solid waste produced (D5) are used to measure "greening" degree of Guangxi manufacturing industry.

The Empirical Evaluation of Guangxi New Manufacturing Industry

Each dimension evaluation is needful before final new degree evaluation. Because comprehensive evaluation is based on four dimension evaluation (Jinrong Zheng and Fuyuan Xu 2010). And every evaluation can decide whether one factor is vital or not. This study uses SPSS16.0 software to make principal component analysis on 30 Guangxi manufacturing industries, and the data almost comes from the "Guangxi Statistical Yearbook of 2010".

Economic Benefit Evaluation

As the 95% accumulative total variance contribution was standard, it could gain weight after orthogonal rotating. Then, data computation could get Table 3.1. The higher comprehensive score the better economy benefit.

We could see some results from Table 3.1. First, in 2009, Tobacco Processing was the best economic benefit in Guangxi manufacturing industries, but it ranked 4th from the bottom in A5. At the same time, it ranked 1st in A1. Second, in the top ten economic industries ranked by economic benefit were light industries. At last, there was great difference among different manufacturing from comprehensive score (Table 3.1).

Table 3.1 Economic benefit ranking of Guangxi manufacturing industries in 2009

Manufacturing industries	Score	Ranking
Tobacco processing	2.486	1
Recycling and disposal of waste	1.463	2
Nonmetal mineral products	0.564	3
Medical and pharmaceutical products	0.403	4
Instruments, meters, cultural and office machinery	0.348	5
Beverage production	0.267	6
Farm and sideline products processing	0.245	7
Printing and record duplicating	0.122	8
Chemical fiber	0.082	9
General equipment manufacturing	−0.070	10
Transport equipment manufacturing	−0.088	11
Raw chemical materials and chemical products	−0.097	12
Timber processing, bamboo, cane, palm fiber and straw products	−0.114	13
Oil processing, coking and nuclear fuel processing	−0.134	14
Smelting and pressing of nonferrous metals	−0.141	15
Food production	−0.145	16
Communication equipment, computer and other electronic equipment manufacturing	−0.189	17
Handicraft and other manufacturing	−0.199	18
Cultural, educational and sports goods	−0.231	19
For special purposes equipment manufacturing	−0.247	20
Rubber products	−0.261	21
Electric equipment and machinery	−0.264	22
Smelting and pressing of ferrous metals	−0.269	23
Plastic products	−0.284	24
Metal products	−0.351	25
Textile industry	−0.429	26
Furniture manufacturing	−0.437	27
Papermaking and paper products	−0.462	28
Leather, fur, feather (wool) and related products	−0.691	29
Garments, shoes and accessories manufacturing	−0.875	30

R&D Ability Evaluation

It was the same as Economic Benefit Evaluation that accumulative total variance contribution, data computation. Guangxi equipment manufacturing industry top ranked in Table 3.2. They are emerging capital-and-technology-intensive industries and their R&D expenditures were much more than other industries (Lianshui Li and Huaiming Wang 2009). Next, The No.1 was still Tobacco Processing in this evaluation. Then, Guangxi labor-intensive industries' R&D ability was weak. Finally, it is a pressing issue to strengthen Guangxi manufacturing R&D ability. Therefore, we should invest more money to R&D and science and technology activity as much as other province (Guangxi Statistical Bureau 2011).

Table 3.2 R&D ability ranking of Guangxi manufacturing industries in 2009

Manufacturing industries	Score	Ranking
Tobacco processing	3.020	1
For special purposes equipment manufacturing	1.889	2
Transport equipment manufacturing	0.732	3
Instruments, meters, cultural and office machinery	0.469	4
General equipment manufacturing	0.293	5
Medical and pharmaceutical products	0.233	6
Electric equipment and machinery	−0.058	7
Beverage production	−0.087	8
Smelting and pressing of nonferrous metals	−0.175	9
Raw chemical materials and chemical products	−0.364	10
Textile industry	−0.404	11
Rubber products	−0.424	12
Food production	−0.446	13
Nonmetal mineral products	−0.465	14
Farm and sideline products processing	−0.484	15
Furniture manufacturing	−0.500	16
Printing and record duplicating	−0.511	17
Smelting and pressing of ferrous metals	−0.530	18
Papermaking and paper products	−0.530	19
Metal products	−0.537	20
Communication equipment, computer and other electronic equipment manufacturing	−0.551	21
Timber processing, bamboo, cane, palm fiber and straw products	−0.569	22

Energy-Saving Efficiency Evaluation

The computing process was similar with before. Table 3.3 showed energy-saving efficiency ranking of Guangxi manufacturing industries in 2009. The no.1 is Smelting & Pressing of Ferrous Metals. The top four industries are traditional energy-intensive. Second, the last was Chemical Fiber, but its ranking of economic benefit was in the top ten. Third, it was worthy noting that the light industries of Guangxi ranked in the end and it was relative to ranking of economic benefit. Fourth, the most part of them were lower than zero, which testified Guangxi manufacturing industries had to pay much attention to energy conservation and energy utilization.

Environmental Protection Ability Evaluation

The computing process was similar with before. There were some conclusions gotten from Table 3.4. First of all, the industries which had better environmental protection ability were light industries. Second, it was conspicuous that Tobacco

Table 3.3 Energy-saving efficiency ranking of Guangxi manufacturing industries in 2009

Manufacturing industries	Score	Ranking
Smelting and pressing of ferrous metals	3.692	1
Smelting and pressing of nonferrous metals	2.398	2
Nonmetal mineral products	1.541	3
Raw chemical materials and chemical products	0.550	4
Farm and sideline products processing	0.442	5
Papermaking and paper products	−0.095	6
Timber processing, bamboo, cane, palm fiber and straw products	−0.130	7
Transport equipment manufacturing	−0.183	8
Metal products	−0.285	9
General equipment manufacturing	−0.288	10
Handicraft and other manufacturing	−0.289	11
Electric equipment and machinery	−0.322	12
Plastic products	−0.331	13
Textile industry	−0.332	14
Beverage production	−0.344	15
For special purposes equipment manufacturing	−0.355	16
Recycling and disposal of waste	−0.372	17
Food production	−0.375	18
Oil processing, coking and nuclear fuel processing	−0.382	19
Medical and pharmaceutical products	−0.383	20
Communication equipment, Computer and other electronic equipment manufacturing	−0.398	21
Rubber products	−0.408	22
Leather, fur, feather (wool) and related products	−0.408	23
Tobacco processing	−0.414	24
Printing and record duplicating	−0.415	25
Garments, shoes and accessories manufacturing	−0.418	26
Furniture manufacturing	−0.420	27
Instruments, meters, cultural and office machinery	−0.462	28
Cultural, educational and sports goods	−0.691	29
Chemical fiber	−0.875	30

Processing was second in this table, and first in Tables 3.1 and 3.2, only ranked in the latter in Table 3.3.

In the case of that, Tobacco Processing was able to be the closest industry of new manufacturing industry if it improved energy-saving efficiency (Lundquist et al. 2008). Overall, Guangxi manufacturing industries had well environmental protection ability. So we can say that was good for people, society and environment, which should be keeping (Guerrieri and Meliciani 2005).

Comprehensive Evaluation

As the 85% accumulative total variance contribution was standard, it could gain weight after orthogonal rotating. Then, it got simplified five factors. Among them,

Table 3.4 Environmental protection ability ranking of Guangxi manufacturing industries in 2009

Manufacturing industries	Score	Ranking
Cultural, educational and sports goods	0.524	1
Tobacco processing	0.519	2
Chemical fiber	0.515	3
Instruments, meters, cultural and office machinery	0.512	4
Communication equipment, computer and other electronic equipment manufacturing	0.496	5
Rubber products	0.488	6
Garments, shoes and accessories manufacturing	0.388	7
For special purposes equipment manufacturing	0.377	8
Furniture manufacturing	0.364	9
General equipment manufacturing	0.346	10
Recycling and disposal of waste	0.334	11
Transport equipment manufacturing	0.319	12
Metal products	0.268	13
Electric equipment and machinery	0.252	14
Medical and pharmaceutical products	0.247	15
Handicraft and other manufacturing	0.173	16
Beverage production	0.127	17
Nonmetal mineral products	0.108	18
Food production	0.103	19
Oil processing, coking and nuclear fuel processing	0.099	20
Smelting and pressing of ferrous metals	0.098	21
Plastic products	0.009	22
Farm and sideline products processing	−0.012	23
Raw chemical materials and chemical products	−0.037	24
Papermaking and paper products	−0.082	25
Textile industry	−0.185	26
Timber processing, bamboo, cane, palm fiber and straw products	−0.297	27
Smelting and pressing of nonferrous metals	−1.839	28
Leather, fur, feather (wool) and related products	−1.869	29
Printing and record duplicating	−2.362	30

the heavier load indexes were: A1, A4, B2, and B3; C1, C2, and C4; B1, and B4; D1, and D2; A5. Data computation would get Table 3.5.

Table 3.5 told us much information. Firstly, Tobacco Processing was the highest level of new manufacturing industry. Meanwhile, it also had strong environmental protection ability. Secondly, there were four FMCG (Fast-moving Consumer Goods) productions in top five industries. And these four industries had high-energy-efficiency. Thirdly, Nonmetal Mineral Products Ranked the last, and other heavy chemical industries also ranked latter on account of low scores in factor F2 and F5. At the end, Transport Equipment Manufacturing had great potential. But it could not rank top five for low score in factor F2 and F5.

Table 3.5 The new degree ranking of Guangxi manufacturing industries in 2009

Manufacturing industries	Comprehensive score	Ranking
Tobacco processing	1.416	1
Farm and sideline products processing	0.722	2
Beverage production	0.710	3
For special purposes equipment manufacturing	0.444	4
Food production	0.339	5
Instruments, meters, cultural and office machinery	0.129	6
Transport equipment manufacturing	0.102	7
Medical and pharmaceutical products	0.089	8
General equipment manufacturing	−0.004	9
Textile industry	−0.069	10
Electric equipment and machinery	−0.094	11
Furniture manufacturing	−0.143	12
Rubber products	−0.197	13
Raw chemical materials and chemical products	−0.213	14
Smelting and pressing of nonferrous metals	−0.249	15
Metal products	−0.261	16
Communication equipment, computer and other electronic equipment manufacturing	−0.279	17
Smelting and pressing of ferrous metals	−0.325	18
Papermaking and paper products	−0.405	19
Timber processing, bamboo, cane, Palm fiber and straw products	−0.521	20
Printing and record duplicating	−0.560	21
Nonmetal mineral products	−0.631	22

Conclusion

To sum up, it could be thought that the relatively high new degree manufacturing industries were mainly labor-intensive industries in Guangxi in 2009. Their economic benefits and R&D ability were better than other industries. So they could drive the overall development of Guangxi manufacturing in the future. Next, the capital-and-technology-intensive industries were following closely after labor-intensive industries. It resulted that it was a future trend that capital-and-technology-intensive manufacturing would be leading in Guangxi. Then, as analyzed before, the value added of capital-and-technology-intensive industries would get a boost in the next few years.

Overall, the new degree of Guangxi manufacturing industries was not high, though its economic benefit was obviously more than other industries. The most important reason of relatively low new degree of Guangxi manufacturing industries was fewer input of R&D, not only funds but personnel. Maybe the reason was the understanding of Guangxi new manufacturing industry was not very well, and most manufacturing industries still drove economic growth through the labor productivity (Fiona 2008). Guangxi manufacturing industries' investment and propaganda were greater in energy-saving & environmental protection. Especially, the difference among them was small. There would be several manufacturing industries which were able to become a national leader in energy-saving & energy-recycling (Andersson 2004). However, it would need much more investment in environmental protection if Guangxi manufacturing industries wanted to develop on a large scale.

References

Andersson M (2004) Co-location of manufacturing & producer services. The Royal Institute of technology Centre of Excellence for Studies in Science and Innovation. Working paper, pp 1–24, www.infra.kth.se/cesis/research/workpap.htm, http://www.kth.se.dokument/itm/cesis/CESISWP08.pdf

Bo Zeng, Aiping Cui, Wei Liu (2008) Symbiosis development between producer services and manufacture industry based on industrial clusters under neo-industrialization – taking economic integration in Yangtze River Delta for example. J Nanchang Inst Aeronaut Technol (So Sci) 10(4):25–30

Fiona T (2008) The contribution of manufacturing and services to employment creation and growth in South Africa. South Afr J Econ 76(2):175–204

Guangxi Statistical Bureau (2011) Guangxi statistical yearbook of 2010. China Statistical Press, Beijing, pp 52–63

Guerrieri P, Meliciani V (2005) Technology and international competitiveness: the interdependence between manufacturing and producer services. Struct Change Econ Dyn 16(2):489–502

Huaiming Wang (2010) The empirical of evaluation of new concept of manufacturing industry of Hubei province. J HuaZhong Univ Sci Technol 24(1):65–71

Jinrong Zheng, Fuyuan Xu (2010) Research on evaluation and maturity model of technological innovation capacity for advanced manufacturing enterprises. Sci Technol Econ 23(3):3–6

Lianshui Li, Huaiming Wang (2009) A research report on the development of China's manufacturing industry. Science Press, Beijing, 155–169

Lianshui Li, Zhanyuan Du (2005) The concept, contents & meanings of "New manufacturing industry". Stud Sci Sci 23(2):184–187

Lundquist KJ, Olander LO, Henning MS (2008) Producer services: growth and roles in long-term economic development. Serv Ind J 28(4):463–477

Shichun Li (2007) Concerning about manufacturing informationization and new industrialization. Sci Technol Res 5:253–255

Yongquan Lv (2010) The countermeasures research of the sustainable and healthy development of Guangxi manufacturing industry. Econ Soc Dev 10:5–9

Chapter 4
The Promote Path Research of GuangXi's New Manufacturing

Lu Ma, Xi Feng, and Xin Zhu

Abstract Guangxi, as the important basement in "Western Development", owns many accumulation areas of manufacturing industries. The manufacturing industry in Guangxi has become one of the major economic development troops, but Guangxi's economy has faced many obstacles to the economic development mode in energy-intensive and high pollution. Starting with the index of the four-dimensional new manufacture, this paper studies the economic benefits, the capability of R&D, energy efficiency and environmental protection. The aim is to find the gap between Guangxi and other manufacturing developed provinces, and to bring Guangxi's manufacturing on the new road to develop well and fast by making a horizontal comparison with other provinces in China about the degree of new manufacturing.

Keywords Manufacturing industries • Four-dimensional index • Horizontal comparison

Introduction

As 'made in China' around the world, China has become the largest manufacturing base in the world. According to "China Statistical Yearbook in 2010", in 2009, the number of employees in China's manufacturing industry reached 34.919 million, accounting for 80.2% in industry; manufacturing has become the largest industry in China. Therefore, many scholars home and abroad, has taken into a lot of research about manufacturing from different angles. Lvyongquan thinks that the extensive and low level development of manufacturing, which not only makes against the manufacturing becoming stronger and bigger, but goes against building a advanced

This paper is supported by Key project of Department of education in Guangxi (201012MS121)

L. Ma (✉) • X. Feng • X. Zhu
Department of Management, Guangxi University of Technology, Liuzhou, China
e-mail: malu6655@163.com; xun05@hotmail.com; zhuxinjupiter@hotmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_4,

basement, and goes against promoting employment and improving the livelihood of the people (Lv Yongquan 2010). Wu Changnan studied about the secondary or tertiary segmented industry of Guangxi's equipment manufacturing industry in a deep-going way. He, from collecting data about the industrial output value, total assets, location quotient, relative efficiency of factor inputs and returns to scale, analyzed the development status and problems of Guangxi's equipment industry, and proposed the development strategy of Guangxi's equipment industry (Wu Changnan 2006). Wang nengmin believes that the implementation of green manufacturing mode is the preferred mode in Western Development (Wang Nengmin and Chen Chuhung 2002).

Calculated by comparable prices, the GDP from 7.585 billion Yuan to 717.158 billion Yuan (1978–2008), an increase about 94 times in just 30 years, in Guangxi. In 2009, The regional GDP reached 7759.16 billion Yuan, and its growth rate ranked fifth in the country. Pearl River Delta, as one of the world's largest manufacturing center, Guangxi's economic development connect directly and the bloom of ASEAN Free Trade Area. The analysis shows that the industry contributed significantly to GDP of Guangxi, and the manufacturing is the main force in industry. Therefore, analyzing and evaluating the manufacturing comprehensively and in-depth, It seems to be very urgent to identify the industries with the bigger economic benefits, the better R&D capacity, the higher energy efficiency and the finer environment protection (Yao Fang et al. 2006).

Build New Evaluation Index System

This paper consults the four-dimensional index system, and takes into account to the actual situation of Guangxi, and proposes 4 first-grade indexes which contain the economic benefits, the capability of R&D, energy conservation efficiency, and the capability of environmental protection and 19 secondary indicators (Table 4.1).

Positive Analysis of Guangxi's New Manufacturing and Evaluation

For a comprehensive analysis of Guangxi's manufacturing of the industry, at first, making the measurement to various industries that contains the economic benefits, the capability of R&D, energy conservation efficiency and environmental protection, before making a comprehensive evaluation of new (Li Lianshui and Wang Huaiming 2004–2008). In this paper, Using principal component analysis to 30 subsectors of Guangxi's manufacturing of the industry by SPSS16.0 software, all those data used in analyzing are from the "Statistical Yearbook of Guangxi in 2010."

The index calculated by the criterion which is the contribution rate of accumulative total of variance is 95%, and obtained the weights by orthogonal rotation, then

Table 4.1 New evaluation index system

New evaluation index system	EBI (Economic Benefits Index)	A1: The proportion of added value in GDP
		A2: The proportion of current assets in total assets
		A3: Sales profit ratio
		A4: Labor productivity
		A5: The proportion of employment population
		A6: The dependency of foreign trade
	RDI (Research and Development Index)	B1: The proportion of R&D funds in GDP
		B2: The proportion of R&D person in EP
		B3: The proportion of technological activity person in EP
		B4: The proportion of technological activity funds in GDP
	EEI (Energy Efficiency Index)	C1: Per production energy consumption
		C2: Per production electricity consumption
		C3: The proportion of industry energy consumption in TEC
		C4: The proportion of electricity consumption in TEC
	EPI (Environmental Protection Index)	D1: The achievement ratio of industrial effluent emission
		D2: The achievement ratio of industrial sulfur dioxide emission
		D3: The achievement ratio of industrial soot emission
		D4: The achievement ratio of industrial dust emission
		D5: The achievement ratio of industrial solid wastes emission

the Tables 4.2, 4.3, 4.4 and 4.5 shows up after data analysis. (Due to limited space, only the high five and the low five scores have been showed.)

The index calculated by the criterion which is the contribution rate of accumulative total of variance is 85%, and obtained the weights by orthogonal rotation, and simplified to the six factors, then the Table 4.6 shows up after data analysis.

The History of Guangxi's New Manufacturing

Base on the new evaluation index system and "Guangxi Statistical Yearbook" (1997–2009), and obtained the comprehensive evaluation index (MDI) of Guangxi's new manufacturing of calendar year, by using the same way that factor analysis and the Table 4.7 shows up. 1997 as the base, set its comprehensive evaluation of a score of 100, according to the formula:

Table 4.2 The rank of economic benefits of Guangxi's manufacturing industry (2009)

Industry	Score	Ranking
Tobacco industry	2.486	1
Recycling and disposal of waste	1.463	2
Non-metallic mineral products industry	0.564	3
Pharmaceutical manufacturing	0.403	4
Instruments, cultural and office machinery	0.348	5
...		
Textile industry	−0.429	26
Furniture manufacturing	−0.437	27
Paper and paper products industry	−0.462	28
Leather, fur, feathers (down) products industry	−0.691	29
Textile and apparel, footwear and headgear industry	−0.875	30

Table 4.3 The rank of the capability of R&D of Guangxi's manufacturing industry (2009)

Industry	Score	Ranking
Tobacco industry	3.020	1
Special equipment manufacturing	1.889	2
Transport equipment manufacturing	0.732	3
Instruments, cultural and office machinery	0.469	4
General equipment manufacturing	0.293	5
...		
Ferrous metal smelting and rolling processing industry	−0.530	18
Paper and paper products industry	−0.530	19
Fabricated metal products industry	−0.537	20
Communications equipment, computers and other electronic equipment manufacturing	−0.551	21
Wood processing and wood, bamboo, rattan, palm fiber and straw products	−0.569	22

Table 4.4 The rank of energy conservation efficiency of Guangxi's manufacturing industry (2009)

Industry	Score	Ranking
Ferrous metal smelting and rolling processing industry	3.692	1
Non-ferrous metal smelting and rolling processing industry	2.398	2
Non-metallic mineral products industry	1.541	3
Raw chemical materials and chemical products	0.550	4
Agro-products processing	0.442	5
...		
Textile and apparel, footwear and headgear industry	−0.418	26
Furniture manufacturing	−0.420	27
Instruments, cultural and office machinery	−0.462	28
Educational and sports goods	−0.691	29
Chemical fiber manufacturing	−0.875	30

Table 4.5 The rank of the capability of environmental protection of Guangxi's manufacturing industry (2009)

Industry	Score	Ranking
Educational and sports goods	0.524	1
Tobacco industry	0.519	2
Chemical fiber manufacturing	0.515	3
Instruments, cultural and office machinery	0.512	4
Communications equipment, computers and other electronic equipment industry	0.496	5
...		
Textile industry	−0.185	26
Wood processing and wood, bamboo, rattan, palm fiber and straw products	−0.297	27
Non-ferrous metal smelting and rolling processing industry	−1.839	28
Leather, fur, feathers (down) products industry	−1.869	29
Printing and record medium reproduction	−2.362	30

Table 4.6 The rank of the new degree of Guangxi's manufacturing industry (2009)

Industry	Score	Ranking
Tobacco industry	1.416	1
Agro-products processing	0.722	2
Beverage manufacturing	0.710	3
Special equipment manufacturing	0.444	4
Food manufacturing	0.339	5
...	...	...
Ferrous metal smelting and rolling processing industry	−0.325	18
Paper and paper products industry	−0.405	19
Wood processing and wood, bamboo, rattan, palm fiber and straw products	−0.521	20
Printing and record medium reproduction	−0.560	21
Non-metallic mineral products industry	−0.631	22

$$MDI_t = 100 + 100 \times \frac{F_t - F_{1997}}{|F_{1997}|}$$

From the track of development, the development of Guangxi's new manufacturing industry has gone through three stages (Fig. 4.1).

Stage I (1997–2001), this is the period of rapid growth, the average annual chain growth of 12.8%. Positive growth has taken on in this stage without fluctuation. Since 1999, the speed of development has been rapid, in 2001, showed growth rates of 28.7%, the fastest speed of growth in the 13 years, and the rate of annual growth reached 45.8%.

Stage II (2002–2005), this stage is the adjustment period with fluctuation, the average annual chain growth is 1.9%, while the negative growth displayed in the overall stage, and strongly negative growth had been showed in 2004–2005, and in

Table 4.7 The history of the Guangxi's new manufacturing

Year	Score	MDI
1997	−1.109	100
1998	−0.925	116.572
1999	−0.849	123.384
2000	−0.456	158.819
2001	0.351	231.615
2002	0.206	218.547
2003	0.38	234.272
2004	0.149	213.431
2005	0.11	209.839
2006	0.335	230.214
2007	0.515	246.381
2008	0.471	242.478
2009	0.821	273.951

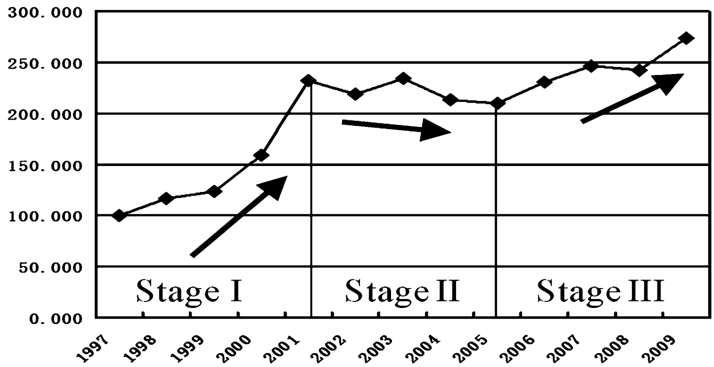


Fig. 4.1 The history of the Guangxi's new manufacturing

that 2 year, the average annual growth rate of −5.5%, and what is more, the maximum annual growth rate of −8.9% in 13 years, in 2004.

Stage III (2006–2009), this stage is the consolidated development period, the average annual growth rate is around 3.6%. There was some fluctuations with small amplitude has happened, but the whole trend showed a completely positive growth, since 2006 development trend changed for the better, while there was a slight negative growth in 2008, and through 1 year of adjustment, the trend changed for the better again, the rapid growth has happened, and the annual growth rate is 13% in 2009.

The positive growth trend of Guangxi's new manufacturing had been showed, in 1997–2009. Although, there were some staged fluctuation and adjustment in the period, the whole trend appeared stably, so from this analysis, the new manufacturing has already entered the period of stable and rapid development.

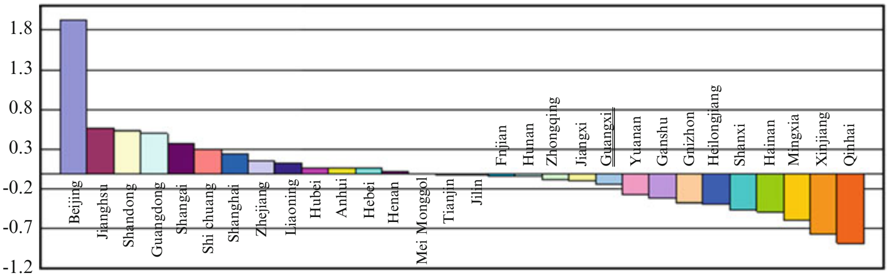


Fig. 4.2 The comparision about the degree of new manufacturing among the 30 provinces

The Horizontal Comparison of Manufacturing Between Other Provinces and Guangxi

Based on the evaluation index system of new manufacturing and regional statistical yearbook, and using factor analysis. It is approachable to evaluate and rank the development of new manufacturing about the 30 provinces in China(Did not include Tibet, Hong Kong and Macao regions, due to the data of available and consistence) (Fig. 4.2).

According to the data analysis from the four dimensions of economic benefits, R&D capacity, energy efficiency, environmental protection and 19 indicators fellows, this paper obtains the top ten provinces or regions are Beijing, Jiangsu, Shandong, Guangdong, Shanxi, Szechwan, Shanghai, Zhejiang, Liaoning, Hubei, Guangxi ranks No. 21 in the whole rank, and at No. 4 in the rank of western provinces and regions. From the rank, (1) the developed areas of new manufacturing in China, that still concentrated in the eastern coastal and littoral currently. The core areas of manufacturing's development in the central and western regions have already been in the top ten in the future, with the strategies of "Rise of Central China" and "Western Development" implementation (Li Lianshui and Du Zhanyuan 2005). However, because of the weak foundation in the western, where developing relative slowly in the manufacturing aspect, which also indicates there is a huge room for the improvement of manufacturing. (2) From the data analysis of industrial output value, the top three regions are Jiangsu, Shandong, Guangdong, and this ranking as similar as the ranking of total score, Guangxi at No. 22. The top three of manufacturing are Shandong, Guangdong, Jiangsu in the rank of total profit, and Guangxi ranking No. 25. The top three about total assets of industry are: Jiangsu, Guangdong, Shandong, Guangxi ranked 24th. Those facts speaks volumes for the large-scale production did not form, the development of manufacturing's facilities and the capability of economic benefits at low level, compared with other developed areas. It will elevate the capacity of Guangxi's manufacturing, and can improve the scale of production to form the large-scale, and increase the investment (Liu Zhe and Sun Linyan 2005). (3) From the rank of total import and export, the top three are Guangdong, Jiangsu, Shanghai, there is a high degree of association between the import and export volume and geography, the top three are all the areas of coastal and littoral, and Guangxi ranked 15th. The 15th has a great relationship with that Guangxi is the frontier region, also because of this, Guangxi, as a tie of the China and ASEAN's economic development, will be one of the factors that improve Guangxi's economic development. (4) The top three of total expenditures in R&D are Beijing, Shaanxi and Szechwan, Guangxi at 24th. Take two in the top three, this fact can be explained clearly, the R&D of the western region has already treasured, with the following implement of the "Western Development". The investment of R&D is still weak in Guangxi, but in the future, the direction of investment will transfer gradually from the regions of eastern and central to west, by labor cost ascending in the eastern areas. The advantage of labor cost will make Guangxi become the major direction of R&D in a long period of future. (5) In aspects of environmental protection and energy efficiency, the top three of the index of Per production energy consumption (C1), which is Beijing, Shanghai, Guangdong. The data specifies, the developed areas take more input of environmental protection and energy efficiency and obtain the better implementing effects than the regions of central and western. While Guangxi, still ranking 11th, is the first of the western region.

As one of the important area of western development, Guangxi's manufacturing industry not only maintains the fate of future economy will be stable and high-speed whether or not, but also is the core area to connect China and the ASEAN (Wei Houkai 2001). The development of Guangxi's manufacturing industry is the important factor that will determine the implementation of "Western Development" is steadier and rapider whether or not.

The Prospect and Design About the Development Path of Guangxi's New Manufacturing

According to the data analysis, the main advantage of Guangxi in the manufacturing is: (1) the labor-intensive manufacturing has a better momentum, tobacco industry is the representative, which has a stronger power, whatever in the economic benefits or in the capability of R&D, compare with other industries, as a leader to leading the whole manufacturing in Guangxi. From the total score, the new degree of tobacco industry is higher than others. It is fully showed that the employees of tobacco industry have to create the highest efficiency in the Guangxi's manufacturing, according to the ranking, which is it at the first of the index of the proportion of added value in GDP (A1), but ranked rearward position relatively in the index of the proportion of employment population(A5). These facts speak volumes for increasing the scale of production of the tobacco industry, will improve the economic benefits of manufacturing in Guangxi, to the greatest degree. (2) The data shows that there are also good momentum in many emerging capital-intensive and technology-intensive industries, such as special equipment, transport and equipment manufacturing and general equipment manufacturing. Just in terms of the special equipment manufacturing, the input of activities in science and technology are leading the second around six times. Those facts shows that the largest investment of R&D is in the capital-intensive and technology-intensive manufacturing, also shows that the added value of products that from the capital-intensive and technology-intensive manufacturing, will be greatly improved in the next few years (Li Shichun 2007). Although the overall level of manufacturing in Guangxi is not very well, there are almost all of industries of manufacturing, just as same as the developed areas, Guangxi held a strong partner – the AFTA which the other region did not, the great geographical location bring the huge room of development. Data shows that the situation of total imports and exports of manufacturing is positive in Guangxi, the geographical advantage AFTA has a deeply influence in Guangxi, and the latter, as a up-and-coming youngster of western, has a weak foundation

According to the rank of the Guangxi's history and the whole country, it is obvious that the disadvantage of Guangxi's manufacturing. (1) the weak ability to create economic benefits of manufacturing, in a certain degree. In 2009, the manufacturing made the contribution in the Guangxi's GDP was less than 30%, it is the very bad data that the manufacturing as the sword of Guangxi's development (Guangxi Statistical Bureau 2011). These facts speak volumes for both the competitiveness of market and the value-added of products are at low level, and this current status should be changed by shifting the labor-intensive industries as the main force of economic development. (2) The capacity of R&D is insufficient, technological innovation is limited. The expenditure of R&D of Guangxi's manufacturing took less than 1.5% of the total output value of the whole industry, the expenditure on new product development took less than 0.5% of the total output value of the whole industry, and the number of science and technology activities took less than 0.8% of the employment population in 2009. From above, fully shows that the invested amount of technology on the aspect of talent and capital is too small in the Guangxi's manufacturing, and it is urgent to improve the input of R&D. (3) Low energy efficiency and high energy consumption. It needs to 1301.3 tons of coal consumption, fuel consumption of 18.2 tons, and around 0.7785 billion kWh consumption, per billion outputs. There is a huge room to improve the energy efficiency.

With the cost advantage of the labor and the production factors are more and more obvious in western region, and where will be the important basement. This status has brought the excellent opportunities that accelerate the rate of foreign investment and increase the cooperation and exchange with the developed areas littoral. It will input the energy in the Guangxi's manufacturing, by highlighting the local advantages constantly and making up the inferior position of the weak economic foundation.

Firstly, using the implementation of the "Western Development" as the starting point, to planning integrally the industrial layout, to upgrade the industrial structure, to rational use of advantages, to make the developed areas of manufacturing as an example, to find a path of development that satisfy the characteristics of manufacturing in Guangxi, to further enhance the development of technology-intensive industries and to accelerate the successful transformation of Guangxi's manufacturing. The new degree of labor-intensive manufacturing industry in Guangxi are higher, comparing with other industries, so Guangxi will pay more attention to the problem of resolving surplus Labor immediately while in the process of the transition, so the large-scale production of Guangxi's manufacturing should be imperative. Only if expanding the scale and accelerating the input can Guangxi ensure the moderate pace of transition. Secondly, increasing the capacity of R&D; improving the added value of products and opening market. Taking full advantage of the benefits that AFTA brings, and actively accepting the manufacturing industry which transferred from the developed areas of the eastern littoral and central region and endeavor to learning. Actively absorbing outstanding technology and management experience from the advanced manufacturing areas, and actively introducing external funds to increase the hardware facilities of manufacturing, raise the base of Guangxi's manufacturing essentially. Thirdly, strengthening energy efficiency, increasing capacity for environmental protection, and adhering to the establishment of a resource saving and environment-friendly society as a basic principle for every enterprise of manufacturing should be taken into account (Guerrieri and Meliciani 2005). And severely remediate the enterprises with the high energy consumption and high pollution. It is important to increase industrial concentration and establishes the path to develop the circular economy, and the industrial cluster with regional characteristic. Fourthly, taking full advantage of geographical advantages, and increasing efforts to import and export products should also be considered. Guangxi is a tie to link the China and ASEAN, also is a China's window to open to foreign trade, and carries major economic power. AFTA will also be the main channel of Guangxi's products goes out of Guangxi and China, and should take full advantage of the advantages of AFTA.

References

Guangxi statistical bureau (2011) Guangxi statistical yearbook 2010 [M]. China Statistical Press, Beijing

Guerrieri P, Meliciani V (2005) Technology and international competitiveness: the interdependence between manufacturing and producer services [J]. Struct Change Econ Dyn 16(2):489–502

Li Lianshui, Du Zhanyuan (2005) "New manufacturing" concept, meaning and significance [J]. Sci Stud 27(2):184–187

Li Lianshui, Wang Huaiming (2004–2008). Chinese manufacturing research report [R]. Science Press, Beijing

Li Schichun (2007) On the informationization of manufacturing and the new style of industrialization [J]. Sci Technol Manag Res 10(5):253–255

Liu Zhe, Sun Linyan (2005) The comparative study of states manufacturing industry practice and theory [J]. Econ Issues 4(6):124–128

Lv Yongquan (2010) Strategy and research of sustained and healthy development of Guangxi Manufacturing [J]. China Ind Econ 1(10):5–9

Wang Nengmin, Chen Chuhung (2002) Selection of manufacturing mode in "Western Development" [J]. China's Popul Resour Environ 15(1):107–111

Wei Houkai (2001) Strategy and prospects of Western Development [J]. China Ind Econ 18(3):5–19

Wu Changnan (2006) Development and strategy of equipment manufacturing industry in Guangxi [J]. Guangxi Econ Manag Cadre College 8(4):75–78

Yao Fang, Sun Linyan, and Zhou Mi (2006) Regional comparison of China's manufacturing development [J]. Xi'an Jiaotong Univ 22(1):19–24

Chapter 5
Resources Cooperative Management in Multi-project Manufacturing Based on Cloud

Fang-yan Yang and Zhi-yuan Shi

Abstract Using ideas of system theory to study multi-project manufacturing, creates parallel distribution of resources and collaborative management. Making use of the theory of cloud, to establish a manufacturing resource hierarchy model, building a cloud of manufacturing resources, and analyze the dependencies among the elements and combinations of manufacturing resources in the cloud, from the view of describing resource elements in a unified parametric point in multi-project manufacturing. Using tools of queuing theory, to analyze the matching process of manufacturing resource capabilities and needs in parallel manufacturing of multiple projects, proposing methods of conflict resolution for manufacturing resources, establishing a multi-project resource allocation model for parallel manufacturing, to realize the coordination between manufacturing resources capability and plan requirement in project manufacturing.

Keywords Cloud manufacturing • Project-based manufacturing • Cooperation • Resource allocation

Introduction

Project-based manufacturing is "an uniqueness of one-time task composing of development, production, installation, operation and maintenance of product, which is keeping the development and production of the product (airplane, vessel, carrier rocket and other large complex products) as main body and keeping the project management as the center" (Yantai Wu 2003). The change of manufacturing resources allocation and ability has a great impact on the project

F.-y. Yang (✉) • Z.-y. Shi
School of Manufacturing Science and Engineering of Southwest, University of Science and Technology, Mianyang, Sichuan 621010, China
e-mail: 12219575@qq.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_5,

execution. As an eventual provider of the project-based manufacturing product, the main manufacturing enterprise is not only making sure of the successful completion under the resource constraints in each project, but also considering the resources optimization and reasonable allocation of multi-project.

The proposition of cloud manufacturing has built a new way of resources allocation for the main manufacturing enterprise in the projected-based manufacturing. According to the definitions of literature 2, cloud manufacturing "is a manufacturing service platform using network and cloud and a new model of networked manufacturing providing for the users' needs according to the online manufacturing resources (manufacturing cloud) organized by the users' needs" (Bohu Li 2010). In this model, the description and the method of allocations of manufacturing resources will have fundamental changes.

The Classification and Characteristics of Project-Based Manufacturing Resources

The Features and Classifications of Projected-Based Manufacturing Resources

Manufacturing resources is sum of objects which are related to helping the enterprise to complete the product design, process design and manufacturing process. These objects provide all sorts of functions to ensure that the stage of product design and manufacturing can be finish smoothly. Form perspective of existence form, manufacturing resources includes physical resources and intangible resources. Physical resources refers to equipment, personnel, tools, sites and other resources like, while intangible refers to funds and technologies etc. (Hui Zhao 2009).

In the production process, to achieve relevant physical object in the multi-project model for parallel manufacturing, including production sites, personnel, tools, materials, equipments and other manufacturing resources, according to the role they play in the production process, they can be divided into specialized resources constituting products especially parts of custom products and craft accessories and general resources, such as personnel, equipment, site, tools and other resources needed in the production process (Jianping Xu 2010).

This paper mainly discusses the physical resources related to production process, especially the management and allocation of capability resources.

The Parametric Description of Manufacturing Resources' Characteristics

Either general resources or specialized resources, each resource can be described by a series of parameters in the projected-based manufacturing, which describes various attributes through basic information and processing property. So we can build a description as Eq. (5.1) shown for projected-based manufacturing resources. Every single projected-based manufacturing resource corresponds to a resource element.

$$
\begin{aligned}
R &= (RInfo, \Pr oPara) \\
RInfo &= \left\{ri_1, \ldots ri_j, \ldots ri_m\right\} \\
ri_j &= \left(RID_j, RN_j, RC_j\right) \\
\Pr o\,Para &= \left\{rp_1, \ldots rp_j, \ldots rp_p\right\} \\
rp_j &= \left(RID_j, RC_j, PS_j\right) \\
PS_j &= \left(p_{j1}, p_{j2}, \ldots p_{jn}\right)
\end{aligned} \tag{5.1}
$$

In the equation, Resources R is made up of basic information (RInfo) and manufacturing parameter (ProPara). And each resource element (ri_j) has its own basic attributes, namely resource ID (RID), resource name (RN) and resource cut (RC).each resource element also has its own properties of manufacturing parameters, which constitutes the manufacturing parameters set (PS). For example, purchased item A has the type of material resources and its PS is correlated to the supplier information, while a certain type of tools belongs to the subtype of cutting tools in capability resources and has the processing type, processing precision forming PS set parameters as is shown in Fig. 5.1. Thus, we can have a total description of all manufacturing resources, which has a hierarchical structure of multiple parameters.

The Management Model of Multi-project Manufacturing Resources Based on Cloud

For there is a strong dependency relationship between attributive parameters of purchased and subcontracted resources and suppliers or enterprise providing components. It has a great difference in capability resources. As the space is limited, this paper will not get into too much more detail. Then we will analyze and research the internal capacity resources of projected manufacturing main enterprise.

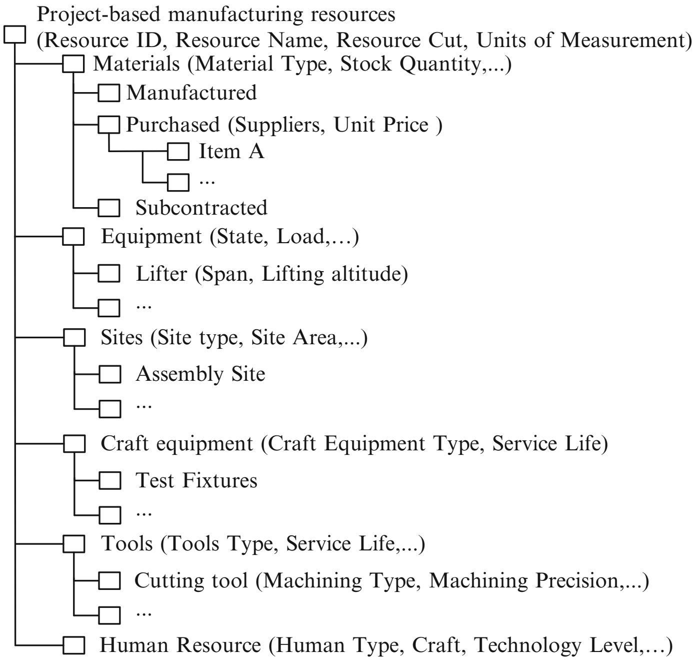


Fig. 5.1 The classify of manufacturing resources and attributes description

Projected Manufacturing Resources Modeling Based on Cloud

We get the parameterized elements of manufacturing resources together and build the manufacturing resources cloud. Figure 5.2 shows the projected manufacturing resources modeling based on cloud.

As is shown in the figure, each capability resources can form a corresponding set. Because we make a united parameterized description on manufacturing resources, we can integrate with all types of manufacturing resources further and thus forming the manufacturing resources cloud. In the manufacturing resources cloud, each resource element can be regarded as instance of resource class, which is available for manufacturing unified deployment (Lin Zhang 2010). According to the production planning and processing requirement of project, we select the available manufacturing resource element under the guidance of manufacturing BOM and compose different resource collection adapting different needs.

However, resource elements are not fully independent; each resource has a dependent and constraint relationship (Qingchao Sun and Gang Guo 2008). Therefore, we must have these analyzed.

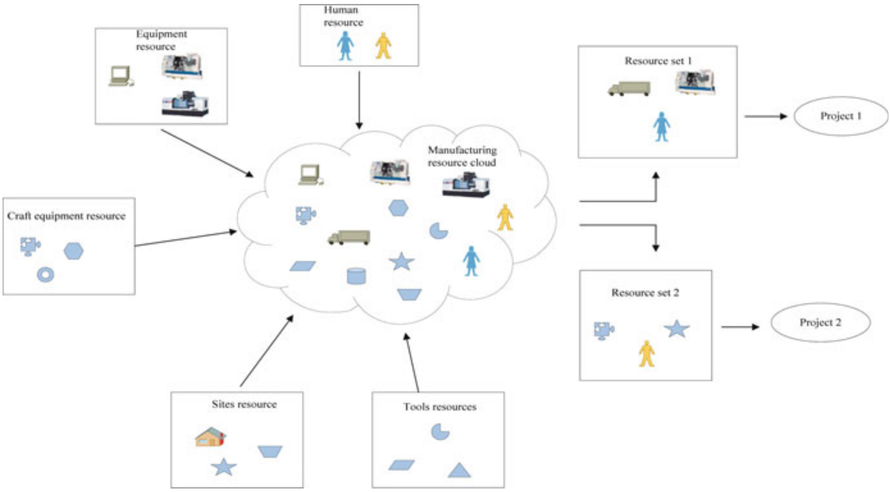


Fig. 5.2 Projected manufacturing resources modeling based on cloud

An Associated Modeling on Multi-project Manufacturing Resource

For single-projected manufacturing resources, the mutual dependent relationship includes who gets together finishing a manufacturing task and what can be done first and what influence will make to subsequent tasks.

$$P(R) = \{r_1, r_2, \ldots r_q\} \tag{5.2}$$

$$F(X) = \begin{bmatrix} x11 & x12 & \ldots & x1l \\ x21 & x22 & \ldots & x2l \\ \vdots & \vdots & \vdots & \vdots \\ xk1 & xk2 & \ldots & xkl \end{bmatrix} \tag{5.3}$$

$$P(W) = \{w1, w2, \ldots, wh\} \tag{5.4}$$

In the Eq. (5.2), P(R) is manufacturing resources set corresponding to project P, which contains the entire resource element needed by project P. In the Eq. (5.3), F(X) is the dependent relationships between resources, x_{ij} means the dependent relationship from r_i to r_j ($i=1,2,\ldots,q; j=1,2,\ldots,i-1,i+1,\ldots,q$). In the Eq. (5.4), P(W) is the set of process route attribute corresponding to project P, the dependency of parameters between process and resources is closely related, remarking w_i and w_j as the resource element r_i and r_j corresponding to the process, wx_{ij} is the dependent relationship from w_i to w_j. That is

$$wxij = f(xij) = \begin{cases} a \\ 0 \end{cases} \tag{5.5}$$

In the Eq. (5.5), that the result is a stands for $xij \neq 0$ and w_i is dependent to the result of w_j; while the result is 0 stands for $xij = 0$ or w_i is not dependent to the result of w_j. Among them, natural number a ranges from 1 to 5.the bigger a is, the higher dependency between w_i and w_j.

In the multi-project parallel manufacturing, the relationship between manufacturing resources also contains dependence and constraints between projects besides its inner dependence and constrains.

$$P(S) = \{s1, s2, \ldots, sk\} \tag{5.6}$$

In the equation P(S) is a set that the whole resources of all projects (i.e. all elements in the resources cloud) are combined by the projects. s_i, s_j are the corresponding combination of resources for projects P_i and P_j. We can use sx_{ij} as the dependency relationship from s_i to s_j, and natural number 1–5 as its dependency degree. The resources dependency relationship of project P is shown as Eq. (5.7).

$$P(SX) = \begin{bmatrix} sx11 & sx12 & \ldots & sx1l \\ sx21 & sx22 & \ldots & sx2l \\ \vdots & \vdots & \vdots & \vdots \\ sxk1 & sxk2 & \ldots & sxkl \end{bmatrix} \tag{5.7}$$

Namely:

$$sxij = \begin{cases} 5 \\ 0 \end{cases} \tag{5.8}$$

In the Eq. (5.8), sx_{ij} gets 5 means s_i and s_j being the same manufacturing resources; 0 means the two resources are irrelevant. If s_i is the common resources of multi-project manufacturing, the load should be considered in making production plan and capability allocation, and we should pay enough attention to the conflict of the resources.

Resources Cooperative Allocation in Multi-project Manufacturing Based on Cloud

From the correlation of project-based manufacturing resource and resource profiles, in some cases, the dependency between resources is much higher especially when related expressions get highest value, namely 5, we think the manufacturing process related or the project will accept the same resources or resources group. However, the amount of resources is limited and in a certain time, we may not have available resources for use. When the plan at all levels of project-based manufacturing has been completed, especially under the condition of multi-project parallel, we must match the limited manufacturing resources (Lei Wu and Chengwei Yang 2010). The set of project-based manufacturing resources based on cloud provides the information live updated and completely shared for the resources matching, based on which the planners will get exact and accurate information so that we can make an accurate determination on resources matching. Thus, we can insure the excitability of project plan at all levels.

Capability load and time attribute are the focus of the conflicts in the attributes of manufacturing resources, especially when multi-project parallels. The resource and process which has a higher dependence becomes the capability bottleneck of project-based manufacturing. How to identify and eliminate the conflicts is the key to ensuring project-based manufacturing execution.

In the project-based manufacturing, the configuration of resources is constrained by the project plan time. Therefore, the resource allocation shall conform to the function of time and load as well as form the process of loop (Xun Xu 2011). According to the queuing theory, the matching process can be divided into the following steps:

Step 1: according to the prospect time of project plan at all levels, we can rank the manufacturing task in period by the priority, neaten the waiting queue of the task and construct the task set.

The prospect time of plan, $T = [t_1, t_2]$, $t_2 > 1$ (t for the current date); in the prospect time, the project-based task needing manufacturing resources allocation $Pti \in J(i = 1, 2, \ldots, c)$ contains the start time TS_i, finish time TF_i and execution period D_i and its like. We do rank for tasks of the set J according to the ascending order of TS_i, using $Prior_i$ for the priority (number) of task Pt_i. In the multi-project parallel manufacturing, task of J comes from different project and the joining time between tasks may not be continuous.

Step 2: gathering the requirement of each kind of resource by the time period.

According to the division of task set and the combination of collection of task resources, we can get the demand about time on each resource collections. Collecting the task and required resource in the time t_i of all the projects, we get the requirement of resource element R_i at t_i. Obviously, the total requirement $Rreq_i$ of R_i in the time of t_i shall be the time function.

Step 3: do matching calculation for results of step 1 and step 2.

We will compare the required resource in the prospect period with resource capability in the corresponding time and analyze if the resource capability can meet the resource requirement.

$$AvailableCi|t = Capa(AvailableCi|t) \tag{5.9}$$

In the Eq. (5.9), $AvailableCi|t$ means the resource capability of resource R_i at the time t. At the time of t, $AvailableCi|t > 0$ means resource R_i free.

Step 4: build a matched matrix on resources according to the calculated results of step 3.

$$aky = \frac{AvailableCk|ty}{F(ty)k} \tag{5.10}$$

In the Eq. (5.10), if $aky \geqslant 1$, it means that resource capability of resource R_k meets the required resource in the period $ty = (a, b)$;

If $aky < 1$, it means that resource capability of resource R_k doesn't meet the required resource and exist the resource conflict;

If there is not a requirement of resource R_k in the period $ty = (a, b)$, let $a_{ky}=1$.

Step 5: adjust the allocation of resources and decompose the resource conflict.

Conclusions

In the project-based manufacturing, the attributive information at all levels and related information of the variety of physical capability of resources of main enterprise is described by parameter and saves in the bottom of a data warehouse forming the cloud and shares by the department of plan at all levels and production through the method of cloud (Gruman 2009). These departments can inquire the load capacity of production of all kinds of resources so that we can do integration and schedule on resources and finally makes a support for the manufacturing process of each project. Through the analysis on resource dependence and matching analysis between requirement and capability of project task in time, project-based manufacturing resources does a reasonable allocation by the method of conflict identification and resolution in the environment of multi-project resource for parallel manufacturing. And we finally guarantee the smooth completion of the project plan (Buyya et al. 2008).

References

Bohu Li (2010) Cloud manufacturing-a new service oriented networked manufacturing model [J]. CIMS 1(16):1–7, 16

Buyya R, Chee YS, Srikumar V (2008) Market-oriented cloud computing: vision, hype, and reality for delivering IT services as computing utilities. Department of Computer Science and software Engineering, University of Melbourne, Australia, July 2008, p 9

Gruman G (2009) What cloud computing really means. InfoWorld, January 2009

Hui Zhao (2009) Project-based manufacturing under the restriction of resources [D]. Chongqing University, Chongqing

Jianping Xu (2010) Manufacturing production planning and control under the restriction of resources based on project-based manufacturing [D]. Chongqing University, Chongqing

Lei Wu, Chengwei Yang (2010) A solution of manufacturing resources sharing in cloud computing environment

Lin Zhang (2010) Key technological research on building manufacturing cloud [J]. CIMS 11(16):2510–2520

Qingchao Sun, Gang Guo (2008) Project management research oriented multi-production collaborative development [J]. CIMS 11(14):2204–2211

Xun Xu (2011) From cloud computing to cloud manufacturing [J]. Robot Comput-Integr Manuf 7:1–12

Yantai Wu (2003) Research on project-based manufacturing cost management [D]. NUST, Nanjing

Chapter 6
Research on Workshop Human Resource Management System Under the MES Environment

Wei-ping Zhang, Kai-chao Yu, and Yue Zhang

Abstract Through the analysis of the current situation of workshop human resource management, combining with the thoughts and ideas of MES, and discuss the necessary of building human resource management system under the MES environment. At the same time, study the interaction, function structure and operation mode of workshop human resources management system. Finally, the paper researches on some key technology of system realization, such as real-time interactive information.

Keywords Human resource management • MES • Personnel allocation • Shop human resources

Introduction

Human resource is "the first resource" of the enterprise; it is the key to determining the success or failure (Guoju Chen 2010). Its history can be traced back to the late 1960s the first generation of human resources management system is a tool to calculate the salary automatically, and neither contains nonfinancial information, nor includes salary history information, almost there is no report generation functions and salary data analysis. The second generation of human resource management system appeared in the late 1970s, gives consideration on the nonfinancial information of human resource and history information of salary, report generation and payroll data analysis capabilities greatly improved. The report generation and payroll data analysis functions have been greatly improved. But it failed to consider the demand and idea of human resource systematically.

W.-p. Zhang (✉) • K.-c. Yu • Y. Zhang
Faculty of Mechanical and Electronic Engineering, Kunming University of Science and Technology, Kunming 650093, China
e-mail: Zhang_weiping@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_6, © Springer-Verlag Berlin Heidelberg 2013

A revolutionary change of human Resource Management System is in the 1980s. Forming an integrated information library by centralizing almost all human resources related data management together from the perspective of human resource management is the characteristics of the third generation of human resource management system (Quanwen Liao 2000; Guanying Liu and Kaichao Yu 2010).

The research of human resource management is relatively mature at the present, but for the shop floor is still relatively small, so it has become inevitable to build shop human resources management system, which relates to the workshop task scheduling, quality management and other issues, shop floor of human resources management with these features is the human resource management under manufacturing execution systems (MES) environment.

The United States is the first countries to carry out MES in the world. The concept of MES was established in November 1990 by Advanced Manufacturing Research (AMR). Expressed as follows: The entire resources of the company is managed according to its management goal, provide implementation target execution means for the company, connection information system theory data and factory actual data by real-time database, and provide the communication between business planning system and manufacturing control system (Zhixin Wang and Shousong Jin 2006; Yunqing Rao et al. 2002; Zhang and Gen 2005; Bin Li and Liping Chen 2005; Huafeng Zhu et al. 2005; Fei Liu 2007). As the Twelfth Five Years Plan unfolds, enterprises pay more and more attention to quality and manufacturing execution control, MES which can provide help get more and more attention from enterprise. Human resources management system is the important part in the MES, it can provide employee status information updated by the minute, to make an effective arrangement based on personnel qualification, working mode etc. This is not only arrangements workers effectively, but also achieve the production plan of integration in the MES platform about personnel, materials, equipment, information and tools. Which fully assurance and improvement the cooperative of the production processes (Shuting Zhang et al. 2000; Jianjun Yang 2000). For the design of human resources management system in MES, in particular, the job shop level task and scheduling management is an important basis on production scheduling and resource scheduling in MES.

System Requirements

The means of workshop human resource management mainly in manual management at this stage, the application level of information technology is relatively low. The application software such as ERP, although establish management module of human resources, but mainly for the management, the workshop management is confined to the basic information, attendance, performance. On the task allocation, also base on the experience of management (Jianjun Yang 2000; Kelly 1995; Object Management Group 1997).

It is difficult to allocation and scheduling scientific and effectively. Manifested mainly in the following aspects:

The Way of Workshop Human Resource Assignment Is Behind

After the tasks organized by the management allocate to the workshop. They will be distributed in the traditional way by workshop manager. Empirically assigned randomly to each line and station, Lack of scientific analysis and positioning. The result of the process is unclear division and information loss. Eventually lead to the poor traceability information of the entire production process.

For the manufacturing enterprise workshop which relative concentration on personnel, materials, equipment, owns the amount of information and variety. While the majority of workshop human resources information gathering completed by hand, the way of acquisition information is behind.

The Difficulties of Real-Time Updates About Workshop Human Resource Information

As mentioned above, the trail of information collection methods in workshop human resources has led to the difficulties of real-time updates about workshop human resource information. It also can't provide effective support for dynamic management and optimized allocation in workshop human resources. So, the achievement about management methods in workshop human resources must depend on the support of management information system, and the system need to realize collection, processing, feedback, and update about workshop human resource information. Therefore, taking advantage of the integration between MES and related internal systems, recording work dynamic of staff and facilities and sending it to the subsystem of materials management and device management may achieve information sharing, control working personnel timely and reduce the circumstances of sabotage and idle workers. Thus, it may achieve transmissions, dispose and application between related material information. Furthermore, it also may realize effective management workshop human resource.

The Low Scientific of Plan Support About Workshop Human Resource

In order to sustain the project of management, the system should generate various report forms fastly, and demonstrate it for the illiterates. Thus, on the one hand, it can reduce heavy statistical work while workers completing the manual report, on the other hand, it also can provide an accurate basis for leader's policy decision opportunely, so the scientific of policy decision is enhanced.

The Information Mode of Management

The management system about workshop human resource is a key component of MES Jian Li (2003). The integration between workshop schedule management and workshop production task management is shown in Fig. 6.1.

The operating process of workshop human resource system includes model optimization, real-time allocation scheduling and real-time information updates.

The Model Optimization About Workshop Human Resource

The workshop human resource management receives information through integrated interface from ERP. In the system, all production stations is allocated, which belong to the production line of tasks , then they constitute a real-time skills requirements matrix, at the same time, all production employees in the production tasks is also allocated to shop floor employees real-time skills matrix, then the Workshop Human Resource Allocation Matrix Model will be built after the operation is started between Station real-time workshop skills needs matrix and shop floor employees real-time skills matrix. After optimization of the computing system, workshop allocation of human resources matrix model output specific optimal

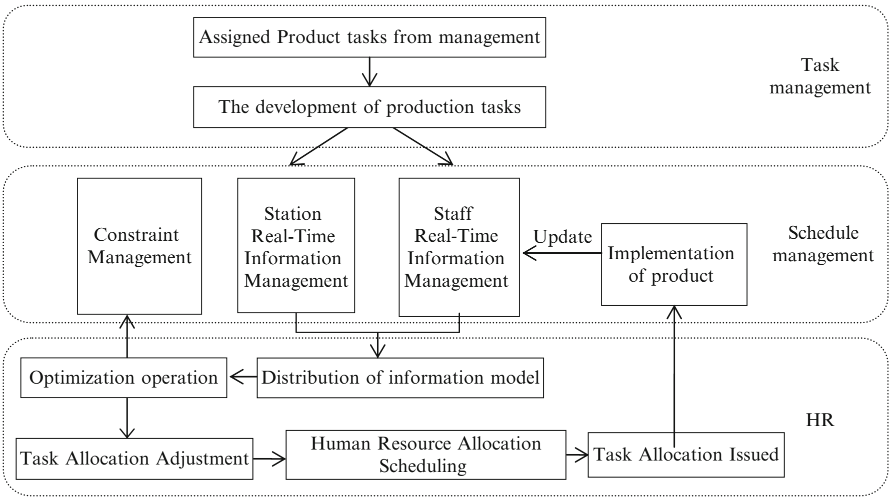


Fig. 6.1 The shop floor of human resources management and operation processes

matching of every process station and production workers in the production tasks. In order to ensure production efficiency, it also accepts the personnel basic information from ERP to fully grasp the movement of staff.

The Dynamic Allocation Scheduling of Production Tasks About Human Resource

Depend on the result of distribution mode optimization operation about workshop human resource. Workshop management according to the demand of production make adjustments to the production tasks of human resources, and make optimal matching about operating staff. After the system complete production task allocation of human resources. The message send by the terminal of MES or mobilephone to relevant staff to fulfill dynamic allocation of human resources of each production task.

Real-Time Information Update of Production Process Information

Through integrated interface with the production schedule management system, the management system about workshop human resource may collect real-time information from various performed production tasks, conduct real-time updates of staff skill matrix and location skill requirements, it also may dynamic control of the workshop production staff skill condition so as to guide human resources and scheduling of each production.

Workshop Human Resource Management System Function System

According to the problems and needs put forward above that exist in Workshop Human Resource Management, and in accordance with the requirements of modular design to complete the functional design of the system, this system is mainly composed of several modules, as shown in Fig. 6.2.

1. System Permissions Management module is the basis of running the system and the guarantee of operating the system security and manages the system users, permissions, logs and data maintenance.
2. System Interface Management Module is mainly integrated Workshop Human Resources Management System and other systems. It accepts the production task information from ERP system and the feedback of the production performance from the production progress management system in MES, after integrating and

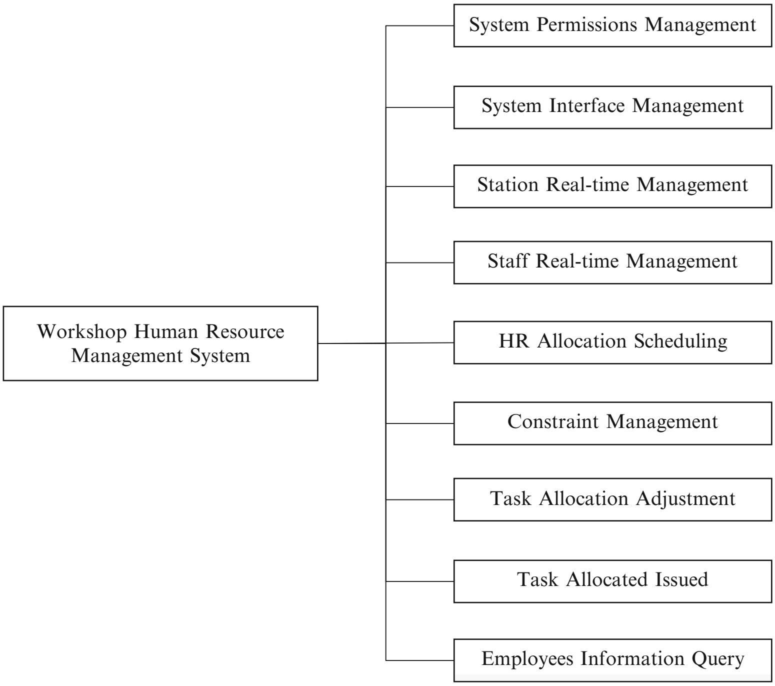


Fig. 6.2 The model of workshop human resource management system

converting, imports them into Workshop Human Resources Management System through the integrated interface. And it reflects human resources real-time status to the MES system.

3. Station Real-Time Skills Demand Management, based on the actual requirements of the production tasks and skills of each production station, builds the employee skill information of each station real-time requirements in the workshop production line.
4. Workshop Staff Real-Time Skilled Information Management is the basis of Workshop Human Resource Management. It can real-time reflect the skill situation of employees in the production workshop, and real-time update the employees' skills information.
5. Human Resource Allocation Scheduling: the workshop human resource configuration scheme is obtained by combining the workshop staff real-time skill information with station real-time skills demand information, that is, the skill configure of each staff corresponded to each station.
6. Production Constraint Condition module needs to consider the actual workshop situation in workshop human resources management process, such as the shortage of the station workers, and the actual training demand of employees.
7. Task Allocation Issued System automatically sends the human resources situation after optimizing configuration to the relevant staff through the MES

terminals and mobile phones. Through the support system of workshop human resource allocation, Integrated information query could get any time of workshop human resource allocation scheme and workshop human resources real-time situation, and carry out workshop human resource related information integrated query, statistics and analysis.

Because the workshop Human Resource Management System is one of the important components of plant MES, so the system management and basic data management module can be run separately, also can be a part of MES system management and basic data management module, and share with MES other function subsystem.

The Key Technology of the Workshop Human Resource Management System

The technology of real-time interactive information is the key technology of the workshop Human Resource Management System. The workshop Human Resource Management System, including information exchange and resources sharing between the workshop layer and management layer, and the integrated operation of production stations and operating workers in the workshop layer. The workshop Human Resource Management System receive the production tasks and work skills requirements from a management system, then through interactive information terminals convey the production tasks and personnel assignment information to each production stations and operating workers. On the one hand, the operating workers could transmitted the production process information to the support system with multi-functional interactive information terminals in the production process timely; on the other hand, the system update the workshop employees real-time skills database and workshop constraint database dynamically to ensure that the workshop of human resources information real-time and accuracy.

Conclusion

Firstly, based on the workshop human resource management practices and combined with the ideas and concepts of MES, the paper put forward the workshop human resources management system model. Secondly established demand analysis, operation mode and function system of workshop human resources management. Finally Based on interactive information terminal in the workshop of human resources information real-time interactive technology researched some of the key technologies of system design and system implementation.

References

Bin Li, Liping Chen (2005) Research on assembly line optimal scheduling of mass customization [J]. China Mech Eng 12:2198–2202

Fei Liu (2007) The MES of discrete manufacturing industry need to achieve the integration with equipment level [J]. Chinese Manuf Inf 18:14

Guanying Liu, Kaichao Yu (2010) A study of enterprise performance management system based on KPI+BSC. Research in third information management, innovation management and industrial engineering international conference, 11

Guoju Chen (2010) Human resource management is the effective way to improve efficiency of the workshop. (Journal of Guangxi University (philosophy and social sciences edition)), Guangxi University, stage S1

Huafeng Zhu, Jianrong Tan, Tao Li (2005) Research on ERP scheduling that based on optimized production technology [J]. Chinese J Mech Eng 04(7):594–597

Jian Li (2003) The informationization of manufacturing industry is a revolution [J]. Manuf Inf Eng China 11:223–232

Jianjun Yang (2000) MES system for the management of the core manufacturing process. Advanced manufacturing mode manufacturing execution systems (863-511-943-003) the subject of the interim research report. Institute of Aerospace, Manufacturing Systems, Beijing

Kelly T (1995) Electronic date system. MES in the age of agile manufacturing [J]. A presentation at MESA Roundtable 4, Chicago, 13 Sept 1995

Object Management Group (1997) Manufacturing domain task force RFI-3 Manufacturing Execution Systems (MES). OMG document mfg/97-11-01, 6 Nov 1997

Quanwen Liao (2000) Human resource development system [M]. Shandong People's Publishing House, Jinan, pp 4–9

Shuting Zhang, Jianjun Yang, Xue Li (2000) Agile manufacturing workshop production management mode and system design [J]. Modern Manag 10(8):39–40

Yunqing Rao, Peigen Li, Shuxia Li et al (2002) The present situation and development trend of manufacturing execution system. Mech Sci Technol 21(6):1011–1016

Zhang HP, Gen M (2005) Multistage-based genetic algorithm for flexible job-shop scheduling problem [J]. Complex Int 1:10–13

Zhixin Wang, Shousong Jin (2006) The manufacturing execution system MES and its application [M]. China Electric Power Press, Beijing

Chapter 7
Steel Enterprise MES System Function Structure Based on the ISA-95 Standard

Jing-dan Shi, Min Li, and Jin-yuan Zhong

Abstract Standardization and integration is significant development trend to new research on MES. Steel enterprise MES which has discrete and process characteristic have more overlap between software system and function module, system structure and function model is not enough unity, there are serious problems in its standardization, integration and standardization. This paper constructs the steel enterprise standardized system structure and function model based on the ISA-95 standards. The model includes production operation, inventory operation, quality operation, maintenance operation, energy management and intelligence analysis and optimization decision support six basic function modules, and unified design system integration interface of enterprise layer and control layer. Advantages and characteristics of standardization and configurable solved the problem steel enterprises MES faced on standardization and integration.

Keywords Function model • ISA-95 standard • Steel MES • System structure

Introduction

Manufacturing execution System promoted by the modern information technology, control technology, manufacturing technology and management technology, is headed to integration, standardization, agilization, intelligentize, visualization, specialization development direction (Zheng Li et al. 2010). Standardization and integration have become important direction about MES research. In addition, MES is not supported by mature basic theory, mainly there is not using basic method of unified management-control system integration technology terms, information

J.-d. Shi • M. Li (✉) • J.-y. Zhong
Department of Electrical Engineering, Kunming University of Science and Technology, Kunming, China
e-mail: liminleah163@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_7,

object model, activities object model and the flow of information, the user or customer, equipment suppliers and system integration have communication needs difficulties, integration difficulties between different hardware and software system and maintenance difficulties after integration. Steel enterprise is a typically compound manufacturing enterprise, first process manufacturing, and then discrete manufacturing. Therefore, steel enterprise MES system structure and function structure have many differences between process and discrete manufacturing, so steel enterprise information systems integration has great inconvenience. Steel enterprise MES standardization and integration have serious problem.

At present, special study on function structure of steel MES system is not many, paper (Li Huiying et al. 2003) analyzes steel enterprise production characteristics and puts forward steel enterprise MES system structure, further discusses the integration function of MES (Li Huiying et al. 2003). Literature (Bi Yingjie 2005) introduces suitable for MES system function of China's steel industry, technical features and future development trend (Bi Yingjie 2005). Literature (Li Tieke et al. 2003) puts forward steel enterprise MES function structure framework and design principle, but without ISA-95 standard (Li Tieke et al. 2003). Although Literature (Pan Cao et al. 2009). puts forward the process industry MES system structure based on ISA-95 standard, steel enterprise is different from other process enterprises (Pan Cao et al. 2009). Accordingly, it is needed to research it specially.

In order to solve these problems and avoid causing unnecessary disputes among different manufacturers, ISA and ISO avoid MES boundary where debates, for more general manufacturing automation system construction reference model, define functions composition of system and the relationship of each functional module. The manufacturer's MES could select the parts of functions architecture to achieve, but with external integration, meeting the functional relationships and data interface relations that ISA-95 standard definites can be integrated effectively. ISA-95 standard is used to build MES system, can effectively solve problems of steel enterprise MES standardization and versatility.

ISA-95 Standard Summarize

ISA-95 is the international standard for enterprise —control systems integration, also called S95 or SP95, which is released by The instrument, system and automation association (ISA) in 2000. 95 represents the 95th project of ISA standard.

ISA-95 standard has six parts. The first part which is Models and Terminology defines the enterprise function data flow model and 31 kinds of information between business system and control system interaction and establish nine models. The second part is Object Model Attributes, defines the attributes of nine models in the first part in detail; The third part: Activity Models of Manufacturing Operations Management, the enterprise manufacturing operations management is divided into production operation, maintenance operation, quality operation and inventory operation four areas, definite eight basic production activities: detailed planning, resource management, assignment, definition management, implementation management, data acquisition, tracking and analysis; The fourth part is Manufacturing Operation Management Object Model And Property, explaining the third part in detail. The fifth is Business-Manufacturing Transaction Processing, defining exchange model between application business and manufacturing activity execution information which is between the third and fourth layer in the first part, the purpose is to make information collection, retrieval, exchange and storage can support enterprise-control system integration (ISA-95.00.01- 2000; ISA-95.00.02- 2001; ISA-95.00.03- 2005; ISA-95.00.04-2005; ISA-95.00.05- 2007). The sixth is designing, will detail manufacturing operation management affairs. ISA-95 standard the first part to the third has been international standard—"IEC/ISO62264 enterprise control system integration" by international standards organization and the international electro technical commission. China, too.

MES application architecture of solution project from design to application modules all could refer to ISA-95 standard, the main module: quality, production and efficiency are all consistent with ISA-95 standard. MES modules penetrate production plan, equipment, production process and resources which are ISA-95 object models.

MES Function System Structure of Steel Enterprises Based on ISA-95 Standard

Function Model and Manufacturing Operation Management of General Activity Model of ISA95 Standard

ISA-95 standard defines manufacturing operation management function model and manufacturing operation management of general activity model (ISA-95.00.03-2005), as shown in Figs. 7.1 and 7.2.

ISA-95 standard hold that finish manufacturing operations process needing to have order processing, production scheduling, production control, material and energy control, purchasing, quality assurance, product inventory management, product cost accounting, product delivery management and maintenance management ten functions, auxiliary R&D and engineering design as well as marketing and sales two externalities activities. MES space is the scope dotting line box in Fig. 7.1. You can see that other function modules all have overlapping problem except production control. ISA-95 divides ten function modules into production operation management, inventory management, quality management, maintenance operation management four function areas (Li Qing 2007).

Manufacturing operation management general activities model as Fig. 7.2, also manufacturing operation management every functional partition external interface

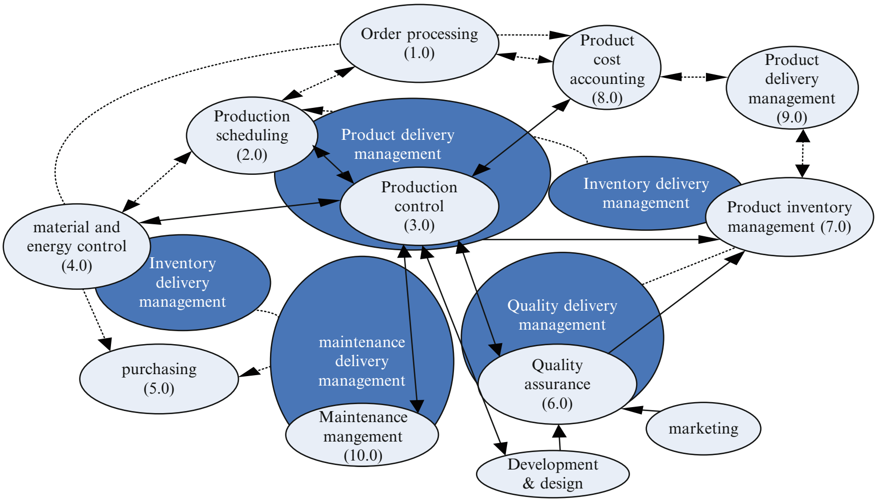


Fig. 7.1 Manufacturing operation management function model

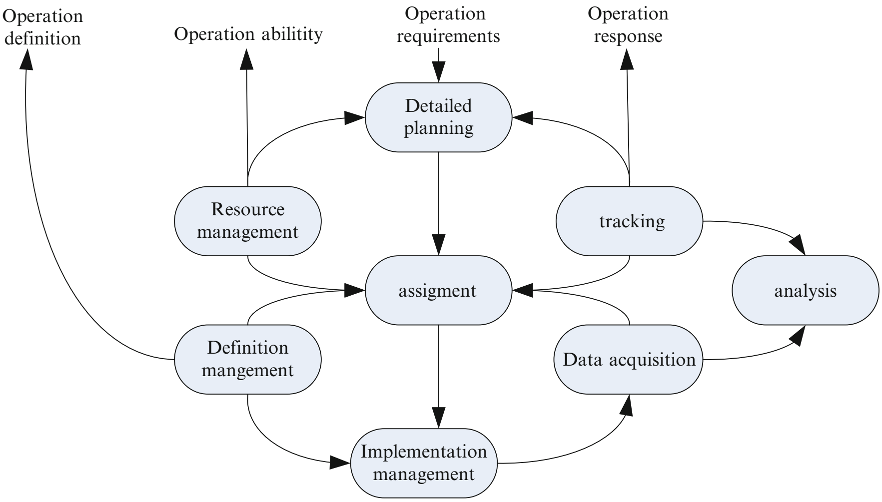


Fig. 7.2 Manufacturing operation management of general activity model

all includes operation definition, operation ability, operation requirements and operation response. And functional partition internal all includes detailed planning, resource management, definition management, assignment, implementation management, data acquisition, tracking and analysis eight functions activities.

MES System Structure and Function Model Figure of Steel Enterprise

Combined with ISA-95 standard and reality of steel enterprise, this paper puts forward steel enterprise MES system structure and function model, Fig. 7.3 showing.

The MES system structure and function model is consist of production operations management, maintenance operation management, quality management, inventory management, energy management, intelligence analysis and decision support optimization function, and ascertain the interface MES system with the business plan layer and the bottom layer of industrial control to collect, storage and transfer data and information effectively. It has good generality, standardization and configurability.

And every subsystem includes eight function modules are corresponding with eight activities of manufacturing operation management activities model.

1. Production operation management function module: when receiving detailed production plans or commands from business plan layer or other function subsystem, "product definition management" manages all information from MES layer required to produce products. Among them, specific production rule information of equipment and process according to specific production task is send to specific instruction to control layer; work center transfers specific product production rule and detailed production path information to "detailed production scheduling", "production dispatching" and "production execution management". Then "production resource management" definite required equipment, material and energy resources for production to meet other production requirements, then providing resource ability information to "detailed production scheduling," transforming availability information of human, equipment, material and energy into "production dispatching", and collecting current state information of resource and its ability and resource capacity from control layer to ensure them could finish production. According to "product definition management" and "production resource management" generating "detailed production scheduling", sorting the minimum equipment start or clean to decide to optimize and use local resource, and collecting WIP (Work in place) from "production tracking" and work finishing report information to ensure commitment resource capacity, thus generating detailed production scheduling. Next, according to "detailed production scheduling" to do "production dispatching", clearly distribute resources used in production work order for production, transferring work instruction to work center and scheduling list information is sent to "production execution management". And then "production execution management" choices, starts and moves work unit to actual production product operation correct sequence. After production operation instruction is transferred to control layer, collecting operation response information and sending them to "production data collection". "Production data collection" gathers, edits and manages production data for specific procedure or production command, actual production and equipment

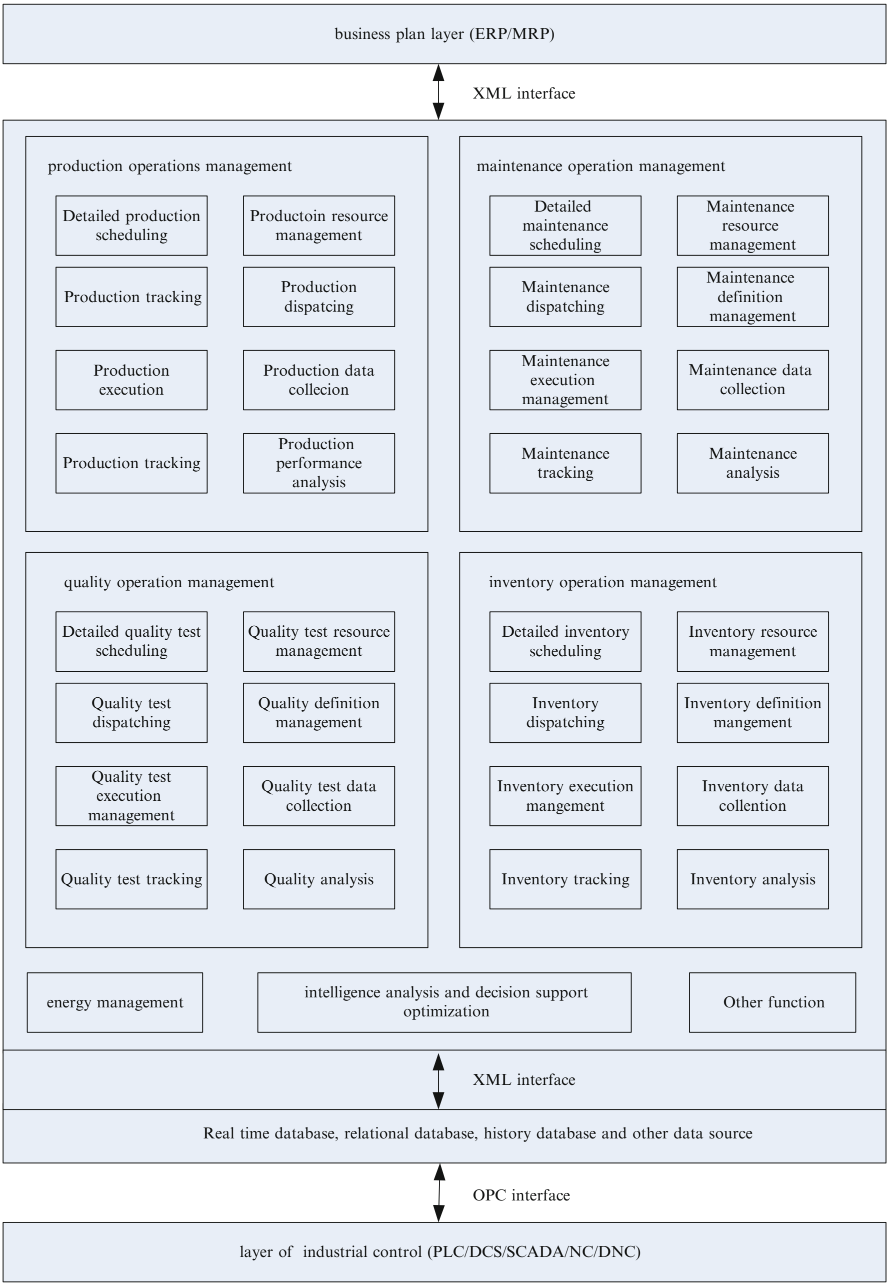


Fig. 7.3 Steel enterprise MES system structure and function model

state information and data information from control layer are respectively feedback to “production dispatching” and “production tracking”, transferring used resources data information to “production performance analysis”. The next “production tracking” collects and reports actual using production information and data of personnel, equipment, material related to production product, tracking and collecting resource historical data information of equipment and process from “production data collection”, WIP and completing production work report information are passed on to “detailed production scheduling”, and production quality and performance data information interacting with “production performance analysis”. Finally, “production performance analysis” analyses information of production units cycle time, used resource, equipment performance, process efficiency and production variation, prepares production response for business plan player.

2. Maintenance operation management function module: after receiving maintenance plans or commands, “maintenance definition management” definite, manages and maintains information and instruction that completing maintenance task needed, specific information of equipment maintenance procedure will be sent to control layer, and specific equipment maintenance rule and detailed maintenance path information to “detailed maintenance scheduling”, “maintenance dispatching” and “maintenance execution management”. And then “maintenance resource management” identifies resources for maintenance and provides current information to make the best decision. At the same time, maintain resource information is sent to “detailed maintenance scheduling”, and availability information of maintenance resource to “maintenance dispatching”. According to maintenance resources, generating “detailed maintenance scheduling” for factory or region, then “maintenance dispatching” distributes and delivers maintenance work single to right maintenance resource. Then “maintenance execution management” guides maintenance command and program to equipment in control layer to execute, and accepts maintenance result information from control layer. Then “maintenance data collection” gathers equipment data information and event maintenance. Then “maintenance tracking” generates or updates record activity about maintenance equipment and utilization rate so as to ensure relative effectiveness of executing maintenance activities and its results. Finally, “maintenance analysis” inspects personnel, equipment, material history activity to summarize past and future performance indicator or future potential problem, collected data and analysis results are transformed into maintenance response.
3. Quality operation management module: its main part quality test operation management. when receiving quality test plans or commands, “quality test definition management” definite and administrates implementation quality testing personnel qualification, quality testing procedure and work instruction, and inspect specific quality rule at work center and detailed quality path information to “detailed quality test scheduling”, “quality test dispatching” and “quality test execution management”. And then “quality test resource management” sure resources for executing quality test, and provides quality resource information for “detailed quality test scheduling”, meanwhile resource availability information to “quality

test dispatching" and receiving current quality information from control layer. Then "detailed quality test scheduling" plans and schedules resource for quality task and transforming them to "quality test dispatching", then it distributes quality work order and send it to right resource. Then according to quality test scheduling list, "quality test execution management" guides test to ensure resources are used correctly, after that, collecting test responses information from control layer. "Quality test data collection" provides standard report or meeting demand for quality inspector. And then "quality test tracking" becomes test result formation into test response, manages useful resource information quality test needing, collects resource history data information and scheduling list information, at the same time interact quality and performance data information with "quality performance analysis". "Quality performance analysis" analyzes quality test results and decides how to improve product quality and "quality test tracking", and transform them into response.

4. Inventory management module: when receive inventory plans or commands, "inventory definition management" identifies rule and information related with material moving and storage, at the same time specific inventory rule and detailed inventory path information at work center are sent to "detailed inventory scheduling", "inventory dispatching" and "inventory execution management", and storage definitions information is sent to control layer. Then "inventory resource management" insures resource and resource ability that material storage and moving required, and resource capacity information is pass on to "detailed inventory scheduling", resource availability information to "inventory dispatching". The next according to inventory request generating "detailed inventory scheduling" meanwhile detailed inventory scheduling information is sent to "inventory dispatching", Afterwards, "inventory dispatching" distributes and sends inventory work order to appropriate resources, according to detailed inventory making scheduling list. "inventory execution management" according to inventory scheduling list, inventory rule and detailed inventory path to execute inventory work meanwhile operation commands are sent to control layer, after that receiving replies information from control layer, and inventory information is sent to "inventory data collection", then it collects and reports relevant inventory and material operation data information and resource historical dating- information is sent to "inventory tracking". Afterwards "inventory tracking" interact inventory quality and performance data information with "inventory analysis", and current inventory and report information of work finishing to a "detailed inventory scheduling". "Inventory analysis" analyzes efficiency of inventory and resource utilization ratio to improve inventory operation, and data information is feedback to response so as to do next operation activity.
5. Energy management module: including energy consumption and emissions monitoring, energy analysis, energy plan and scheduling three functions.
    1. Energy consumption and emissions monitoring. Collect every factory or workshop, process, unit, equipment, products of all energy consumptions and emissions to set up a corresponding database to store data.

2. Energy analysis. Energy analysis about supply and demand balance, it collects energy historical information, establishes database and energy forecast model; collects energy consumption index, makes energy evaluation objective, analyzes product energy consumption and comprehensive energy consumption per ton steel.
3. Energy planning and scheduling. According to supply and demand plan of energy balance, preparing energy production plan, export plan and purchasing plan. Thus, arranging energy production plan, Energy on-line scheduling, formulate plan to prevent energy shortage and emergency plan of energy disruptions.

6. Intelligence analysis optimization and decision support function module: it provides intelligent analysis optimization and decision support of the whole work flow. With manufacturing intelligence, which based on data, information, synthesis and analysis ability of knowledge, quickly summarizing the actual situation of business operation, providing support for managers to make right and timely decisions.
7. Other function module: such as information management, document management. Specific function depends on practical situation.

System integration interface is as follow:

1. Information integrated platform based on Extensible Markup Language—XML interface: In many varieties and variable mass production mode, there are a lot of individuation dynamics information, how to rationally storage, organize and share them is the key to realize system integration and share information (Hong Zhucai et al. 2003). XML technology makes it is possible to describe all sorts of irregular information standardization, it is an inevitable trend of information technology development that build enterprise information integration platform on XML technology (Zhang Feng et al. 2001). XML technology in the MES system has the following specific advantages:

   1. Can effectively realize knowledge and data integration of every function within the system. XML can express the content and structure of data, can be applied to dynamic information, and greatly reduce extra application cost caused by business rule changing, support openly structured data, facilitate network transmission.
   2. Can effectively implement heterogeneous data integration and sharing with upper ERP system and the bottom of control. XML is a new standard, its content and form is separated and has since description, open, extensibility, simple and flexible properties (Chen et al. 2003). It uses a DTD (document type definition) to provide a set of rules about mark symbols syntax and semantics rule, describe information about material, meaning, structure, feature and relation, while appearance form of material sheet is done by style, improving XML data interchangeability and reusability. MES takes standard XML interface of ISA-95 can be connected directly every ERP manufacturers up to ISA-95 standard. ISA-95 provides a standard for

exchanging information, reducing the cost of MES—ERP integration, and working together with product life cycle management, providing production ability and state as well as information integration architecture and standard model improving flexibility of production. It is suitable for batches, continuous and discrete process.

These advantages can effectively solve data sharing and interaction problem between different application systems and data sources.

2. OPC interface based on control and integration of OPC technology: in traditional control system layer, because of a lack of specifications, there are many software/hardware device interface standards defined by different manufacturers, leading to difficulty of product integration. OPC (OLE for process control) is object linking and embedding technology application in process control, the aim is to establish an effective data exchange interface, provide uniform standard for industrial automation software object-oriented development, improve automation applications in manufacturing and process control industry (Zhang Feng et al. 2001). OPC follows C/S (Client/Server) model will see data source part (device drivers) as OPC Server, other access port (applications) as OPC Client. OPC Server packages data communication logic for specific hardware device and provides standard OPC interface for client access. The OPC provides the function of internal links for different vendors' equipment and software package. Because of unified interface, as long as different customer program and different server program fit for OPC standard, can be articulated and cooperatively work, thus forming a kind of software bus structure. So, it is perfect that MES links control layer with OPC.

Discussion

Research on multi-objective intelligent decision mechanism of product optimization and saving energy and reducing consumption that raw materials and product demand are multiple and uncertain, and the key technology of production plan integration and production scheduling dynamic optimization, production equipment, logistic, quality, real-time monitoring of energy consumption and emissions, intelligent analysis and optimization of all production process information along with data integration platform, develop standardized and configurable MES products in metallurgy industry, realize multi-objective closed-loop management and control of the whole manufacturing process is china's current goal of process industry MES.

This paper proposes steel enterprise MES system structure and function model and ensures the information system integration interface based on the ISA-95 standard. It satisfy above MES requirements of process industry, this is a characteristic in the paper.

Conclusion

MES is developing toward the next generation of MES: it will base on the ISA-95 standard, which characteristic is easy to configuration, easy to change, easy to use, no customized code, good integration and provide gateway (Portal) function, its main goal is to achieve production cooperative by engine of MES in worldwide (Shao 2006). As process of manufacturing enterprise information, the standardization requirement of all kinds of software system integration is increasing day by day, and ISA-95 standard affects more deeply in manufacturing, it is used to guide research and practice in manufacturing enterprise informatization has become new issue in the field(Xiao Liyong et al. 2011). ISA-95 standard is applied in discrete manufacturing will be the next research objective.

References

Bi Yingjie (2005) MES overall structure and application in steel industry [J]. Control Eng (14):530–532

Chen Xiaorong, Yu Kaichao, Hou Kaihu, Huang Dongxin (2003) E-commerce application system based on XML [IJ]. J Kunming Univ Sci Technol (Sci Technol) (2):112–115

Hong Zhucai, Shi Jinfei, Zhang Zhisheng (2003) Study on a new XML-based expressing method of dynamic quality information [J]. China Mech Eng (7):613–615 (Chinese)

ISA-95.00.01-2000. Enterprise-control system integration part 1: models and terminology

ISA-95.00.02-2001. Enterprise-control system integration part 2: object model attributes

ISA-95.00.03-2005. Enterprise-control system integration part 3: models of manufacturing operations management

ISA-95.00.04-2005. Enterprise-control system integration part 4: object models and attributes for manufacturing operations management

ISA-95.00.05-2007. Enterprise-control system integration part 5: business to manufacturing transactions

Li Huiying, Wu Daxun, Chai Tianyou (2003) Manufacturing execution system research on steel enterprise [J]. Metall Autom (36):35–37 (Chinese)

Li Qing (2007) Manufacturing execution system [M]. China Power Press, Beijing

Li Tieke, Zhang Wenxin, Cui Jianshuang (2003) Steel enterprise manufacturing execution system structure [J]. Metall Autom (7):18–21 (Chinese)

Pan Cao, Yang Xiaoying, Shi Lianmin, Liu Zhongjie, Wang Hongyuan (2009) Process industrial manufacturing execution system design and implementation based on the S95 standard [J]. Comput Appl Sci (8):1027–1030 (Chinese)

Shao Xinyu (2006) Present situation and prospect of MES technology development. Huazhong University of Science and Technology, Wu Han (Chinese)

Xiao Liyong, Su Hongye, Chu Jian (2011) Manufacturing operation management system based on the IEC/ISO62264 standard [J]. Comput Integr Manuf Syst (7):1420–1429 (Chinese)

Zhang Feng, Wang Jun, Wang Hongan (2001) The implementation and application of XML based on information integration system [J]. Comput Eng Appl (24):123–147 (Chinese)

Zheng Li, Jiang Pingyu, Qiao Lihong, Xi Lifeng (2010) Research challenge and frontier of manufacturing system [J]. J Mech Eng (21):124–136 (Chinese)

Chapter 8
A Lean Shop Floor Tracking System

Ming-jian Yuan, K.C. Yao, C.Y. Chen, and J.Y. Jheng

Abstract Lean production and push production are the two major types of production control philosophy. Push production has acquired the benefits of computerization from standard packages for a long time. On the other hand, lean production emphasizes human involvement, and its computerization is relatively late in comparison and has not yet acquired standard package. To make the information flow more real-time and intellectual, this paper presents a shop floor tracking system for lean production. The system upgrades the shop floor computerization of lean production to the same level as its counterpart in push production, and at the same time reduces waste and delay from physical kanban. In addition, the lean SFT can be integrated with conventional ERP, thus not only giving lean production the best benefits of ERP, but also making ERP more effective and flexible in shop floor control.

Keywords Lean production • Push production • Shop floor tracking • ERP

Introduction

Lean production and push production are the two major types of production control philosophy. Push production has been continuously computerized using standard packages for a long time. Lean production, in contrast, emphasizes human involvement, and its computerization lags behind to some extent and has not yet acquired standard package. To make the information flow more real-time and intellectual, this paper presents a shop floor tracking system for lean production. The system upgrades the shop floor computerization of lean production to the same level as its

M.-j. Yuan (✉) • K.C. Yao • C.Y. Chen • J.Y. Jheng
Department of Industrial Engineering and Management, National Yunlin University of Science and Technology, Douliu, Taiwan
e-mail: yuanmj@yuntech.edu.tw

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_8,

counterpart in push production, thereby reducing waste and delay from physical kanban. Moreover, the lean SFT can be integrated with conventional ERP Data Systems Consulting Inc (2006b), thus not only giving lean production the best benefits of ERP Holsapple and Sena (2005), but also making ERP more effective and flexible in shop floor control. This paper introduces conventional shop floor control in section "Conventional Shop Floor Control". In section "Lean Production", lean production is briefly reviewed. A Lean SFT is then proposed in section "Lean Shop Floor Tracking". And section "Discussion and Conclusion" is dedicated to further discussions and conclusions.

Conventional Shop Floor Control

According to the definition of SAP (SAP Community Network 2007), "the Shop Floor Control (SFC) is concerned with the detailed management of activities and the flow of materials inside the plant- including the workers, materials, machines and time utilized in production." Figure 8.1 is a general SFC diagram (Melnyk et al. 1985). The SFC activity starts after the planning is done in an ERP system, including the creation of purchase orders and the conversion of planned orders to work orders, as shown in the upper part of Fig. 8.1.

The SFC includes the following activities in sequence, as shown in the middle part of Fig. 8.1. (1) *Order release* is to notify the shop floor that a specified work order can go into production; (2) Work in process *checks in* a work station to get registered when it is transported to the work station; (3) *Dispatch* is to determine the next work in process to be operated according to certain priority rules; (4) *Operation* is the production according to a manufacturing route; (5) *Unload* is to move a semi product out of a machine; (6) *Data collection* is to record production parameters or quality investigation results; (7) Work in process *checks out* a work station to record the machine time or labor time consumed, and is then moved to a next work station or a warehouse- a semi product may need *rework* if a flaw is detected. And finally, (8) Finished product may need to be *classified* to a quality grade for sales purpose.

When a work order completes all the activities above, it is disposed and the finished product is stocked in a warehouse. The SFC activities are so complicated that a management information system is usually required to make the activities smooth and effective. Some of the systems have been developed specifically for highly-automated environment, such as IC foundry, TFT-LCD Optronics, and PCB industries. Those systems are known as manufacturing execution systems (MES) (MESA International White Paper No. 3 2000). Many other systems have been developed as ERP modules (Data Systems Consulting Inc 2006a), in that SFC activities are not independent and have to be integrated with many other business activities to complete enterprise goals (Howells 2000). Figure 8.2 is a conventional ERP OTD process (Order-to-Delivery). The shadowed area in the figure is the production process, in which the upper part deals with the production planning while the lower part *executes* and *tracks* the production.

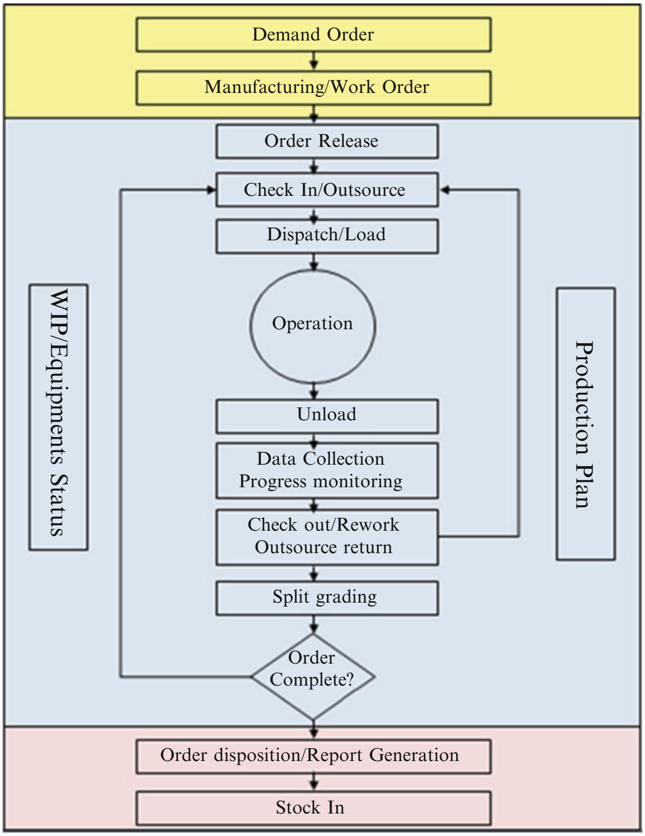


Fig. 8.1 SFC function diagram

The lot requirement planning (LRP) in Fig. 8.2 computes the quantities of the items to be purchased or manufactured by balancing customer orders, the inventory in stock and in transit, and the work in process. LRP results in a procurement plan and a production plan. Approved procurement plans are converted to purchase orders, which is processed through the purchase cycle. On the other hand, approved production plans are converted to work orders, and a production cycle follows. A work order then starts from lot splitting and releasing, and each lot can be tracked individually. Materials are withdrawn before production, and then the lots go through the production. A lot repeatedly checks in and checks out each work station as specified in a manufacturing route. Various ERP vouchers are generated to record the production during the process, such as releasing vouchers, WIP transfer vouchers, and stock-in vouchers. As stated earlier, a lot may need rework if a flaw is detected. When a lot completes all the production, it is stocked in a warehouse with a tracking number assigned.

As shown in the right side of Fig. 8.2, when purchased items are received and accepted, an account payable process is initiated. And in the left side of Fig. 8.2,

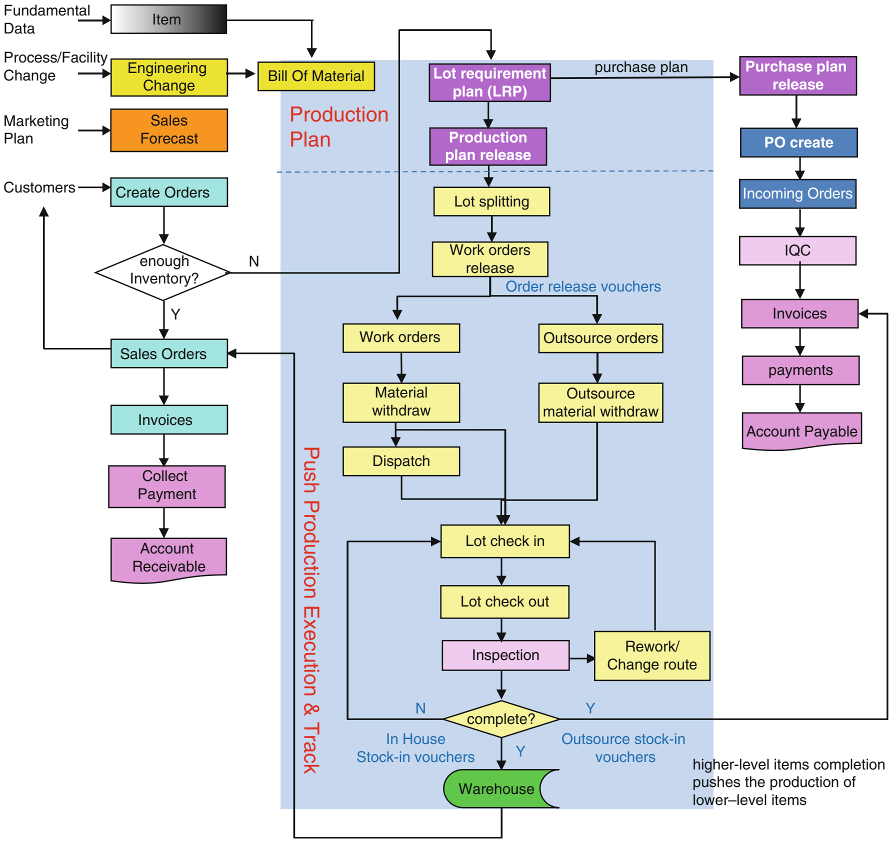


Fig. 8.2 A conventional ERP OTD process

finished products are shipped to customers, and an account receivable process follows. This completes the entire OTD process. The process is conventional “push” style since it has the following features:

1. Work orders are the focus of plan and control. Work orders and the materials flow are *pushed* forwardly from front work stations to the back.
2. The direction of production control is *pushed* from higher-level to lower-level items. That is, the production of lower-level items is triggered by the completion of the associated higher-level items.

SFT (Shop Floor Tracking) (Data Systems Consulting Inc 2006a) is an example of ERP module that facilitates the shop floor process above. SFT monitors the progress of each lot in a plant and links their operations seamlessly. For instance, when the work in process checks out a work station, the system will notify the next work station so that the work in process can be published in the check-in list when it arrives. In addition, when a higher-level item finishes production, SFT will automatically check if there is an associated lower-level work order to be released, so

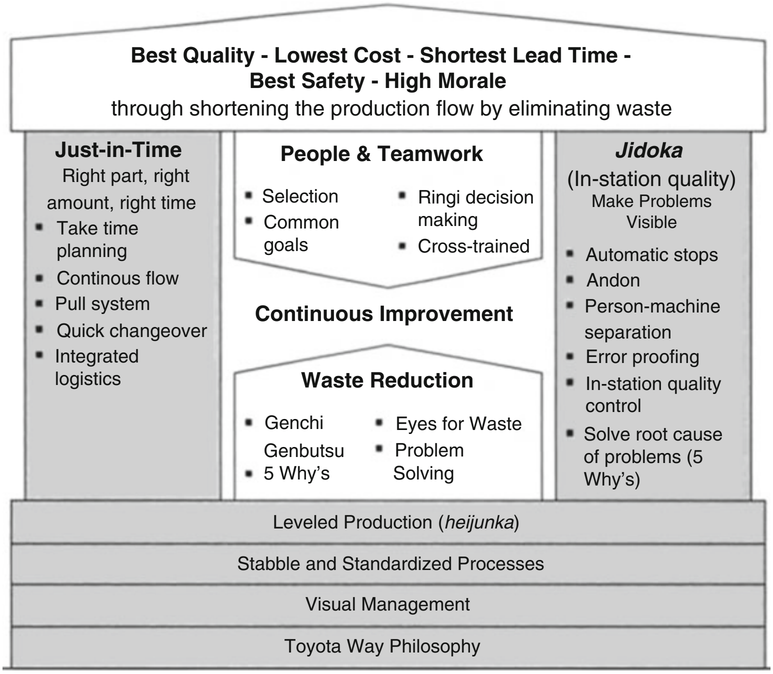


Fig. 8.3 A Toyota production system house (Liker 2003)

that a production manager can be reminded to release the order at the earliest moment. SFT makes shop floor information transparent to both the managers and the workers, and has been considered indispensable to effective shop floor control.

Lean Production

Lean production (Womack and Jones 1996) evolves from Toyota Production System (TPS), which is an efficient production philosophy. TPS is usually described as a house, as shown in Fig. 8.3 (Liker 2003). The house foundation represents the needs for standardized, leveled production processes, and visual management. The roof represents the system goals: best quality, lowest cost, in-time delivery, best safety, and high morale. The goals are accomplished by eliminating waste in all aspects. Just-in-Time and Jidoka are the two major practices of the system. JIT is to produce the right item, at the right quantity, and at the right time. The ideal production is one-piece flow that makes one unit at a time at the rate of consumers' demand, called takt time. Jidoka is automation with human minds, which will halt production whenever a defect is detected and ask the workers to resolve the problem immediately, before it resumes production. People are in the center of the system, which emphasizes consensus decision making, common goals, and crossed training.

The philosophy above evolves into lean production. One of the most important characteristics of lean production is the pull mechanism that drives the production by demands. A production is initiated only when there is an actual demand, so that inventory can be kept at the lowest possible level. The concept comes from supermarkets: customers withdraw goods from shelves, and empty shelves are then replenished. There are a number of "stores" in lean production to hold products or semi-products. When the products in stores are withdrawn to fulfill customer orders, the production is triggered to replenish the products, similar to the supermarket operations. When products or components are consumed, it demands or "pulls" production. Accordingly, the production control is going backward from the back work stations to the front work stations.

More than a few researches have studied lean production and found that a lean production system can achieve the following benefits (Vadim Kotelnikov 2006):

- Waste reduction
- Production cost reduction
- Manufacturing cycle time decrease
- Labor reduction
- Inventory reduction while enhancing customer service levels
- Capacity increase in current facilities
- Higher quality
- Higher system flexibility in reacting to changes in requirements
- More strategic focus
- Improved cash flow through increasing shipping and billing frequencies

Lean Shop Floor Tracking

A kanban system was employed in a Toyota production system or a lean production system to control the shop floor operations. The traditional kanban systems use physical cards as the pull mechanism. Wan and Chen (2007) pointed out, although successful in many manufacturing industries, physical kanban suffers from human errors, limited tracking capability and labor consumption. To make the information flow more real-time and effective, a number of computerized kanban systems have been developed (Wan and Chen 2007; Thong-Inn Shieh et al. 2009; Cutler 2005). This paper presents a shop floor tracking system for lean production with the same intent in mind. The system is named Lean SFT and is a web application, similar to push-style counterpart in a conventional ERP. Lean SFT is not only an electronic kanban system, but can also be integrated with ERP, giving ERP the benefits of pull mechanism. What follows is the workflow and functions of Lean SFT.

Figure 8.4 presents the OTD process of lean production, and is the counterpart of push production. The shadowed area in Fig. 8.4 is the production process, in which the upper part deals with the planning while the lower part *executes* and *tracks* the production. We will introduce Lean SFT along with the OTD process as follows.

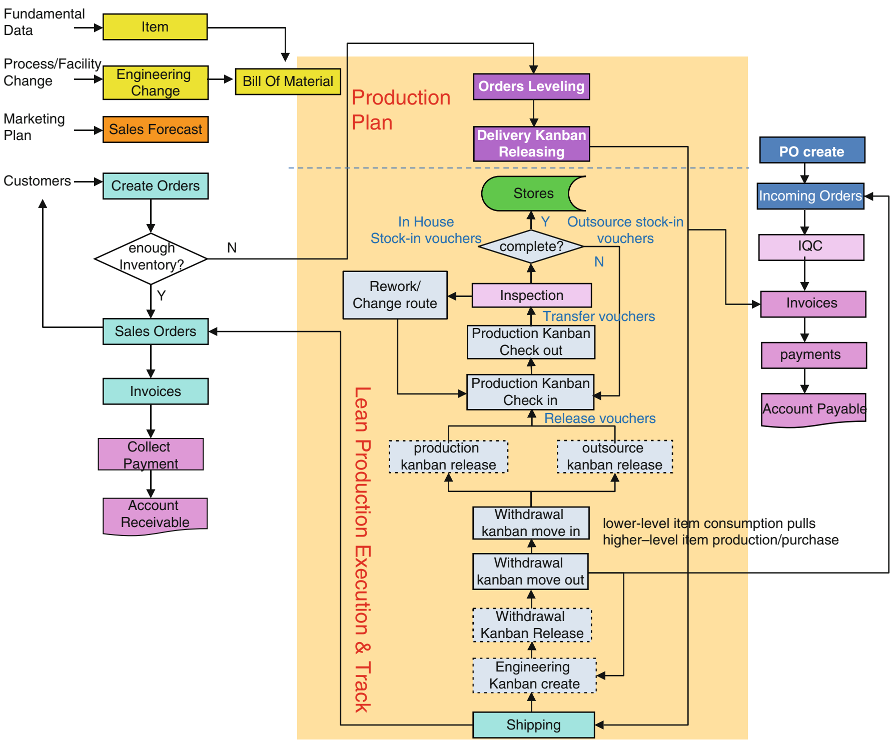


Fig. 8.4 A lean OTD process

Orders' leveling in the top of the shadowed area is to split customer orders to delivery kanban, so that the delivery can be distributed over a period of time, making production balance in terms of products diversity and quantity. The delivery kanban is then assigned a delivery date. Figure 8.5 is the assignment interface. The upper part of the interface lists the unassigned kanban, and the lower part resembles a physical leveling box or a *Heijunka*. The production manager drags a kanban to its delivery date. A window opens to select the exact delivery segment. Each leveling box summarizes and displays the accumulated quantity so that the manager will not over-assign. It can be noted that the control starts from output planning rather than release planning in a lean production.

The shop floor activities are triggered by shipping, as shown in the bottom of Fig. 8.4. Figure 8.5 demonstrates the shipping interface, where the upper grid automatically lists the kanban to be shipped in a day. In addition, the system checks the kanban status and uses colors to distinguish the status: a green sign indicates that the kanban has been shipped, a blue sign indicates the kanban is ready to go, while a red sign warns that the kanban is still short in quantity. The lower part of the interface displays the detailed kanban information. The operator clicks on the shipping button to deliver the selected kanban. Meanwhile, the system does a couple of responses in the background: a shipping voucher is generated and the

Fig. 8.5 Assigning delivery date to delivery kanban

shipping number is returned to the window. In addition, an engineering kanban is generated to signal the replenishment. The engineering kanban is held in a batching box to accumulate the size until a specified level is reached. In a conventional TPS shop floor, all the kanbans and boxes are physical and have to be manually monitored. Although visual management is a key practice to lean production, manual monitor is in fact a kind of *waste*. Lean SFT has turned all the physical kanban and boxes to electronica and monitored their status automatically. A manager will be informed of any abnormality once it is detected, thus accomplishing a more transparent shop floor and more effective “visual” management (Fig. 8.6).

When an engineering kanban has accumulated to a specified level, a production kanban is generated. Before the production kanban is released, the system looks for the raw materials or components required by the production and issues their withdrawal kanban. The withdrawal kanban will then be published in a move-out interface, as shown in Fig. 8.7, notifying the transporters to move the materials either from a store or a warehouse. The system also checks and displays the status of the withdrawal kanban: a green sign indicates the kanban has been moved out, a blue sign indicates there is sufficient material ready for transportation, while a red sign indicates the material is short and the kanban cannot be moved. In the case when a raw material or component is insufficient, the supplier or outsourcer will be notified immediately. In the conventional TPS system, a supplier or outsourcer gets the new replenishment instruction only at the time when they deliver a previous replenishment. The lead time can thus be reduced by the system.

Shop floor transporters move the withdrawal kanban according to the directions in the interface, without going around the floor to check the needs for movement. When a withdrawal kanban is moved out, an engineering kanban is generated again to *pull* the replenishment of the consumed components or material. As stated

Fig. 8.6 Shipping interface

Fig. 8.7 Withdrawal kanban move out interface

earlier, the engineering kanban will be put in a batching box. In addition, a notice will be published in a move-in interface so that the materials can be checked in when it is transported to the destination work station.

When a withdrawal kanban is transported to a work station, the transporter checks in the kanban in a move-in interface, notifying the system that the kanban has arrived. The system then checks whether all the materials or components are

Fig. 8.8 Production kanban check out

ready for the associated production kanban. If ready, the system will automatically release the production kanban to notify the work station of the first operation. Workers choose the kanban listed in the check-in interface to start the operation, notifying the system to record the start time. A checked-in kanban will be forwarded to the check-out interface, waiting for the operation to be completed.

When a kanban finishes its operation, a worker checks out the kanban in the interface as shown in Fig. 8.8. Its upper grid displays all the kanbans that are about to be completed, a worker clicks on the kanban and its route card is displayed in the bottom of the interface. The system will compute and record the machine time used by this kanban. If the kanban has operations to continue, it will be published in the check-in list of the next work station. A transfer voucher is generated by the system and the voucher number is returned to the window. When a kanban completes all the operation, it will be put in a store of the work station and a stock-in voucher will be generated. All the ERP vouchers are generated by the system without manual paper work. When a kanban checks out a work station, additional user-defined production parameters or inspection results can be entered in the interface.

After a kanban is moved to a store, the system updates the store statistics. A manager can browse the items in a store at any time and at any place where the Internet is connected. Figure 8.9 is the store browsing interface. A manger can select an item and investigate its quantity with respect to each lot. Meanwhile, a manager can also browse the batching boxes to investigate the accumulation of engineering kanban.

As shown in the right side of Fig. 8.4, when purchased or outsourced items are received and accepted, an account payable process is initiated. And in the left

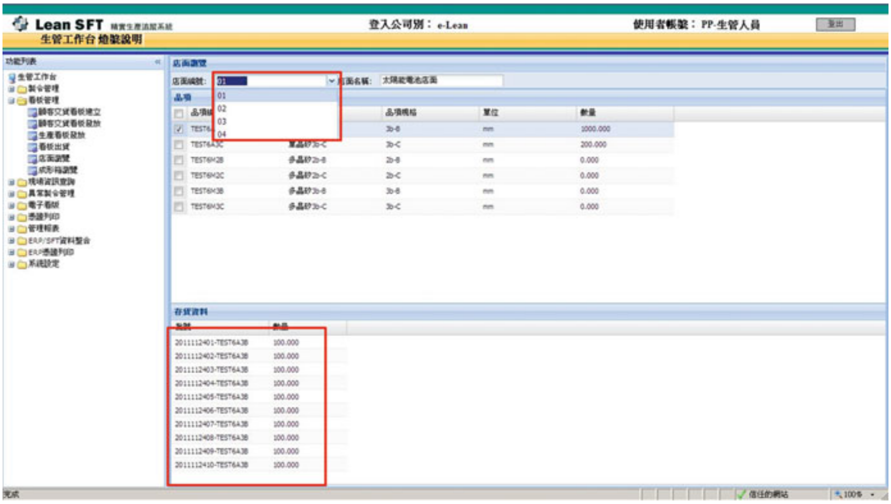


Fig. 8.9 Store browsing interface

side of Fig. 8.4, when finished products are shipped to customers, an account receivable process will follow. This completes the entire OTD process for the lean production.

Discussion and Conclusion

In this section, lean production and push production are compared in the following four aspects:

1. Lead time: lean production is driven by demand and can respond to customer demands faster than push production. Usually, products can be assembled and delivered right after an order is received in a lean system, whereas it takes a longer lead time for a push system if there are not enough inventories.
2. Equipment utilization: the production is usually in large batches in a push system to achieve higher equipment utilization. In fact, utilization is a key performance index for most push systems. On the contrary, a lean system pursues JIT delivery. Unnecessary production is considered to be a waste and utilization may not be a major concern.
3. Inventory level: the production is pulled by actual demand in a lean system, so that the inventory can be controlled at a lower level. Utilization is pursued by a push system, hence resulting in early productions and higher inventories.
4. Computerization: most push systems have heavily relied on computer systems, which make the shop floor more transparent. For the same reason, push systems are vulnerable to computer problems. In contrast, the lean systems rely on

kanban operations and are less susceptible to computer problems. As a tradeoff, the shop floor information in a lean system is not as real-time as that in a push system. Lean SFT as proposed in this paper has resolved this dilemma so that a lean system can now enjoy both the kanban convenience and transparent shop floor information.

The comparisons above are not meant to claim which system is superior as they have different philosophical bases and different applicable conditions. For instance, in the case where the market demand is strong for a product, it would be advisable to adopt push production to rush out the products to market. On the other hand, when a market suffers from a weak demand, one may be inclined to adopt a lean production to control the inventory level.

The lean SFT presented in this paper is expected to improve the effectiveness and intelligence of a lean system to the same level as its counterpart in a push system. Moreover, the lean SFT can be integrated with conventional ERP, thus not only giving lean production the best benefits of ERP, but also making ERP more flexible in shop floor control.

References

Cutler TR, Kanban E (2005) A key to lean, Automation.com Articles and White Papers. http://www.automation.com

Data Systems Consulting Inc. (2006a) Shop floor tracking systems user manual

Data Systems Consulting Inc. (2006b) Workflow ERP- production management module user manual

Holsapple CW, Sena MP (2005) ERP plans and decision-support benefits. Decis Support Syst 38(4):575–590

Howells R (2000) ERP needs shop-floor data. Manuf Eng 125(4):54–63

Hung-da Wan, Chen FF (2007) A Web-based Kanban system for job dispatching, tracking, and performance monitoring. Int J Adv Manuf Technol 38(9–10):995–1005

Liker JK (2003) The Toyota way: 14 management principles from the world's greatest manufacturer. The McGraw-Hill Companies, New York

Melnyk SA, Carter PL (1987) Production activity control. Richard D. Irwin Inc., Homewood

Melnyk SA, Carter PL, Dilts DM, Lyth DM (1985) Shop floor control. Dow Johns-Irwin, Homewood

MESA International White Paper No. 3 (2000) The controls layer: controls definition and MES to controls data flow possibilities, MESA International

SAP Community Network (2007) Shop floor control. http://wiki.sdn.sap.com/wiki/display/BPX/Shop+Floor+Control

Thong-Inn Shieh (2009) The design of shop floor tracking for Toyota production system and integration with ERP. Master thesis, Department of Industrial Engineering and Management, National Yunlin University of Science and Technology

Vadim Kotelnikov (2006) Lean production- doing more with less. http://www.1000ventures.com/business_guide/lean_production_main.html

Womack JP, Jones DT (1996) Lean thinking. Simon & Schuster, New York

Chapter 9
Application of TOPSIS for the Optimal Welding Parameters Design of Aerospace Aluminum Alloy Thick Plate

Jhy-Ping Jhang and Hung-shu Wu

Abstract This research proposes an economic and effective experimental design method for multiple quality characteristics to deal with the parameter design problems that have many continuous parameters and levels. We use Taguchi experimental method, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), and Cross analysis to find the optimal parameters combination for the weldment of thick aerospace aluminum alloy plates. The primitive results show the potential improvement over previous experimental methods. Because the model can learn the relationship between the welding parameters and the quality responses of different materials to facilitate the future applications in the decision-making of parameter settings for automatic welding equipment, it can also be presented to the relevant welding industries as a reference to improve the product quality and welding efficiency.

Keywords TIG • TOPSIS • Aerospace aluminum alloy • Weldment • Taguchi method

Introduction

The welding of different metal materials has superior mechanical characteristics, but the welding parameter setting of the TIG (Tungsten Inert Gas) is difficult, due to some hard and crisp inter-metallic compounds created within the weld line. Normally, the setting for optimal welding parameters does not have a formula to follow; it usually depends on experts' knowledge and experiences. Once exceeding the rule of thumb, it becomes impossible to set up feasibly optimal parameters, and

J.-P. Jhang (✉) • H.-s. Wu
Department of Industrial Engineering and Management Information, Hua Fan University, Taiwan, People's Republic of China
e-mail: jpjhang@huafan.hfu.edu.tw

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_9,

the past researches mostly focused on thin alloy plate. This research proposes an economic and effective experimental design method of multiple characteristics to deal with the parameter design problem with many continuous parameters and levels for the aerospace aluminum alloy thick plate.

It is difficult to solve the optimization problem of multiple parameters by analytical methods, and the search algorithm could easily fall into local optimal but not global optimal. In order to efficiently solve optimal parameters problems, many techniques were developed in the past years. Some of the approaches and applications are briefly described in the following paragraph.

Jhang and Chan (2001) applied Taguchi Method with orthogonal table of L18 and quality characteristic of smaller-the-better to improve the process yield rate for air cleaners in Toyota Corona.

Tong and Wang (2000) proposes an algorithm of Grey relational analysis and TOPSIS for multiple quality characteristics.

Tong and Su (1997a, b) proposes multi-response robust design by principal component analysis and by Fuzzy multiple attribute decision making.

Su et al. (2000) use soft computing techniques to overcome the limitations of practical applications for Taguchi method. The methods used the ANN (Artificial Neural Network), SA (Simulated Anneal) and GA (Genetic Algorithm), to compare and find the global optimal solution for multiple quality characteristics.

Juang and Tarng (2002) find that welding current and welding torch drift speed are two most important factors for the quality of welding.

Chan et al. (2006) propose a new method for the propagation system evaluation in wireless network by neural networks and genetic algorithm.

Chang (2006) The proposed approach employs a BPN (Back Propagation Neural) network to construct the response model of the dynamic multi-response system by training the experimental data. The response model is then used to predict all possible multi-responses of the system by presenting full parameter combinations.

Chi and Hsu (2001) propose a Fuzzy Taguchi experimental method for problems with multi-attribute quality characteristics and its application on plasma arc welding.

Lin and Lin (2002) propose the use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristics.

And we uses Taguchi experimental method, TOPSIS and Cross analysis to find the global optimal parameters combination for the aerospace aluminum alloy thick plate welding.

Methodologies

Structure

Two types of quality characteristics data were collected from welding Taguchi experiments. There are non-destructive quality characteristics such as weld width, thickness, the ratio of melting into the deep, and the destructive quality characteristics such as tensility, shock. We calculate S/N ratios, response graph, response table, the optimal combination of factor levels, ANOVA, contribution rate for multiple quality characteristics, which are compiled into a cross table to find the integrated optimal combinations. Then we use TOPSIS method to integrate all the S/N ratios of multiple quality characteristics into Ci and to find other integrated optimal combinations. Finally, the global optimal solution is obtained by the confirmation experiment of different optimal solutions with respect to different methods.

TOPSIS

Hwang and Yoon (1981) have developed multiple criteria evaluation method called TOPSIS, taking into account the basic concept that are the distances from each program to the ideal solution and negative ideal solution, so the selected program is near ideal solution and far from the negative ideal solution. The analysis steps are as follows:

Step 1. Create the performance matrix with respect to the evaluation criterion.

Step 2. The performance values are standardized. As follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{9.1}$$

where x_{ij} is i program under j evaluation criteria.

Step 3. The performance matrix is multiplied by the weight of each criterion.

Step 4. To calculate the distance of ideal solution (S_i^+) and the distance of the negative ideal solution (S_i^-).

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \tag{9.2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \tag{9.3}$$

where, $v_j^+ = \max_i [v_{ij}]$, $v_j^- = \min_i [v_{ij}]$.

Step 5. Arrange the priorities of the programs.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{9.4}$$

where C_i is between 0 and 1, the priority of the ith program is higher when C_i is closer to 1.

Experimental Planning

Experimental Allocation

In this study, the welding material is the aerospace aluminum alloy (7075) thick plate (8 mm), size is 80 mm × 60 mm × 8 mm, the welding diagram is similar to Fig. 9.1, five sets of control factors are considered; each control factor has three levels. Please refer to Table 9.1 for the experimental factor and its level. The noise factor is three different welding operators. This research adopts the orthogonal Table of L_{27}.

There are five quality characteristics as follows.

1. Welding thickness and width
   In the welding track of aluminum alloy plates, from left to right, we measure the welding thickness and width for the five points of 20, 25, 30, 35, and 40 mm.
2. The ratio of melting into the deep
   The ratio is welding length in the front side over the reverse side.
3. Tensile strength and shock value
   Tensile test specimens conform CNS 2112G2014, and in accordance with the specimen 13B. Shock test is the specimen compliance CNS 3033G2022, and in accordance with V-concave regulations.

   The formula of energy shock is

$$E = Wh_1 - Wh_2 = W * R * (\mathrm{COS}\beta - \mathrm{COS}\alpha) \tag{9.5}$$

Where, Wh_1: initial weight height
Wh_2: weight height after shocking
α: initial angle, 143°
β: shocking angle
W: weight, 26.63 kgf
R: radius, 0.635 m

Analysis of Individual Quality Characteristic

The quality characteristics of welding thickness, tensile strength and shock value are all considered as larger-the-better, but the quality characteristics of welding width and the ratio of melting into the deep are considered as nominal-the-best.

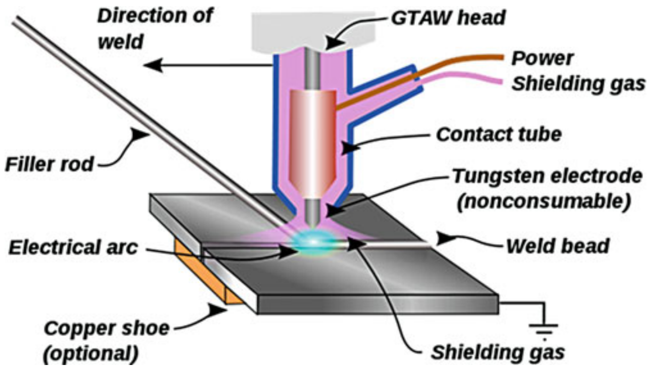


Fig. 9.1 The welding graph (from Wikimedia Commons)

Table 9.1 Experimental factors and levels

Control factor	I	II	III	Unit
A. Electric current	170	180	190	A
B. Moving speed	15	16	17	cm/min
C. Welding gap	1.5	1.7	1.9	mm
D. Striking tungsten length	5	8	11	mm
E. Gas flow rate	11.5	13.5	15	l/min
Noise factor		**3 different welding operators A, B, C**		

$$\text{nominal-the-best} \quad S/N = 10 \times \log\left[\frac{S_m - V_e}{n \times V_e}\right] \tag{9.6}$$

$$\text{larger-the-better} \quad S/N = -10 \times \log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \tag{9.7}$$

where, $S_m = \frac{\left(\sum y_i\right)^2}{n}$,

$$V_e = \frac{1}{n-1}\left(\sum y_i^2 - S_m\right).$$

Analysis of Multiple Quality Characteristics

We compute the S/N ratios, the optimal combination of factor levels, ANOVA, contribution rate of multiple quality characteristics respectively, which are compiled into a Cross Table to find the optimal combinations.

We also use S/N ratios of multiple quality characteristics to transform into the Ci value of TOPSIS, then we use response table of the Ci value to find the total optimal combinations.

Results Analysis

Cross Analysis

We calculate the S/N ratios, combination of factor levels, ANOVA, contribution rate of multiple quality characteristics, which are all compiled into a Cross Table to find the optimal combinations, as shown in Table 9.2.

The Optimal Combinations of TOPSIS

We use TOPSIS method to integrate all S/N ratios of multiple quality characteristics into Ci and to find the optimal combination as shown in Table 9.3.

Table 9.2 Cross table

Factor	A	B	C	D	E
Welding thickness (10%)					
Optimal combination	A3	B1	C1	D1	E3
Significant of S/N	*			*	*
Contribution rate (%)	18%	2%	4%	43%	12%
Welding width (10%)					
Optimal combination	A2	B2	C3	D1	E2
S/N significant	*	*	*		*
Contribution rate (%)	0%	3%	5%	26%	0%
The ratio of melting into the deep (25%)					
Optimal combination	A2	B2	C1	D3	E2
S/N significant		*		*	
Contribution rate (%)	15%	2%	3%	37%	10%
Shock value (15%)					
Optimal combination	A3	B1	C3	D2	E3
S/N significant		*	*	*	*
Contribution rate (%)	4%	4%	4%	4%	4%
Tensile strength (40%)					
Optimal combination	A2	B2	C3	D2	E3
S/N significant			*	*	*
Contribution rate (%)	6%	0%	23%	15%	6%
Optimal parameters levels	A2	B2	C3	D2	E3

* means that it is important

Table 9.3 Response table of Ci

	Factor	A	B	C	D	E	Average
Ci (TOPSIS)	Level1	0.45	0.47	0.46	0.34	0.45	0.43
	Level2	0.56	0.55	0.43	0.57	0.53	0.53
	Level3	0.49	0.48	0.61	0.58	0.54	0.54
	Comparison	0.10	0.08	0.18	0.24	0.14	0.14
	Best level	A2	B2	C3	D3	E2	
	Rank	3	4	2	1	5	
	Significant			*	*		

* means that it is important

Table 9.4 The comparison Ci of confirmation experiment

Optimal combinations	Cross table A2B2C3D2E3	TOPSIS A2B2C3D3E2
Ci value	0.77	0.90

Confirmation Experiment

The 95% Confidence interval of Ci for the confirmation experiment is [0.44, 1.07].

Results and Discussions

From Table 9.4, the Ci of TOPSIS is larger than Ci of Cross Table, and it falls into the 95% confidence interval of Ci for the confirmation experiment. So the optimal combination A2B2C3D3E2 of TOPSIS is the overall best welding parameters of aerospace aluminum alloy thick plate.

We also find that the significant factors are welding gap and striking Tungsten length.

Conclusion

The conclusions are summarized in the following:

1. The TOPSIS method used in this case is better than others. So the optimal combination A2B2C3D3E2 of TOPSIS is the optimal welding parameters design of aerospace aluminum alloy thick plate.
2. The significant factors are welding gap and striking Tungsten length in this case. That is confirmed with literatures.
3. In the future, we can consider to use the ANN, GA and SA to find the optimal solution for multiple quality characteristics. We can also consider other welding

techniques, such as CO_2 welding, GMAW (Gas Tungsten Arc Welding) and LAFSW.

4. The model can learn the relationship between the welding parameters and the quality responses of different materials to facilitate the future applications in the decision-making of parameter settings for automatic welding equipment.

References

Chan HL, Liang SK, Lien CT (2006) A new method for the propagation system evaluation in wireless network by neural networks and genetic algorithm. Int J Inf Syst Logist Manag 2(1):27–34

Chang HH (2006) Dynamic multi-response experiments by backpropagation networks and desirability functions. J Chin Inst Ind Eng 23(4):280–288

Chi SC, Hsu LC (2001) A fuzzy Taguchi experimental method for problems with multi-attribute quality characteristics and its application on plasma arc welding. J Chin Inst Ind Eng 18 (4):97–110

Hwang GL, Yoon K (1981) Multiple attributes decision making methods and applications. Springer, New York

Jhang JP, Chan HL (2001) Application of the Taguchi method to improve the process yield rate for air cleaners in Toyota Corona vehicles. Int J Reliab Qual Saf Eng 89(3):219–231

Juang SC, Tarng YS (2002) Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel. J Mater Process Tech 122:33–37

Lin JL, Lin CL (2002) The use of the orthogonal array with grey relational analysis to optimize the electrical discharge machining process with multiple performance characteristics. Int J Mach Tools Manuf 42(2):237–244

Su CT, Chiu CC, Chang HH (2000) Optimal parameter design via neural network and genetic algorithm. Int J Ind Eng 7(3):224–231

Tong LI, Su CT (1997a) Optimizing multi-response problems in the Taguchi method by fuzzy multiple attribute decision making. Qual Reliab Eng Int 13:25–34

Tong LI, Su CT (1997b) Multi-response robust design by principal component analysis. Total Qual Manag 8(6):409–416

Tong LI, Wang CH (2000) Optimizing multi-response problems in a dynamic system by grey relational analysis. J Chin Inst Ind Eng 17(2):147–156

Chapter 10
The Local Search and Experiments of Job-Shop Scheduling Problem

Ning Zhao and Si-yu Chen

Abstract The Job-shop Scheduling Problem is a typical scheduling problem, which is regarded as NP-hard because of its complexity. Improvement based on traditional local search methods is realized with the combination of neighborhood and critical path. Firstly, feasible solution is achieved by heuristic approaches or just randomization. Secondly, makespan optimized solution is achieved by improved local search. Finally, the improved local search method is proved effectively by experiments, moreover the searching process is visible and suits man–machine interaction.

Keywords Local search • Job-shop scheduling problem • Man–machine interaction • Critical path

Introduction

JSP stands for the Job-shop Scheduling Problem. It means to combine time with jobs closely in order to meet the requirements of the productions' progress. The result of scheduling directly influences the completion time of products, the arrangement of workers and the utilization rate of machines. In the context of diversified market demand, in order to meet the production modes of multispecies, singleton and small-lot, Flexible Manufacturing and Agile Manufacturing emerged. The production line is more complicated, but the delivery time is shortened. In order to resolve these conflicts, researchers from different fields start to focus on the efficient and accurate JSP.

The deterministic job-shop scheduling problem can be briefly described as follows: given a finite set of jobs, each is a finite sequence of operations subjected to precedence constraints, each operation needs to be processed exclusively on a machine from a

N. Zhao (✉) • S.-y. Chen
School of Mechanical Engineering, University of Science and Technology Beijing, Beijing 100083, China
e-mail: zhning@sina.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_10,

finite set of machines for a prescribed time interval, the goal is to find a schedule which can complete all operations in the shortest time (Murovec and Suhel 2004).

As the augment of the number of jobs and machines, the number of solutions can increase exponentially. Researchers regard this kind of problems as NP-hard (non-deterministic polynomial) (Jain and Meeran 1999).

The history of JSP's study can date back to half a century ago. It is the result of development. Its valuable and challengeable arouse a lot of researchers' interests to study. The methods to solve JSP have experienced the process of simple to complex, single to multiple and theoretical to practical, and have yielded many excellent results. These algorithms can be divided into two categories: Optimization Algorithms and Approximation Algorithms (Shao-li Dai et al. 1999).

Optimization Algorithms can assure an optimal result. It includes methods of operations research (such as branch-and-bound algorithm, linear programming, dynamic programming and nonlinear programming) and enumeration. The methods of operations research use equalities and inequalities to express the problem, and solve the objective function under the constraints. Enumeration, however, tries to list all possible solutions, and then find the feasible ones and the optimal one among them.

Approximation Algorithms play an important role recently to solve JSP. They are classified to three groups in this paper, Constructive Method, Artificial Intelligence and Local Search.

Constructive Method can obtain a feasible solution quickly, but the solution is always in bad condition. A common one is the Priority Distribution Rule, it is to construct a rule set, and the operation which meets the rules can be written on the schedule first, by such analogy, other operations can be on the schedule at last. Artificial Intelligence is to use the artificial theories and techniques to guide searches and provide effective searching program to find better solutions. Ant System (Xiao-rong Wang 2003) and Neural Network are representatives.

The method of Local Search means to start from several initial solutions, and realize optimization by searching neighborhood and replacing current solutions. At first, the search is only limited to the local. It is easily realized, but the searching results largely depend on the neighborhood functions and initial solutions (Ling Wang 2003). In recent years, in order to get better global optimized results, the improved Genetic Algorithm, Taboo Search and Simulated Annealing improve it from different perspectives with different searching mechanisms and strategies. Moreover, a new trend of solving JSP recently is to combine different kinds of local search methods into mixed heuristic algorithms, and has achieved some results.

Although different kinds of algorithms are put forward, and among them we can find effective ones, till now, none of the algorithms can completely solve JSP. The drawbacks of the algorithms mentioned above are listed as follows:

1. Optimization Algorithms
   Optimization algorithms can obtain the optimal solutions, but the cost is searching all solutions that is possible to be optimal. So it is time wasting for large-size problems and is well known for its low efficiency.

2. Approximation Algorithms
   Approximation algorithms can overcome the drawbacks of Optimization algorithms and good at solving large-scale optimization problems. But they also have some shortages.

   (1) Priority Distribution Rules: it can build a feasible solution quickly, but the solution is always bad.
   (2) Ant system: the amount of computation is large, and the ability of describing complex issues is weak.
   (3) Neural Network: can only solve small-scale scheduling problem, the calculated complexity is large and it can't promise the best solution.
   (4) Taboo Search, Simulated Annealing and Genetic Algorithm: they can achieve better results, but the quality of the results depends on the selection of parameters, and they are always time-consuming. And they can't promise the best solution.

Furthermore, all the algorithms mentioned are highly mechanized. Once they start to calculate on the computer, one cannot participate in it. In practical, the experience of human-being is very important for scheduling. In order to solve dynamic real-time scheduling problem and give full play to human-being in scheduling, we must develop an interactive scheduling system (Qing Zhang 2004). Among all the algorithms mentioned above, local search is the best one which suits to man–machine interaction, but need to be improved.

Improved Local Search by Critical Path

Definition 1: Critical Path, it means the uninterrupted processing path running through the period from the starting time of the first operation to the finishing time of the last operation.

On critical path, every operation's completion time and the next operation's start time are closely linked. In order to explain the definition vividly, we cite the graph raised by (Nowicki and Smutnicki 1996) here (Fig. 10.1):

The graph above is typical JSP's Gantt Graph. The critical path in the graph is: 1.1-4.2-5.2-2.2-2.3-1.2-3.1-4.3-5.3-5.4-6.4-1.3-3.3-3.4-2.4-1.4-4.4.

The operations on the critical path are Critical Operations. As the length of critical path determines makespan, we must shorten critical path's length so that we can get the shortest makespan.

Definition 2: Critical Block, it means that on the critical path, every machine has one or more adjacent operations, the adjacent operations which belong to the same machine are called a critical block.

For example, in the graph above, for M2, 1.1–2.2 is a block, and on M1, 2.3–5.3 is a critical block.

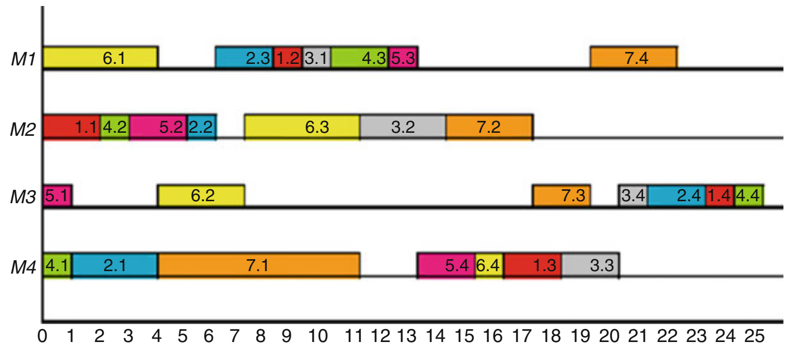


Fig. 10.1 Neighborhood of Nowicki and Smutnicki

It is also to be noted that every scheduling result may have more than one critical path.

The meaning of Local Search is the procedure of starting from the current results, utilizing the neighborhood functions (specific changing pattern), searching the neighborhood of current results and replacing them. In this paper, the local or the neighborhood means two adjacent operations on the same machine. Studies show that we can generate a new schedule if we swap the sequence of operations on the same machine (Jian-shuang Cui and Ke-tie Li 2009). The swap here is also a neighborhood function. As a result, for JSP problem, local search in neighborhood function can be replaced as Local Swap. If we make some local swap on current solutions, we can reach some new feasible solutions. These solutions are neighbors of current solution.

Of course, not all local swaps can result in feasible solutions or optimal solution. Some swaps may lead infeasible ones. And as the scale improves, the number of neighborhoods increases explosively. How to deduce compute capacity and avoid some infeasible local search is the point of studying.

Experiments

We major in Single-step Optimization in this paper. The Single-step Optimization means that we can only change one operation’s place each time. If we have some initial solutions, one or more Single-step Optimization may obtain the optimal solution.

We conduct these experiments on IESS (Industrial Engineering Scheduling System) which is self-developed for experimenting. The system is visible and interactive. Our experiments are to make some manual adjustments on different initial solutions and observe the effectiveness and drawbacks of local swap.

Table 10.1 FT06

Initial solution	Final optimal solution	Steps from initial solution to local optimal solution	Global optimal solution
89	79	2	55
71	62	4	55
86	65	5	55
83	69	4	55
79	73	1	55

Table 10.2 FT10

Initial solution	Final optimal solution	Steps from initial solution to local optimal solution	Global optimal solution
1,420	1,300	9	930
1,369	1,369	0	930
1,387	1,273	9	930
1,326	1,166	12	930
1,291	1,282	2	930

In order to make the experiments more persuasive, we set some swapping rules here:

1. Distinguish critical paths and critical blocks
   We find the critical paths and critical blocks from the back to the forward in current solution. If there is more than one critical path, we should choose the one of job predecessor.
2. Operation swapping
   Every critical block and critical operation of initial solution is studied first. In principle, we should try every two operations of initial solution that can be local swapped and calculate makespan, the best one is kept as local optimal solution. The local optimal solution is set to be initial solution and new local optimal solution can be reached by the same way. If new local optimal solution is equal to initial solution, the local optimal solution is kept as the final optimal solution.

During the search procedure, man can easily involved in searching by interaction, but the question is whether the final optimal solution is good enough to practical use.

In the experiment, we test on two classical test samples: FT06 and FT10. We obtain the initial solutions by randomization, and conduct five experiments on every sample. The results are as follows:

The final optimal solution means that when using the swap rules above in the current solution, every swap on the critical path will make the current makespan worse. We can see from the results that if create an initial solution randomly, one can easily jump into the final optimal solution no matter the problem is FT06 or the more complex FT10, and can't move towards the global optimal result.

As the experiments are based on randomly generated results, in order to prove how initial results influence the final schedule, we add a rule of making initial result: "operation which its job has the most remnant operations" + "random", which means

Table 10.3 FT06

Initial solution	Local optimal solution	Steps from initial solution to local optimal solution	Global optimal solution
66	59	4	55
62	59	1	55

Table 10.4 FT10

Initial solution	Local optimal solution	Steps from initial solution to local optimal solution	Global optimal solution
1,221	1,119	13	930
1,219	1,162	5	930

that the system will choose the operation meet the first condition, if there are more than one operation can be chosen, then choose one randomly. It can be proved that this method of constructing solutions can generate better solutions to the FT samples, because they have the same amount of operations, and every job's total processing time is more or less the same.

We can see that the initial solutions are better than the randomly generated ones, and the improvements on the initial solutions can influence the local optimal solutions on a large scale.

If the conclusion above is true, then we can believe that, every JSP must have a rule set to construct a good initial result, and on the basis of the result we can jump to the optimal solution with single-step optimization. But the rule set is very difficult to build. For example, to FT06, we can find a rule set: "the operation which has the longest surplus time" + "operation which its job has the most remnant operations" + "random", these rules' priority decrease progressively. The initial result is 58, and we can get the global optimal solution 55 only by two single-step optimizations. But if we add the rule set onto FT10, the initial result is 1,191, which is better than all the experiment results above, and we can get the local optimal solution 1,090 by ten steps, but there is still a certain distance to the global optimal solution 930.

Conclusion

We can prove from the experiments that on IESS, based on the initial solutions which are obtained by several rules, we can get the global or local optimal solution with the help of Single-step Optimization. But this method is not developed well enough. We still need intensive study in these aspects:

1. With what rule set can we construct better initial solutions, and jump to the optimal solution by less steps.
2. Put forward a set of complete swapping rules so that humans' affection can be reduced.
3. Realize automatic Single-step Optimization on IESS.

This paper is sponsored by the Fundamental Research Funds for the Central Universities of China FRF-TP-12-071A.

References

Jain AS, Meeran S (1999) Deterministic job-shop scheduling: past, present and future [J]. Eur J Oper Res (113):390–434

Jian-shuang Cui, Ke-tie Li (2009) Global local search method to solve JSP [J]. Comput Integr Manuf Syst 15(7)

Ling Wang (2003) Job-shop scheduling and genetic algorithm [M]. Tsinghua University Press, Beijing

Murovec B, Suhel P (2004) A repairing technique for the local search of the job-shop problem [J]. Eur J Oper Res (153):220–238

Nowicki E, Smutnicki C (1996) A fast taboo search algorithm for the job-shop problem [J]. Manag Sci 42(6):797–813

Qing Zhang (2004) Man machine interactive job-shop dynamic scheduling method [A]. Mech Manuf 42(476)

Shao-li Dai, Yue-jin Tan, Hao Wang (1999) System research in job-shop scheduling methods [J]. Syst Eng (1):41–45

Xiao-rong Wang (2003) Theoretical model of ant system and application research in job-shop scheduling. Ph.D. thesis, ZheJiang University

Chapter 11
Order Acceptance and Capacity Balance for Steel Plant Based on Production Capacity Network Flow

Zhi-min Lv and Jian-zhong Du

Abstract There is a collaborative problem between the production department and marketing department of steel enterprise because of the diversity of varieties and the complexity of production process. For this kind of issues in the condition of multi products and multi processes, this paper proposes a production capacity network flow (PCNF) model that can quickly extract the information of problem and simplify the process of mathematical modeling. To solve the problem of order acceptance and capacity balance in steel enterprises, we abstract the capacity of supply and demand in the steel manufacturing process into a PCNF model, and develop a mathematical model. The model is solved by a heuristic algorithm, and the objective of solution is based on degree of satisfaction in practical production, rather than seeking the optimal solution of the problem. Instances of the application show that the accuracy and efficiency of the algorithm can meet the practical demand.

Keywords Order acceptance • Capacity balance • Production capacity network flow model • MTO • MTS

Introduction

As the steel market has changed from sellers' to buyers', order-driven production mode becomes the mainstream. But in steel plant, it is difficult to reverse the product demand to capacity demand because of the long and complex process, so it is necessary to find an effective method to complete this transform. In addition, there are both MTO and MTS mode in steel enterprises. The flexibility of MTS

Z.-m. Lv (✉) • J.-z. Du
National Engineering Research Center for Advanced Rolling,
USTB, Beijing, China
e-mail: lvzhimin@nercar.ustb.edu.cn; jasonerydu@gmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_11,

brings another problem of how to choose varieties. Therefore, finding an effective method to solve that problem and achieve the balance of production capacity will be difficult and urgent. Due to the process is not unique, combining different products or adjusting the process might be a possible method to achieve that goal. Hence, this paper is from a new point to solve those problems.

In the past years, most researchers assumed that the production process was fixed and the order attribute is simple when they balanced the problem of order acceptance and production capacity. Slotnick (2011) had reviewed the past research on order acceptance problem. Kalantari et al. (2011) presented a novel decision support system for order acceptance/rejection in a hybrid MTS/MTO production environment, which considered the constraint of production capacity. Cao Junjie and Shi Hongbo (2010) developed a practical model of order planning with resource constraints based on compressor enterprise, and adopted improved genetic algorithm to search for the decision situation. With the multi nodes production environment, Xiao Yiyong et al. (2008) introduced an order acceptance model, which solved by simulated annealing algorithm that optimized both selection and sorting for orders. For multi processes issue, Lao Ben-xin and Li Xiao-hua (2010) discussed how to calculate the capacity requirement when there are optional processes.

Nowadays, many researches focus on the coordinated approach to production and sales for manufacturing enterprise. But for steel industry features multi varieties and multi processes, related research is rare on the knowledge of authors. In some researches, order planning is decomposed into mid-term and short-term production planning, and an integrated steel enterprise mid-term planning model is presented (Song Xiaoqing et al. 2011; Lv Zhimin et al. 2011). On the basis of mid-term planning, the demand of capacity is allocated for every process and then coming into a short-term planning which could guide production scheduling (Lv Zhimin and Song Xiaoqing 2011). This model is closer to actual production process of iron and steel enterprise, which can be a guide for system design.

In this paper, according to the characteristics of the steel production process, the production capacity network flow model is proposed. It is abbreviated by PCNF. PCNF shows the relation between production capacity demand and supply. It can help to develop the mathematical model and solution method. Instead of complex mathematical method, a practical logic process is proposed to calculate and evaluate capacity quickly.

Problem Description and Mathematical Modeling

Problem Description

The process of steel production can be divided into several stages, including ironmaking, steelmaking, refining, continuous casting, hot rolling and cold rolling and so on. Every stage as well is also divided into a number of processes, which contains

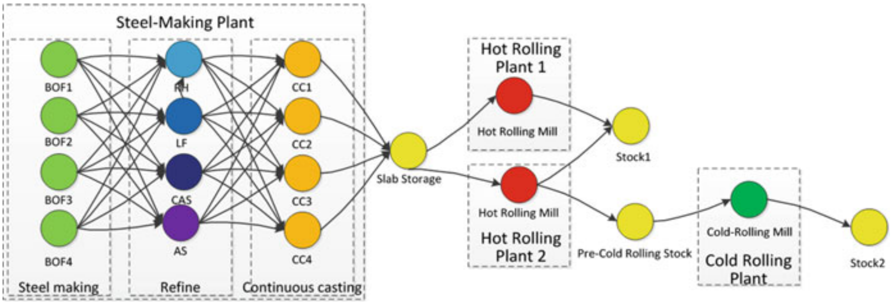


Fig. 11.1 The network structure of steel production flow

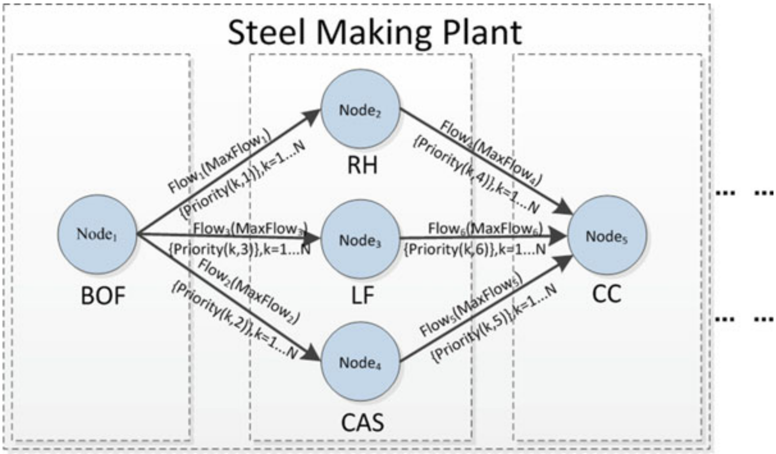


Fig. 11.2 Diagram of production capacity network flow

multiple units. Capacity utilization influences each other during the processes, which forms a complex network structure as shown in Fig. 11.1.

We extracted a part of network flow from production process, which is shown in Fig. 11.2. This is a production capacity network flow (PCNF) model that can extract the information of problem and simplify the process of mathematical modeling. As shown in Fig. 11.2, $Node_i$ represents the equipment. $Flow_j$ represents the occupied production capacity by which directed lines point to. Meanwhile the maximum available flow is represented by $MaxFlow_j$. Products have different process routes from the initial node to the final node, which are not parallel but distinguished by their priorities. The higher priority is, the more possible the route will be selected. The same path for different products may have different priority. Priority(k,j) represents the priority on route j to product k. {Priority(k,j)} represents the priorities set of all the products at this route. Penalty factor is available to represent priority in model calculation.

The node of production capacity network can not only express a single device in the production, but also a group of equipment with the same considerable attributes. The latter is more suitable for representation and calculation of production capacity.

There is a flow restriction in production capacity network flow. For this kind of network, there are various studies of maximum flow problem. Punnen and Zhang (2009) classified several well-studied bottleneck problems such as the bottleneck transportation problem (BTP), bottleneck assignment problem (BAP), bottleneck path problem (BPP) as bottleneck network flow problem (BNFP). Meanwhile he put forward a complex algorithm of $O(\min\{m(n\log n)^{2/3}, m^{3/2}\sqrt{\log n}\})$, which reduced the time complexity of the algorithm. Melkonian (2007) introduced flows in dynamic networks with aggregate arc capacities, and gave a linear programming formulation for the problem which is based on the time-expanded network of the original dynamic network.

Because the variability of equipment's working state, the number of network nodes, flow and network access conditions will change over time, the production capacity network is a more complex dynamic network model.

In this paper, the production process abstracted into network flow model to unify capability of manufacturing process including smelting, casting, hot rolling (including finishing), cold rolling (including cold rolling finishing) and other major processes.

Mathematical Model

The establishment of mathematical model is simplified according to the production capacity network flow model. The mathematical model is abstracted based on the following assumption: (1) Sales department would provide the market demand forecasting, or the forecasting of future sales proposal. (2) Sales contracts and its execution state in the past, current and future period are known. (3) The working time and effective operating rate of equipment are known. (4) The fundamental data of process and capacity demand on every device for each variety and specification is known. (5) The hot metal supply quantity in future period is known. (6) The quantity constraints of producible products with limit specification are known. (7) The selling price has been determined. (8) The quantity of the materials with open order in inventory is known. (9) The expected costs for all related products are known. (10) The current production process is clear.

- Description of symbols
  Notations used for the problem formulation:

  N: Total number of product;
  L: Total number of processes;
  M_j: Total number of equipment at process "j";
  F_{cost}: The fixed cost of production;
  x_i: Planned output of product "i";

I_{ij}: The inventory of product "i" at process "j";
ω_{ij}: Whether product "i" passes process "j" or not;
λ_i: Whether product "i" is extreme material or not;
φ: The achieved satisfaction degree to the least extent;
θ_{ij}: The yield rate of product "i" at process "j";
p_i: The price of product "i";
c_{ij}: The cost of product or semi-finished product of product "i" at process "j";
q_{ij}: The number of WIP of product "i" at process "j";
$D_b(ij)$: The minimum production lot of product "i" at process "j";
$D_{up}(ij)$: The maximum allowed quantity of product "i" with limit specification at process "j";
Or_{jk}: The capacity occupied by signed contracts of device "k" at process "j";
$D_{order}(i)$: The signed production quantity of product "i" in planning period;
$D_{pre}(i)$: The proposal quantity of product "i" in future period;
$obligate_i$: The necessary quantity of product "i";
Cap_{ijk}: The capacity per hour of device "k" of product "i" at process "j";
Q_{jk}: The available capacity during the current planning period of device "k" at process "j", in hours;
T_{jk}: The available time of device "k" at process "j";
M_{jk}: The maintenance time of device "k" at process "j";
L_{jk}: The capacity occupied by active product of device "k" at process "j".

- The objective:

$$\sum_{i=1}^{N} (x_i \cdot p_i) \tag{11.1}$$

$$\sum_{i=1}^{N} [x_i \cdot p_i - \sum_{j=1}^{L} c_{ij} \cdot x_i] - F_{\mathrm{cos}t} \tag{11.2}$$

$$\sum_{i=1}^{N} \sum_{k=1}^{M_j} \frac{(\frac{\omega_{ij}(x_i + D_{order}(i))}{\theta_{ij}} + q_{ij})}{Cap_{ijk}} \leq \sum_{k=1}^{M_j} (T_{jk} - M_{jk}) \tag{11.3}$$

- Subject to:

$$\sum_{i=1}^{N} x_i >= \sum_{i=1}^{N} obligate_i \tag{11.4}$$

$$\omega_{ij} = 0, 1$$

$$\begin{cases} \frac{x_i}{\theta_{ij}} \geq 0; \quad if \quad \omega_{ij} = 1 \\ \frac{x_i}{\theta_{ij}} = 0; \quad if \quad \omega_{ij} = 0 \end{cases} \quad i = 1, 2 \ldots N; \quad j = 1, 2 \ldots L \tag{11.5}$$

$$\begin{cases} \frac{x_i}{\theta_{ij}} \geq D_b(ij) || \frac{x_i}{\theta_{ij}} = 0; \quad if \quad \omega_{ij} = 1 \\ \frac{x_i}{\theta_{ij}} = 0; \quad if \quad \omega_{ij} = 0 \end{cases} \quad i = 1, 2 \ldots N; \quad j = 1, 2 \ldots L \tag{11.6}$$

$$\lambda_i = 0, 1$$

$$\begin{cases} \frac{\lambda_i x_i}{\theta_{ij}} \leq D_{up}(ij); \quad if \quad \omega_{ij} = 1 \\ \frac{\lambda_i x_i}{\theta_{ij}} = 0; \quad if \quad \omega_{ij} = 0 \end{cases} \quad i = 1, 2 \ldots N; \quad j = 1, 2 \ldots L \tag{11.7}$$

$$x_i \leq D_{pre}(i) \quad i = 1, 2 \ldots N \tag{11.8}$$

$$\begin{cases} L_{jk} = \sum_{i=1}^{N} \frac{\omega_{ij} q_{ij} \theta_{ijk}}{Cap_{ijk}}; \quad \text{if } j \text{ is the post process} \\ L_{jk} = 0; \quad \text{if } j \text{ is the pre-process} \end{cases} j = 1, 2 \ldots L; \; k = 1, 2 \ldots M \tag{11.9}$$

$$Or_{jk} = \frac{\omega_{ij} D_{order}(i)}{\theta_{ij} Cap_{ijk}} \quad j = 1, 2 \ldots L; \quad k = 1, 2 \ldots M \tag{11.10}$$

$$Q_{jk} = T_{jk} - M_{jk} - L_{jk} - Or_{jk} \quad j = 1, 2 \ldots L; \quad k = 1, 2 \ldots M \tag{11.11}$$

$$Q_j = \sum_{k=1}^{M_j} Q_{jk} \quad j = 1, 2 \ldots L; \quad k = 1, 2 \ldots M \tag{11.12}$$

$$U_j = \frac{\sum_{i=1}^{N} \sum_{k=1}^{M_j} \frac{\omega_{ij} x_i}{\theta_{ij} Cap_{ijk}}}{Q_j} \tag{11.13}$$

(11.1), (11.2), and (11.3) are objective, which respectively represent sales revenue, profit and proportion of capacity occupied. Among them, the targets of sales revenue and profit can be set based on the acceptable degree of practical application.

Equation (11.4) is mandatory minimum throughout constraint. Equation (11.5) is process route constraint. Products pass the process while $\omega_{ij} = 1$, then the process output must be greater than 0. Equation (11.6) is minimum production lot constraint.

Every process has its minimum production lot size. If the product has been planned, the planning production quantity must be greater than the minimum. Otherwise, the products would not produce any more. Equation (11.7) is product lot size constraint with limit specification. The planning output of these materials cannot be greater than maximum capacity. Equation (11.8) is general output constraints according to experience. Equation (11.9) expresses that the process capacity before WIP would not consume anymore while there are WIP inventories. Equation (11.10) is used for calculating the capacity occupied by contract plan. Equation (11.11) expresses that the available production capacity of equipment equals to standard capacity minus the occupation of equipment maintenance, WIP and signed contrasts. Equation (11.12) is used for calculating available capacity; Eq. (11.13) is occupied ratio of process capability.

Solution Procedure

The mathematic model shown in section "Problem Description and Mathematical Modeling" can be solved by intelligent optimization algorithm or other mixed optimization method. But in our research, we introduced heuristic method to solve the model. The heuristic method is based on predefined strategies. The procedure is as follows: (1) assessing supply and demand of capacity by using Eqs. (11.10), (11.11), (11.12), and (11.13); (2) identifying the bottleneck units or processes; (3) eliminating the bottleneck units or processes according to predefined strategies; (4) allocating surplus capacity. In practical applications, we can predefine various strategies to improve the applicability of algorithm.

To illustrate the solution procedure, a simple process example is shown in Fig. 11.3. Based on the technical definition, there are eight process units. When given the product demand, according to the solution procedure, bottleneck processes are 6, 1, 5 and 8 in order by utilization after assessing supply and demand of capacity. The bottleneck unit identification result is shown in Fig. 11.4. As shown in Fig. 11.4, when adjust the process which has the most utilization, the related process units are adjusted too. Choose the next process to adjust until all of the utilizations are less than 100%. Then the set of surplus processes are known as $CAP = \{1,2,3,4,5,7,8\}$. Sort all of orders by strategy which have the process as Proc and $CAP \cap Proc = Proc$ and subject to Eqs. (11.7) and (11.8), such as $Proc = \{1,2,5,7,8\}$. Allocate the surplus capacity for them until there is no matched order. The solution procedure flow is illustrated in **Procedure**:

Procedure

Step 1: Initialize processes for the varieties of orders;

Step 2: Calculate capacity utilization based on the initial process and the past, present and future sales contracts;

Step 3: Identify the processes whose utilization is greater than 100% as bottleneck units;

Step 4: Sort bottleneck units by utilization;

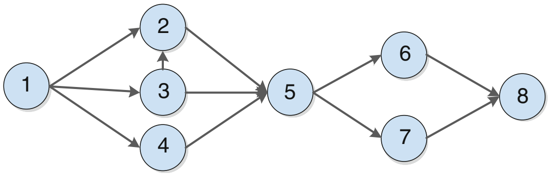


Fig. 11.3 Example of process

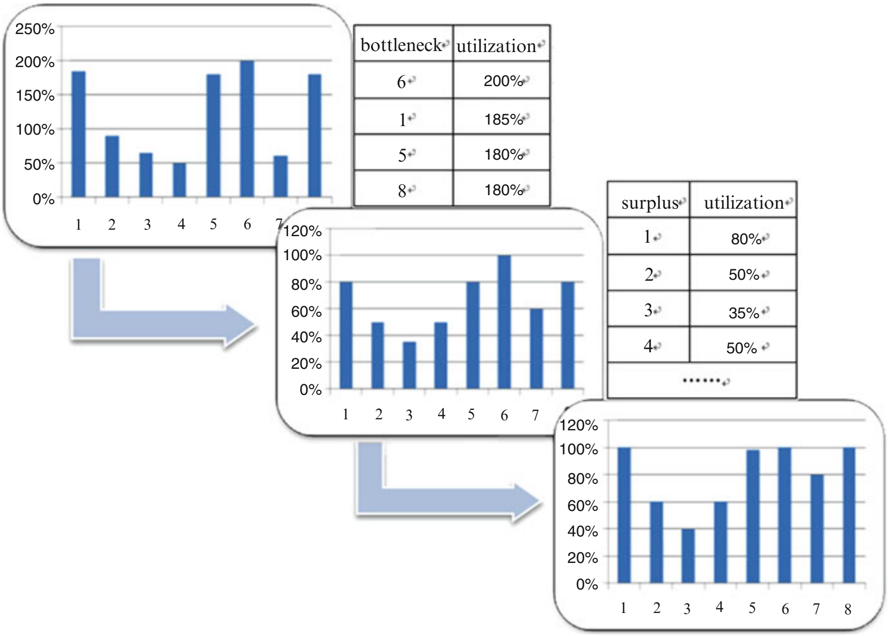


Fig. 11.4 Solution procedure

Step 5: For (units: all bottleneck units)
(1) Sort orders which include units according to strategy;
(2) Drop the first order;
(3) Calculate capacity utilization again;

IF the utilization of unit $<100\%$

Continue;

ELSE

Back to 2);

End For;

Step 6: Define a set of processes which have surplus capacity as CAP = {ai,bj,...};

Step 7: Sort orders dropped according to strategy, defining whose process is Proc (i) = {a,b,c...};

Step 8: For (order: orders dropped)

IF CAP∩Proc(i) = Proc(i)

Calculate suitable output;
Update CAP;
IF CAP is empty

Break;

End IF;

End For;

Application

Utilizing the PCNF model and the solving process, we design the product capacity calculating and planning system for an integrated steel enterprise, which has 1 steel-making plant, 2 hot-rolling plants and 1 cold-rolling plant. The steel enterprise has 18 main devices in total and its maximum throughout per month is 762,600 t.

To prove the PCNF model and solution procedure are feasible and practical, we give an example of data of some month, which has a scale of 400 orders among which 85 orders with higher priority. The total demands are 1,337,300 t. When we put total demands as the input of the model, the result of calculating capacity utilization without adjusting is shown in Fig. 11.5. If we balance the production capacity and production demand based on the predefined strategies, one result of utilizations after adjusting is shown in Fig. 11.6. Before adjusting, BOF, CC and

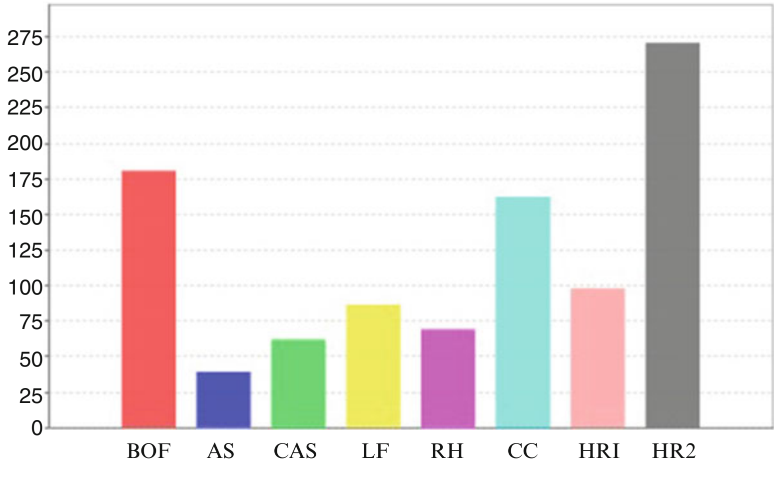


Fig. 11.5 Utilizations before adjusting

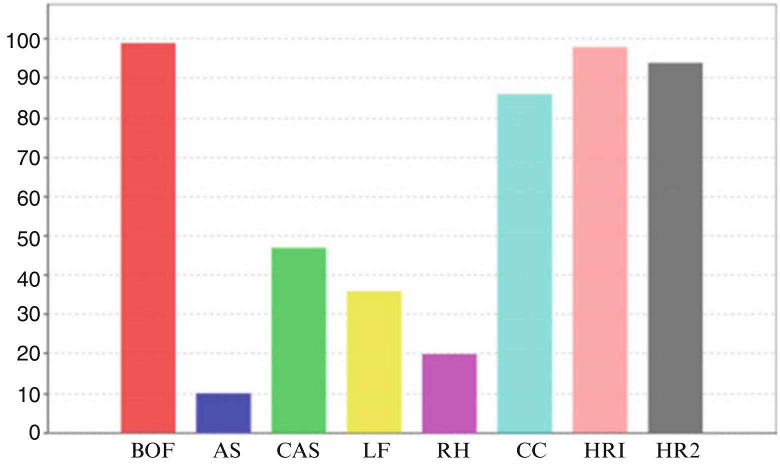


Fig. 11.6 Utilizations after adjusting

Table 11.1 Running results

Item	Value	Item	Value
Runtime	75 s	Best utilization	99%
Avg. utilization	63.20%	1st priority orders	85
Orders accepted	262	Orders adjusted	125
Total demands/t	1,337,300	Total output/t	738,100

HR2 are bottleneck process, and HR2 has the highest load rate. After adjusting, utilizations of all the processes are less than 100%. As BOF, CC, HR1 and HR2 are working on almost full load, they already can't increase the output.

This application is run on the computer, which CPU is Intel i5 2.67 GHz, RAM is 6 G Bytes. The other results are shown on Table 11.1. From this table, we know that the efficiency can completely meet the requirement of practical production. After adjusting by strategies, the work load rate of main devices, such as BOF, HR1, HR2, etc. is nearly 100%. And the output has reached 97% of the max throughout. In addition, all the orders with 1st priority will be produced in planning period.

The bigger the scale of orders is, the longer runtime will be requested. But the runtime is still within acceptable limit. Its efficiency and effectiveness can absolutely meet the needs of practical application.

Conclusion

It is an important subject that reducing production cost, improving economic benefit and providing better services for consumers by effectively using current resources. Order acceptance is the key to ameliorate customer services, maximize plant throughputs and reduce inventory levels. The contribution of this paper is that it gives a solution of the problem of order acceptance and capacity balance for steel plant. The proposed production capacity network flow model, which is called PCNF, is effective and efficient to set up the mathematical model. The actual test result shows that the model and solution method by using the predefined strategies is quick enough to calculate and evaluate the capacity, and can improve the coordination between sales department and manufacturing department.

References

Cao Junjie, Shi Hongbo (2010) Multiple order management model with resource constraints and solution with improved GA. In: 8th conference of decision-making science professional committee, systems engineering society of China, Changzhou, Jiangsu, pp 324–329 (Chinese)

Kalantari M, Rabbani M, Ebadia M (2011) A decision support system for order acceptance/rejection in hybrid MTS/MTO production systems. Appl Math Model 35(3):1363–1377

Lao Ban-xin, Li Xioo-hua (2010) Study on ERP capacity requirements and production scheduling in process manufacturing industry. Info Technol Informatiz 25(3):18–20 (Chinese)

Lv Zhimin, Song Xiaoqing (2011) Balanced short-term capacity planning for steel plant based n constraint genetic algorithm. In: 2011 4th IEEE international conference on computer science and information technology, Chengdu, China, 3:338–342

Lv Zhimin, Song Xiaoqing, Dong Shaohua (2011) Mid-term production plan modeling and algorithm for integrated steel enterprise. Comput Integr Manuf Syst 17(1):89–94 (Chinese)

Melkonian V (2007) Flows in dynamic networks with aggregate arc capacities. Inf Process Lett 101(1):30–35

Punnen AP, Zhang R (2009) Bottleneck flows in unit capacity networks. Inf Process Lett 109 (6):334–338

Slotnick SA (2011) Order acceptance and scheduling: a taxonomy and review. Eur J Oper Res 212(1):1–11

Song Xiaoqing, Lv Zhimin, Dong Shaohua (2011) Model and algorithm based on goal programming of mid term production planning for steel plant. In: International Conference on Computer Science and Logistics Engineering-ICCSLE, Zhengzhou, pp 607–611

Xiao Yiyong, Chang Wenbing, Zhang Renqian (2008) A research on order acceptance model of multi-line and multi-stage. Ind Eng Manag 13(6):26–31, Chinese

Chapter 12
Decision of Planning Input for Make-to-Order System

Bi-xi Zhang, Jing Song, Sheng-qiang Hu, and Ying-ying Guan

Abstract Decision of planning input for make-to-order system based on learning rate is researched in the paper, affect of employee learning rate on the qualified rate in the manual operating system is analyzed and characteristics of the qualified rate' s random fluctuation under the changing production condition are studied. We propose that the random fluctuation of qualified rate is determined by different requirements in specifications, technical difficulties, materials of make-to-order and the random uncertainty characteristics of the production system itself. Considering of affects of learning rate and random factors on the qualified rate, a model of decision-making of planning input is established with the objective to minimize the total expected expenses composed of the costs about excess output, output gaps and scrap losses. By simulating with MathCAD, it is proved that there is an optimal input as customers' orders are certain.

Keywords Learning rate • Planning input • The qualified rate • Make-to-order

Researches Status Review

In the fierce market competition, it has become very important for enterprises to win customers' orders whether enterprises can completely meet customers' demand by delivering accurately their orders on time. In the traditional production plan management people pay more attention to delivery date and product quality, but there are few researches about how to determinate rational planning input in order to ensure accurate delivery with low cost and high benefit according to customers' demand. It is necessary for enterprises to make a reasonable decision of planning

B.-x. Zhang (✉) • J. Song • S.-q. Hu • Y.-y. Guan
School of Management, Guangdong University of Technology, Guangdong, P. R. China
e-mail: zbx@gdut.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_12,

input according to the features of production systems and the characteristics of customers' orders considering of customer requirements and enterprise cost.

In 1936, Wright T. proposed the first learning curve when he studied that the tact time gradually decreased with the increasing of production number in the plane production (Wright 1936). Then learning curve is widely used in workers choose, quality control, plan, cost control and so on (Zhou zhantao and Li li 2006; Tian yungang 2003; Chen zhixiang 2007). Pan et al. (2008) established two models of the customer demand for the normal distribution and average distribution with the objective of the total cost minimization and studied the relation between learning curve and order batches, insurance inventory, lead time. Anzanello and Fogliatto (2007) put forward to categorize by product similarity and determine the learning curve of each group according to the customization features. Jaber and Guiffrida (2008) researched the production system which can be disrupted when there existed produced rework, and constructed several new quality learning curve to guide the production process quality control. There are many researches of learning curve and their extended field (Liu and Qi 2006), but its application in make-to-order produce system is not yet discovered. In the research of planning input Zhang bixi and Songjing (2008) has studied the planning input of make-to-order produce system and constructed the corresponding decision model (Zhang bixi and Songjing 2008). Michael A. Lapre based on the organization learning literature, derive a quality learning curve that links different types of learning in quality improvement projects to the evolution of the factory's waste rate (Lapre et al. 2000).

This paper studies the decision of planning input for make-to-order system based on learning rate and the random fluctuation of the qualified rate.

The Model of Decision of Planning Input Regardless of Learning Rate

The production cost decided the benefit of enterprises when customers' orders are certain. Therefore, the decision-making model of planning input is built with the objective to minimize the production cost as follows:

Define: D = the demand of customers; F = unit fee of input setup; C_q = unit rearrangement cost of shortage; C_g = unit disposal cost of excess; C_r = unit disposal cost of the unqualified products; P = planning input; r = the qualified rate of products (Assuming it is normally distributed);

$R(r) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(r-\mu)^2}{2\sigma^2}}$, R(r) is the probability density function of r

u = the median of the qualified rate of the product

Respectively the loss of excess and shortage are calculated as follows:

1. the expected loss of excess:

$$\begin{cases} W(P) = \int_{\frac{D}{P}}^{1} \left[C_g(rP - D) + C_r(1 - r)P\right] R(r)dr \\ st.\ rP \geq D \end{cases} \tag{12.1}$$

2. the expected loss of shortage:

$$\begin{cases} S(P) = \int_{0}^{\frac{D}{P}} \left[C_q(D - rP) + C_r(1 - r)P + F\right] R(r)dr \\ st.\ rP \leq D \end{cases} \tag{12.2}$$

3. Object to minimize the total excepted loss, the model of planning input is as follows:

$$\begin{cases} Min\ E(P) = \min\ \ (W(P) + S(P)) \\ st.\ \ P \geq 0,\ \ \ \mathrm{r} \geq 0 \end{cases} \tag{12.3}$$

Case: There is one enterprise which got one order: $D = 600$ T; $C_g = 120$ yuan/t; $C_q = 180$ yuan/t; $C_r = 100$ yuan/t; $F = 2{,}000$ yuan/unit; $r = 0.6 \sim 1$; $\mu = 0.8$; $\sigma = 0.2$.

Using MathCAD to calculate Eqs. (12.1), (12.2), and (12.3), we get the expected loss curve of excess and shortage in Fig. 12.1 and the total expected loss curve in Fig. 12.2. At the same time we find the optimal planning input is 780 t and the minimum expected loss is 12,070 yuan.

The Model of Decision of Planning Input Considering of Learning Rate

In manual operation system, workers proficiency has a direct impact on the qualified rate of unit product, in other words, the qualified rate will raise if production repetitions increases. In manual operation system the unit qualified rate is affected by systemic growth trend and fluctuations caused by random factors of system. According to learning curve, we suppose the unqualified rate of the product x is: $S_1 x^{\frac{\log b}{\log a}}$, The qualified probability is:

$$h_x = 1 - S_1 x^{\frac{\log b}{\log a}} \tag{12.4}$$

h_x = the qualified probability of the product x; S_1 = the qualified probability of the first product; b = Learning coefficient (The smaller the value of b the better the learning); a = constant; x = Output (production repetitions);

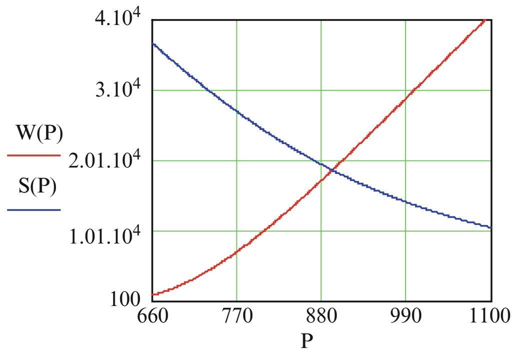


Fig. 12.1 The expected loss curve of excess and shortage

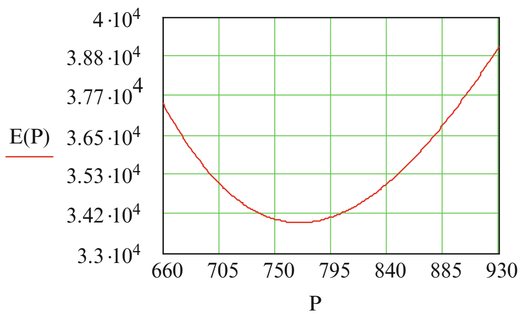


Fig. 12.2 The total expected loss curve

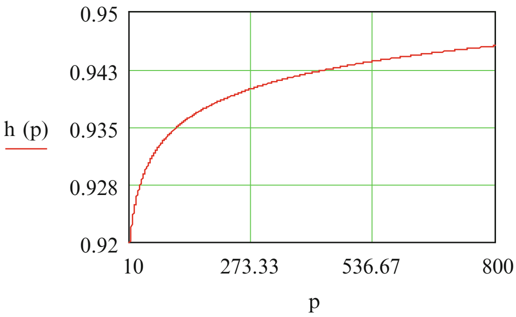


Fig. 12.3 The curve of the qualified probability

If $b = 0.92$, $a = 2.5$, $S_1 = 0.1$, with the output increasing the curve of the qualified probability is as shown in Fig. 12.3:

Supposed P is the planning input b, a and S_1 are given we get the equation of Q_x regardless of random factors:

$$Q_x = \int_0^P \left(1 - S_1 x^{\frac{\log b}{\log a}}\right) dx \tag{12.5}$$

Given P = 10,000 units, from Eq. (12.5) we get the actual output as follows:

$$Q_x = \int_0^{10000} \left(1 - 0.1x^{\frac{\log 0.92}{\log 2.5}}\right)dx = 9524(\text{unit})$$

When the planning input is 10,000 units, the actual average qualified rate is 95.24 %.

We analyze the loss of planning input with the objective of minimize the expected loss as follows:

1. the expected loss of excess as Eq. (12.6):

$$\begin{cases} W(P) = \int_{\frac{D}{P}}^{1} \left(C_g\left(r\int_0^P \left(1 - S_1 \cdot x^{\frac{\log b}{\log a}}\right)dx - D\right) + \left(C_r(1-r)\cdot\int_0^P \left(1 - S_1\cdot x^{\frac{\log b}{\log a}}\right)dx\right)\right)R(r)dr \\ st.\ rP \geq D \end{cases} \tag{12.6}$$

The definition of all parameters in Eq. (12.6) is the same to Eq. (12.1), the first part of Eq. (12.6) is the disposal cost of excess and the second part is the disposal cost of the unqualified products. $\int_0^P \left(1 - S_1 x^{\frac{\log b}{\log a}}\right)dx$ Indicate the influence of learning rate to the qualified rate, and r is the influence of random factors to the qualified rate.

2. the expected loss of shortage as Eq. (12.7):

$$\begin{cases} S(P) = \int\limits_0^{\frac{D}{P}} \left(C_q\left(D - r\int\limits_0^P \left(1 - S_1\cdot x^{\frac{\log\ b}{\log\ a}}\right)dx\right) + \left(C_r(1-r)\cdot\int\limits_0^P \left(1 - S_1\cdot x^{\frac{\log\ b}{\log\ a}}\right)dx + F\right)\right)R(r)dr \\ st.\, r\cdot P < D \end{cases} \tag{12.7}$$

The definition of all parameters in Eq. (12.7) is the same to Eq. (12.2), the first part of Eq. (12.7) is the rearrangement cost of shortage and the second part is the disposal cost of the unqualified products, the third part is the fee of input setup.

3. Object to minimize the total excepted loss, the model of planning input is as follows:

$$\begin{cases} min\ E(P) = min[W(P) + S(P)] \\ st.P \geq 0, \quad r \geq 0 \end{cases} \tag{12.8}$$

Assuming: $C_g = 180$, $C_q = 160$, $C_r = 120$, $D = 10000$, $E = 3000$, $\sigma = 0.12$, $u = 0.96$, $b = 0.92$, $a = 3$, $S_1 = 0.08$

Using MathCAD we get Fig. 12.4.

From Fig. 12.4 we find that when the planning input is 11282.5, the minimum expected loss is 93,070 yuan if we consider the learning rate.

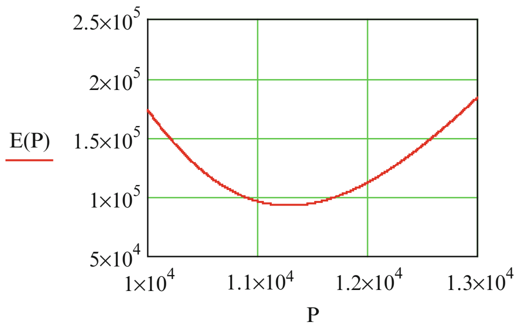


Fig. 12.4 The total expected loss curve

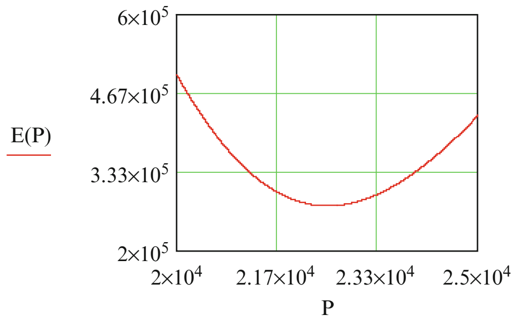


Fig. 12.5 The total expected loss curve considering of learning rate

Numerical Cases

An enterprise which professionally produces aluminum section uses the pattern of make-to-order. Because there are many random factors in its produce system, the situations of excess or shortage occur all the time. Now one customer ordered the product *j*, the demand quantity is 20,000 kg. According to the historical statistics: the excess will be melt as wastes and the cost of melt is 260 yuan/t; the rearrangement cost of shortage is 230 yuan/t; the disposal cost of the unqualified products is 180 yuan/t; unit fee of input setup is 3,000 yuan/unit. Now we need to determine the optimal planning input.

Because: $C_g = 260$, $C_q = 230$, $C_r = 180$, $D = 20000$, $F = 3000$, $\sigma = 0.12$, $b = 0.92$, $a = 2.5$, $S_1 = 0.1$, $u = 0.96$. Using MathCAD from Eq. (12.8) we get Fig. 12.5 as follows:

Considering of the learning rate, we find that when the optimal planning input is 22,298 kg, the minimum expected loss is 27,800 yuan.

Conclusions

Because of learning rate, the qualified rate will raise if production repetitions increases. This paper proposes a model of planning input with the objective to minimize the expected loss of excess and shortage considering of random fluctuation and learning rate. At last it is proved that this model can effectively deal with the problem of planning input of make-to-order enterprises to reduce the operation cost and increase the enterprise efficiency.

Acknowledgment This research was supported in part by National Natural Science Foundation of China under Grant Nos. 70671030 and 70971026; Natural Science Foundation of Guangdong Province under Grant No. 915100900100045 and Humanities and Social Sciences Department of Education of Guangdong Province Key Base Project under Grant No. 08jdxm63004.

References

Â Pan, Jason Chao-Hsien, Lo Ming-Cheng (2008) The learning effect on setup cost reduction for mixture inventory models with variable lead time. Asia-Pac J Oper Res 25(4):513–529 (Chinese)

Anzanello MJ, Fogliatto FS (2007) Learning curve modeling of work assignment in mass customized assembly lines. Int J Prod Res 45(13):2919–2938

Chen zhixiang (2007) Learning curve and its application in production operational research [J]. Eng Sci 9(7):82–94 (Chinese)

Jaber MY, Guiffrida AL (2008) Learning curves for imperfect production processes with reworks and process restoration interruptions. Eur J Oper Res 189(1):93–104

Lapre MA, Mukherjee AS, Van Wassenhove LN (2000) Behind the learning curve: linking learning activities to waste reduction. Manag Sci 46:597

Liu L, Qi ES (2006) Research on applying method of APS in make-to-order production plant [J]. Modul Mach Tool Autom Manuf Tech 10:100–104

Tian yungang (2003) On the use of learning curve in enterprise management [J]. J Shanxi Agric Univ 2:142–144 (Chinese)

Wright T (1936) Factors affecting the cost of airplanes [J]. J Aeronaut Sci 3(2):122–128

Zhang bixi, Songjing (2008) Decision-making of planning quantity put into production for make to order system [J]. Syst Eng Theory Pract 28(7):165–168 (Chinese)

Zhou zhantao, Li li (2006) The research on computer-aided dynamic time quota system based on the skilled curve [J]. Modul Mach Tool Autom Manuf Tech 10:26–29 (Chinese)

Chapter 13
Study on an Affected Operations Rescheduling Method Responding to Stochastic Disturbances

Ya-qin Zhou, Bei-zhi Li, Jian-guo Yang, and Peng Yang

Abstract Literature on job shop scheduling has primarily focused on the development of predictive schedules in static environment. However, when the schedule is carried out in job shop, it may affected by varied disturbances. These disturbances will make the original schedule worse, even invalid. Rescheduling is the process of finding a new schedule to respond to the stochastic disturbances. In this paper, an affected operations rescheduling method (AORM) is studied to respond to disturbances. First, the basic theory of the method is given. Then the algorithmic procedure is introduced. The objective functions evaluating the rescheduling method are given. At last, an illustration example is tested and analyzed. The result shows that the rescheduling method proposed can produce new optimal schedules to respond to stochastic disturbances.

Keywords Affected operations rescheduling • Dynamic scheduling • Repair method • Rescheduling method

Introduction

Most of the literature on production scheduling focuses on how to generate a schedule to guide production assuming some specialty of the problem known. The schedule generated can solve the conflict between resources by controlling the release time of job to workshop. It can ensure the raw material needed to be ordered on time and the job to be delivered on time to satisfy the due date. Scheduling problem is a typical NP-complete problem (Garey et al. 1976). For static job shop scheduling problem, many optimization methods to obtain the optimal schedule have been proposed, such as neural network (Ibrahim et al.

Y.-q. Zhou (✉) • B.-z. Li • J.-g. Yang • P. Yang
College of Mechanical Engineering, Donghua University, Shanghai, China
e-mail: zhouyaqin@dhu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_13,

2009; Zhao et al. 2010), simulated annealing algorithm (Jamili et al. 2011; Zhang and Wu 2010), tabu search (Eswaramurthy and Tamilarasi 2007; Geyik and Cedimoglu 2004), and genetic algorithm (Ritwik and Deb 2011; Wang et al. 2009). In the dynamic job shop environment, some random disturbances will disturb or interrupt the implement of the original optimal schedule to make it invalid and rescheduling is needed. The varied disturbances which always appear in workshop include the machine failure, the delay of raw material, the insertion of new job, and the cancellation of the order etc. Most of the disturbances can be modeled as machine failure, which may make the machine unavailable for a period of time.

Rescheduling is a process to generate a new feasible schedule when the disturbance occurs. Most job shop is dynamic, so it is more important to study on rescheduling method, which attracts many researchers' attention recently (Abumaizar and Svestka 1997; Adibi et al. 2010; Cao and Du 2011). In this paper, an affected operations rescheduling method is studied for job shop scheduling problem. Firstly, the basic principle of the affected operations rescheduling method is given, and then its algorithm process is introduced, with the indicator function measuring rescheduling method's performance given. Finally, an illustration is analyzed to testify that the rescheduling method proposed can generate a new schedule to direct production responding to random disturbance.

The Basic Principle of the Affected Operations Rescheduling Method

The affected operations rescheduling only reschedule the operations which are affected directly or indirectly by the disturbance during the execution of the schedule. This algorithm is based on a binary tree algorithm (Li et al. 1993). The affected operations rescheduling is a heuristic rescheduling method. Its objective is to obtain a new schedule with a smallest makespan increment, while keeping the job's processing sequence as in the original schedule.

In most manufacturing systems scheduling, dispatching the process sequence of jobs is based on jobs' processing route. Any feasible schedule, satisfying the jobs' processing route constraints, must determine the processing sequence, start and end time of each task (job) on each equipment (machine) to get the optimal or near optimal value of the selected objective.

The sequence of job and machine processing can be represented by a binary tree. The tree is a graph starting from a single (root) node (the first one of the affected processes). The binary tree is a tree with nodes connected without cycles, that is, each node has at most two branches (as shown in Fig. 13.1). Each node represents a operation, the left branch of each node represents the job branch, that is, the next operation of the job (*noj*), which can be obtained from the job's processing route constraints, while the right branch represents the machine branch, that is, the next

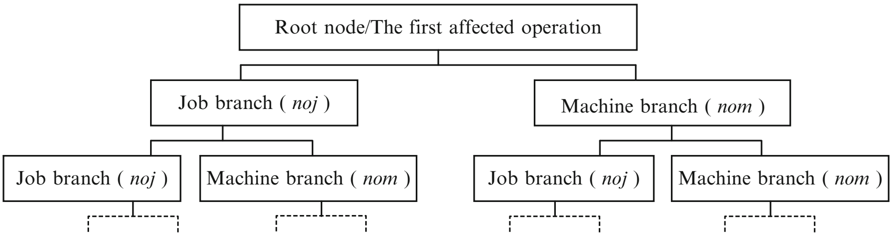


Fig. 13.1 The binary tree description of a schedule

operation to be processed on the machine of current operation (*nom*), which can be get from the processing sequence of the operations on the machine in the original schedule.

The basic principle of the affected operation rescheduling is to delay the start processing time of certain operations with a minimum amount of time to respond to any disturbance. The minimum amount of time must: (1) make the jobs' processing route constraints satisfied; (2) maintain the initial processing sequence of operations on each machine as in the original schedule.

The effect of the first affected operation (the first operation disturbed by the disturbance) on its job and machine branch and the effect of these branched on their corresponding job and machine branches are studied to solve the effect of the disturbance. That is to track the spread of the effect of the disturbance on the "rescheduling" binary tree branches, and re-update the binary tree. The first affected operation is the root node with each successor node representing one of the affected operations.

The Algorithm of the Affect Operation Rescheduling Method

Symbol Definition

The definition of the symbols used in the affected operation rescheduling algorithm is given as follows:

R: The set of the remaining operations needed to be rescheduling when the disturbance occurs. (Including the disturbed operations and the operations not yet started when the disturbance occurs).
O: The set of the probably affected operations.
A: The set of the affected operations after rescheduling (with new starting time and ending time).
noj: The next operation of the job (job branch).
nom: The next operation on the machine (machine branch).

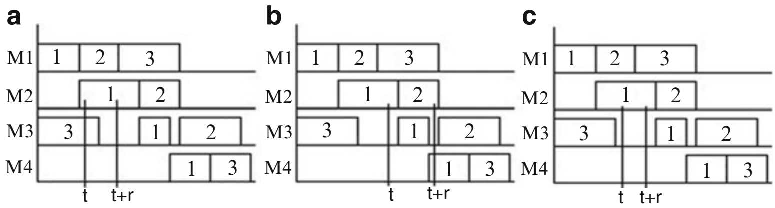


Fig. 13.2 The effect of machine failure on the original schedule

jST: The starting time of the operation, restricted by the former operation of the job.
mST: The starting time of the operation, restricted by the former operation on the machine.
ST: The starting time of the operation in the original schedule.
ET: The ending time of the operation in the original schedule.
newST: The starting time of the operation in the new schedule.
newET: The ending time of the operation in the new schedule.
devST: The deviation of the starting time of the operations between the original schedule and the new schedule.

readyTime: The ready time of the machine.
noR: The number of the set R (The number of the remaining operations).
noA: The number of the set R (The number of the affected operations).
i: The index of the set A.
g: The index of the set O.

Abbreviations and Acronyms

Step 1: Set $i = 1$, $g = 1$, $devST = 0$, $O = \varnothing$, $A = \varnothing$, *jST* and *mST* of all the operations equal to 0. Determine the first affected operation $O[1]$. The effect of the disturbance (machine failure) on the original schedule has three cases, as shown in Fig. 13.2. At time t, there is a disturbance occurring on machine M3 with duration time of r, thus, $O[1]$ belongs to one of the three cases as following:

(a) The interrupted operation, the effect of the interruption is as shown in Fig. 13.2a.
(b) If there is no operation being interrupted, select the first remaining operation on the machine if the operation exists and its ST is smaller than the *readyTime* of the shut down machine (The *readyTime* of the shut down machine equals to the stopping time t plus duration time r), as shown in Fig. 13.2b.
(c) Otherwise, the algorithm stops, there is no operation affected (Rescheduling is not needed), as shown in Fig. 13.2c.

Step 2: $O[1]$ is as the current operation, its *mST* equals to the *readyTime* of the shut down machine, g pluses 1.

Step 3: The *newST* of the current operation equals to Max (*jST* of the current operation, *mST* of the current operation). The *newET* of the current operation equals to *newST* of the current operation pluses the processing time of the current operation.

Step 4: If the current operation can not be matched to any affected operation v in set A , go to step 5, otherwise, reset the attribute of $A[v]$ as following, then go to step 7.

devST = *devST* + Max(*newET* of the current operation-*newET* of $A[v]$, 0).
newST of $A[v]$ = Max(newST of the current operation, *newST* of $A[v]$).
newET of $A[v]$ = *newST* of $A[v]$ + the processing time of $A[v]$.

Step 5: Set the i-th affected operation $A[i]$ as the current operation, i pluses 1.

Step 6: *devST* = *devST* + (*newET* of $A[i]$-*ET* of $A[i]$).

Step 7: Get the job branch *noj* of the current operation from the of process route of the job, if *noj* exists and its *ST* is less than *newET* of the current operation. Then set $O[g]$ = *noj*, *jST* of $O[g]$ = *newET* of the current operation, g pluses 1.

Step 8: Get the machine branch *nom* of the current operation from the original schedule if *nom* exists and its *ST* is less than *newET* of the current operation. Then set $O[g]$ = *nom*, *mST* of $O[g]$ = *newET* of the current operation, g pluses 1.

Step 9: Remove the current operation from the set O. Add the new operations of step 7 and 8 into the set.

Step 10: If $O = \emptyset$, end. Otherwise, select randomly an operation from set O as the current operation, then go to step 3.

Performance Measurement

Three performance measurement indexes are used to evaluate the new schedule generated by the affected operation rescheduling method, in order to evaluate the performance of this rescheduling method: the change rate of Makespan, the starting time deviation of each operation, and the sequence deviation between the new schedule and the original schedule.

1. The change rate of Makespan (M_p)
   The change rate of Makespan can be defined as following:

$$M_p = \left[\frac{M_m - M_0}{M_0}\right] * 100\% \tag{13.1}$$

   where, M_0 is the Makespan of the original schedule, M_m is the Makespan of the new schedule generated by the rescheduling method.
2. The starting time deviation (*devST*)

The starting time deviation is a valid measurement of the efficiency of rescheduling method, especially in the job environment where the auxiliary resources (such as tools and fixtures) is delivered to machine based on the original schedule. Obviously, if the material is delivered earlier than the demand, the change of jobs' starting time may incur storage costs and, more importantly, if the demand for cutting tools and materials is earlier than the original schedule, it will incur emergency ordering cost. The start time deviation is calculated by calculating the sum of the absolute operation ending time difference value between the new schedule and the original schedule. The starting time deviation consists of two parts, the delay time, which equals to the sum of the positive ending time difference, and the ahead of time, which equals to sum of the absolute value of the negative ending time difference

$$devST = \sum_{i=1}^{n} \sum_{j=1}^{hi} \left| newET_{ij} - ET_{ij} \right| \tag{13.2}$$

where n is the number of job, hi is the operation number of job i.

3. Sequence deviation ($devSQ$)
If the adjustment is prepared in advance based on the initial operation sequence on the machine, then this measurement of sequence deviation is critical. It is measured using the following method.

For each operation j on machine k in the new schedule, define S_1 as the set of the operations processed before operation j in the original schedule, S_2 as the set of the operations processed after operation j, $S = S_1 \cap S_2$, N_{jk} = the cardinal number of set S (the capacity of the set). The sequence deviation can be obtained by calculating the sum of the sequence deviation on each machine:

$$devSQ = \sum_{k} \sum_{j} N_{jk} \tag{13.3}$$

For affected operation rescheduling method, the change rate of Makespan and the starting time deviation is very small. It has no sequence deviation because it only reschedules the affected operations.

Illustration

The case La31 (30 jobs and 10 machines) proposed by Lawrence (1984) is used to test. The original schedule with the optimal makespan 1784 is obtained by the biological intelligent method (Zhou et al. 2006), with the Gantt chart shown in Fig. 13.3. In Fig. 13.3, the processing sequence of jobs on each machine is given, with the number in the box representing job. If there is no enough places, then the job is shown in the top of the box.

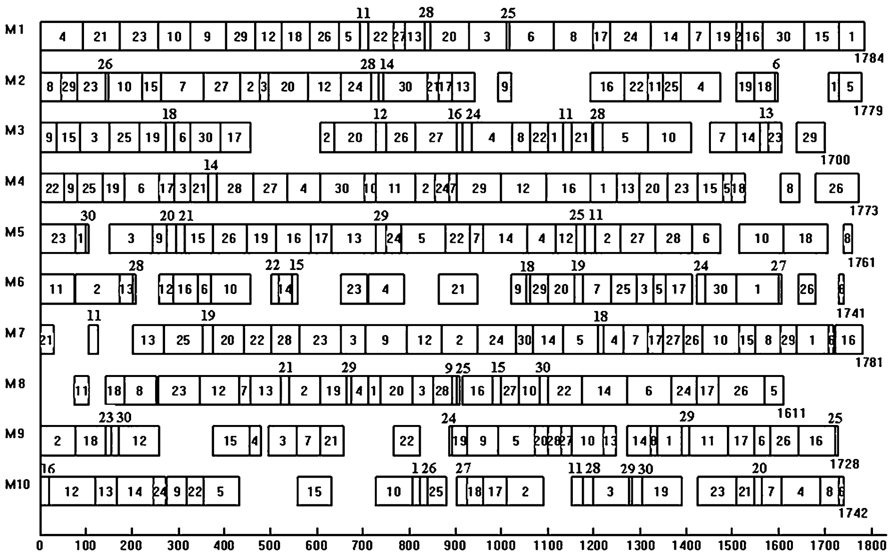


Fig. 13.3 The Gantt chart of the original schedule of La3

The majority of disturbance occurring during production can be mapped to machine failure. The disturbance of machine failure is tested. Assume that when the original schedule shown in Fig. 13.3 is carrying out, there is a breakdown occurring at time 800 on machine M9, with the duration time of 80 time units.

For this disturbance, a new schedule is generated by using the affected operation rescheduling method proposed in this paper, with the Gantt chart shown in Fig. 13.4. In the figure, the dashed line on the machine M9 means the interruption time of the machine. In the new schedule, the processing of the operations before the interruption is not changed, only the operations after the disturbance in the original schedule are rescheduled. The new starting time and the ending time of each affected operations are calculated to get the Makespan of the schedule 1791. For Figs. 13.3 and 13.4, it is shown that only the affected operations have new starting time and ending time. By comparing the new schedule generated by the AORM and the original schedule, it is shown that the Mapespan only increases 7 time units while the machine M8 is invalid for 80 time units, the change rate of Mapespan is 0.4% and the processing sequence of each operation is not changed, there is no sequence deviation.

Conclusion

During the schedule execution in workshop, the schedule will be interrupted by a variety of random disturbances, and therefore a new schedule proposed by rescheduling to respond to random disturbances has a good guide to the actual

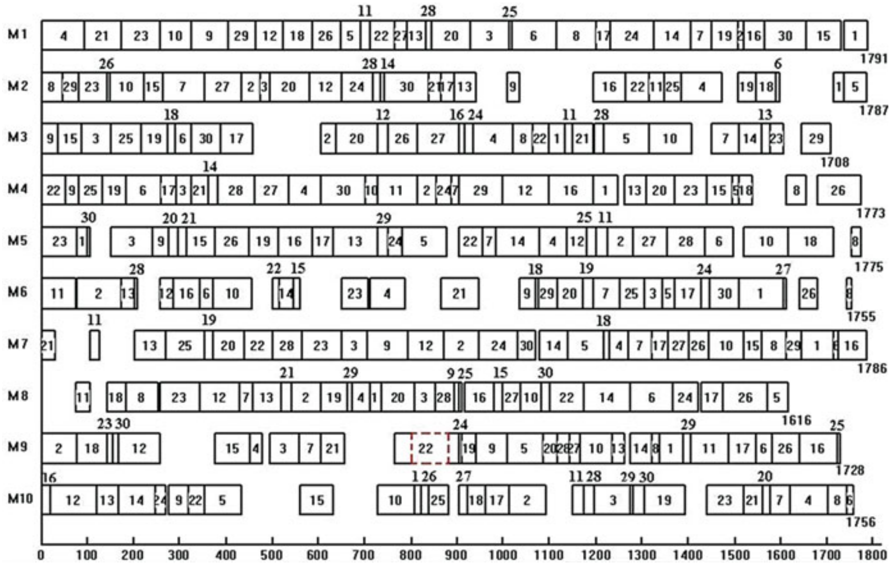


Fig. 13.4 The Gantt chart of the new schedule generated by AORM

production. Affected operations rescheduling method is proposed in this paper, with the principle and algorithm process. The result of the illustration shows that the proposed rescheduling method can produce a new optimal schedule to respond to disturbance.

Acknowledgement This research was partially supported by the National Science Foundation of China (70371040), Shanghai Leading Academic Discipline Project (B602) and the Fundamental Research Funds for the Central Universities.

References

Abumaizar RJ, Svestka JA (1997) Rescheduling job shops under random disruptions. Int J Prod Res 35(7):2065–2082

Adibi MA, Zandieh M, Amiri M (2010) Multi-objective scheduling of dynamic job shop using variable neighborhood search. Expert Syst Appl 37(1):282–287

Cao Y, Du J (2011) An improved Simulated Annealing algorithm for real-time dynamic job-shop scheduling. Adv Mater Res 186:636–639

Eswaramurthy VP, Tamilarasi A (2007) Tabu search strategies for solving job shop scheduling problems. J Adv Manuf Syst 6(1):59–75

Garey EL, Johnson DS, Sethi R (1976) The complexity of flowshop and jobshop scheduling. Math Oper Res 1:117–129

Geyik F, Cedimoglu IH (2004) The strategies and parameters of tabu search for job-shop scheduling. J Intell Manuf 15(4):439–448

Ibrahim S, El-Baz MA, Esh E (2009) Neural networks for job shop scheduling problems. J Eng Appl Sci 56(2):169–183

Jamili A, Mohammad A, Tavakkoli-Moghaddam R (2011) A hybrid algorithm based on particle swarm optimization and simulated annealing for a periodic job shop scheduling problem. Int J Adv Manuf Technol 54(1–4):309–322

Lawrence S (1984) Resource constrained project scheduling: an experimental investigation of heuristic scheduling techniques (Supplement). Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh

Li R, Shyu Y, Adiga S (1993) A heuristic rescheduling algorithm for computer-based production scheduling systems. Int J Prod Res 31(8):1815–1826

Ritwik K, Deb S (2011) A genetic algorithm-based approach for optimization of scheduling in job shop environment. J Adv Manuf Syst 10(2):223–240

Wang YM, Yin HL, Wang J (2009) Genetic algorithm with new encoding scheme for job shop scheduling. Int J Adv Manuf Technol 44(9–10):977–984

Zhang R, Wu C (2010) A hybrid immune simulated annealing algorithm for the job shop scheduling problem. Appl Soft Comput J 10(1):79–89

Zhao FQ, Zou JH, Yang YH (2010) A hybrid approach based on Artificial Neural Network (ANN) and Differential Evolution (DE) for job-shop scheduling problem. Appl Mech Mater 26–28:754–757

Zhou YQ, Li BZ, Yang JG (2006) Intelligent scheduling algorithm for problems with batch and non cutting time. Jixie Gongcheng Xuebao/Chin J Mech Eng 42(1):52–566 (Chinese)

Chapter 14
Integrated Optimization of Production Planning for Large and Complex Discrete Manufacturing System

Xiao-ying Yang, Xue Wang, and Guo-hong Shi

Abstract The integrated optimization problem of multi-level production planning for large and complex discrete manufacturing system was taken as research object in this paper. Firstly, the decision-making process of multi-level distributed production planning in large and complex system was proposed based on system survey. Secondly, the integrated optimization theoretical model of multilevel production planning was formulated by weighted combinatorial optimization method, considering customer satisfaction (quality and delivery), lean manufacturing (bottleneck utilization and cost) as the optimization objective. Finally, augmented lagrangian relaxation method and Heuristic algorithm were adopted and a rule-based hybrid algorithm was designed in order to efficiently solve nonlinear inequality constraints combinatorial optimization problems. This study provided a theoretical approach to solve the scientific problem of production planning decision for the large and complex discrete manufacturing system.

Keywords Augmented lagrangian relaxation method • Combinatorial optimization • Hybrid heuristic algorithm • Large and complex discrete manufacturing systems • Multi-level production planning

X.-y. Yang (✉)
Department of Management, Jiangsu University, Zhenjiang 212013, China

Department of Mechanical and Electrical Engineering, Henan University of Science and Technology, Luoyang 471003, China
e-mail: lyyxy111@163.com

X. Wang
Department of Mechanical and Electrical Engineering, Henan University of Science and Technology, Luoyang 471003, China

G.-h. Shi
Department of Management, Jiangsu University, Zhenjiang 212013, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_14,

Introduction

Research on the production planning has been more than 50 years. Research methods are more and more mature, but there is still a great gap between the study results and industrial state (Kempf et al. 2011). With the development of science and technology, production planning will do inevitably toward the direction of integrated, dynamic and practical, multiple objectives, high-level optimal and the research trend will be seen from centralized manufacturing to the development of distributed manufacturing (Argoneto et al. 2008). Large discrete manufacturing system is a complex multi-level distributed manufacturing system whose production planning with multi-project and multi-parts, different processes, multilevel features, all levels of planning was influenced and constrained by each other (Cai et al. 2011). Today's production planning problems should be able to deal with the problem from advanced to low-level collaborative integrated decision-making (Maravelias and Sung 2009). Decision-making of production planning for large discrete manufacturing system is characteristic of multiple objectives, multiple constraints and uncertainty, whose integrated optimization model is well known as a NP-hard problem. At present, existing research achievements are less, such as the literatures (Maravelias and Sung 2009; Luo Chunpeng and Rong Gang 2009; Sugimura et al. 2001; Li et al. 2012; Gang 2009; Kis and Kovacs 2012) made only a preliminary study. However, the issue considered was one-sided in current research as that only attached the importance to production cycle, inventory cost, and so on, which has not formed a complete theoretical system (Kis and Kovacs 2012); The research object involving discrete manufacturing system, system characteristic, environment and uncertain factors were generally not taken into consideration, so it was difficult to get a solution in line with the industrial actual state and the demand of the industrial. Therefore, the research and application still face some challenges (Stadtler 2005).

Integrated optimization problem of multi-level production planning for large and complex discrete manufacturing system was taken as research object in this paper. The process of decision-making of production planning was combed based on actual investigation and analysis of system. Considering customer satisfaction (quality and delivery) and enterprise operational efficiency (output and lean production) comprehensively as the optimization objective, the integrated optimization theoretical model with actual system characteristics of multi-level production planning was formulated, and then a effective solution scheme and algorithm for it was sought. This study provided a theoretical approach to scientifically solve the problem of production planning decision for the large and complex discrete manufacturing system.

Decision-Making Process of Multi-level Distribution Production Planning

Modern large discrete manufacturing system makes geographically dispersed a number of enterprise users, suppliers, and the association of manufacturers and enterprises manufacturing plants and internal several manufacturing workshops integrated classifically using information technology and network technology, the network multi-level distributed manufacturing system is established.

The classification decision system of production planning based on information system is shown in Fig. 14.1.

In this paper, aiming at large discrete manufacturing system, production planning decision will be divided into four levels: the first level is called the enterprise level plan, and the other three levels are respectively called the project manager level plan, the factory level plan and the workshop level plan.

Optimization Decision Model

Sets and Input Parameters

I: set of products, indexed by i

R: set of product parts, $R = \{r_{ij}, i = 1,\ldots,n;\ j = 1,\ldots,m\}$

K: set of processing steps, $K = \{K_{ijp}, i = 1,\ldots,n; j = 1,\ldots,m;\ p = 1,\ldots,q\}$, p is the number of steps

T: set of manufacturing times, $T = \{t_{ijp},\ i = 1,\ldots,n; j = 1,\ldots,m;\ p = 1,\ldots, q\}$, t_{ijp} is the quota of process p

W: set of weights of products and components $W = \{W_{ijp}, i = 1,\ldots,n; j = 1,\ldots,m, p = 1,\ldots,q\}$;

M: set of stations, $M = \{M_e, N_e, e = 1,\ldots,E\}$, M_e is set of the amount of type of equipment, assuming only one part can be processed on one machine at the same time

α: state index of equipment is used, when in use $\alpha = 1$, otherwise $\alpha = 0$

C_{ij}: total cost of production of part j of product i

W_{ijp}: the weight of part j of product i at the end of process p

$w_{ij,p,p-1}$: amount of material transporting of part j of product i between the process p and the process $p-1$

$d_{ij,p,p-1}$: distance of material transporting of part j of product i between the process p and the process $p-1$

$T'_{e,t}$: in course of task time of equipment of type M_e within time t

$O_{ij,t}$: order of part j of product i within t

t'_{ij}: delivery of part j of product i

t_{ij}: manufacturing completion time of the part j of product i

$h_{ijp,e}$: unit time cost per when part j of product i using equipment of type M_e to process p

$t_{ijp,e}$: time of the part j of product i using equipment of type M_e to process p

Q_{ijc}: customer demand for products quality index

Q_{ije}: comprehensive technical performance index of equipment;

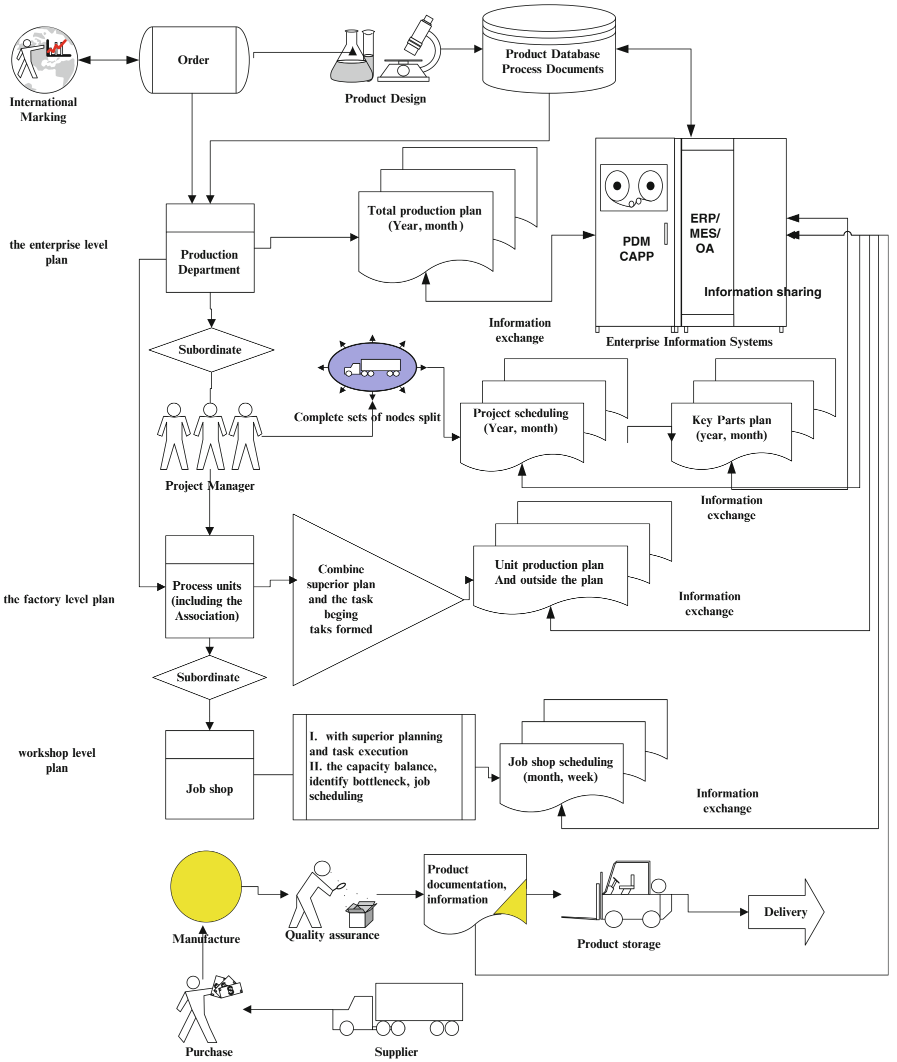


Fig. 14.1 Classification decision system of production planning based on information system

β_h: multi-objective integrated weights

δ: state index whether the type M_e is bottleneck machine, when M_e is, $\delta = 1$, otherwise $\delta = 0$

Optimizing Objectives

According to the actual production, customer satisfaction (the product quality and delivery for the index) and enterprise operation efficiency and benefit are mainly used as decision-making objectives of production planning for large discrete manufacturing systems. Output capacity (with bottleneck equipment utilization index) and lean production and zero waste are generally used as operation efficiency and benefit of enterprise. In this paper, dimensionless indexes are adopted, each of which is independent of each other. Specific indexes are described as follows:

1. *The customer satisfaction: quality index of product*. The quality of mechanical products mainly depends on machining and assembly, and the precision of machining mainly depends on the precision index of comprehensive performance of the equipment. The precision index of comprehensive performance of a single equipment is: $Q = \sqrt{\frac{\sum (\frac{T_{pi}}{T_{si}})^2}{n}}$, here, Tpi is the single precision value of element of i of actual measurement of the equipment; Tsi is a single precision value of standard article; n is the number of terms of actual measurement. Quality index of product is represented by reliability assurance index. That's to maximize the ratio of the comprehensive technical performance index of equipment and the quality index of customer demand of product.

$$Z(Q) = \max \sum_{i \in I} \sum_{j \in R} \frac{Q_{ije}}{Q_{ijc}}, Q_{ije} = \sum_{e \in E} Q_{ijM_e} \tag{14.1}$$

2. *A second customer satisfaction index: product delivery*. It is represented by delivery completion rate index, that's to minimize the ratio of the actual completion time and order delivery, and it is also a basic task of the production system to plan and organize.

$$Z(T) = \min \sum_{i \in I} \sum_{j \in R} \frac{t_{ij}}{t'_{ij}} \tag{14.2}$$

3. *Utilization index of bottleneck equipment: According to Theory of Constraints, output capacity depends on the utilization of bottleneck resource*. Bottleneck can be identified by manual or intelligent system. The index is to maximize the ratio of actual working time and available working time of bottleneck equipment (system time minus the time that is running and that has plans to carry out its mandate).

$$Z(U) = \max U = \max \sum_{i \in I} \sum_{j \in R} \sum_{e \in E} \frac{t_{ijp,t,e}.\alpha.o_{ij}.\delta}{N_e(T_{e,t} - T'_{e,t})}, 0 \le U \le 1, T_{e,t} \ne T'_{e,t} \tag{14.3}$$

4. *Objectives of lean production: waste at least.* If production planning and organization of large discrete manufacturing system improper can often result in the phenomenon of "big car Mara" and high logistics cost, the product tardiness problem and other issues, which can cause a great waste. Lean production, zero defect, zero waste, JIT production are objectives of the modern enterprise in business to pursuit excellence. This paper minimize the ratio of sum of cost of using equipment and cost of transportation and total cost as one optimizing objective.

$$Z(V) = \min \sum_{i \in I} \sum_{j \in R} \frac{\sum\limits_{p \in K} \sum\limits_{e \in E} h_{ijp,e} t_{ijp,e} + \sum\limits_{p \in K} w_{ij,p,p-1} d_{ij,p,p-1}}{C_{ij}} \tag{14.4}$$

Integrated Optimizing Model

Integrated optimization problem of decision-making of production planning is a combinatorial optimization problem with characteristic of computational complexity, which need obtain the optimal solution from set of feasible solution of the problem of combination. This paper, weighting coefficients β_h are set according to degrees of importance that the multiple objective functions are to the systems. The optimization model was established as follow by using a weighted combination method:

$$\begin{aligned} Z &= \min \sum_{h \in H} \beta_h Z_h = \min\{-\beta_1 Z(Q) + \beta_2 Z(T) - \beta_3 Z(U) + \beta_4 Z(V)\} \\ &= \min \Bigg\{ -\beta_1 \sum_{i \in I} \sum_{j \in R} \frac{Q_{ije}}{Q_{ijc}} + \beta_2 \sum_{i \in I} \sum_{j \in R} \frac{t_{ij}}{t'_{ij}} - \beta_3 \sum_{i \in I} \sum_{j \in R} \sum_{e \in E} \frac{t_{ijp,t,e}.\alpha.o_{ij}.\delta}{N_e(T_{e,t} - T'_{e,t})} + \\ &\quad \beta_4 \sum_{i \in I} \sum_{j \in R} \frac{\sum\limits_{p \in K} \sum\limits_{e \in E} h_{ijp,e} t_{ijp,e} + \sum\limits_{p \in K} w_{ij,p,p-1} d_{ij,p,p-1}}{C_{ij}} \Bigg\} \end{aligned} \tag{14.5}$$

$$s.t. : \quad Q_{ije} \geq Q_{ijc}, \quad \forall Q_{ijc}, \quad Q_{ije} \in Q \geq 0 \tag{14.6}$$

$$t_{ij}(1 + \zeta) \leq t'_{ij}, \quad \forall t \in T, \quad T \geq 0, \quad 0 < \zeta < 1 \tag{14.7}$$

$$\sum_{i \in I} \sum_{j \in R} \sum_{e \in E} (t_{ijp,t,e} \alpha o_{ij}) \leq N_e(T_{e,t} - T'_{e,t}), \forall t \in T, e \in E \tag{14.8}$$

$$t_{k_{ijp}} \geq t_{k_{ijp-1}} \geq 0, \forall k_{ijp} \in K \tag{14.9}$$

$$0 \leq W_{ij} \leq \sum_{p \in K} W_{ijp} \tag{14.10}$$

$$0 \leq Z(V) \leq \theta < 1 \tag{14.11}$$

$$\sum \beta_h = 1 \tag{14.12}$$

$$T_{e,t} \neq T'_{e,t}, E \geq 0, N_e \geq 0, o_{ij} \geq 0, w_{p,p-1} \geq 0, d_{p,p-1} \geq 0$$

Formula (14.5) is the integrated optimization objective of decision-making of production planning of factory and job shop scheduling. Constraints (14.6) ensure quality of the product. Constraints (14.7) limit the delivery of each product, here ζ is liberalization ratio of random factors. Constraints (14.8) limit capacity of station with given amount time, considering the task which is being executed and that has been planned to implement. Constraints (14.9) limit the process. Constraints (14.10) limit the weight of parts. Constraints (14.11) is the cost control, supposing the waste of the production system no more than θ.

Solution of Model

In current related literatures, heuristic algorithm (Iskander 1997), genetic algorithm (GA) (Sortrakul et al. 2005), particle swarm optimization ant colony algorithm (Guo et al. 2009), hybrid evolutionary algorithm (Li et al. 2011) and augmented lagrange method (Shah et al. 2011; Nishi et al. 2007) are mainly used methods for solving global optimal solutions of combinatorial optimization problems of production planning. In this paper, general augmented lagrange relaxation method is adopted, which solve the solution by transforming the nonlinear inequality constrained optimization problem into the unconstrained minimum problem. Multiplier vector λ^T and parameter σ of penalty function are introduced, and then the general augmented lagrange function L hestenes-powell is constructed as follows:

$$L(x, \lambda, \sigma) = \min f(x) + \lambda^T g(x) + \sigma |g(x)|^2.$$

The Augmented Lagrange Relaxation

Augmented lagrangian relaxation is one of the most widely used methods presented for solving the complicated optimization problem, which decompose the combinatorial optimization problem into sub problems (Shah et al. 2011). The objective function (14.5) and constraint condition functions (14.6, 14.7, and 14.8) are converted to construct the augmented lagrange function as follows:

$$
\begin{aligned}
L(x,\lambda,\sigma) =\min\Bigg\{ & -\beta_1 \sum_{i\in I}\sum_{j\in R}\frac{Q_{ije}}{Q_{ijc}} + \beta_2 \sum_{i\in I}\sum_{j\in R}\frac{t_{ij}}{t'_{ij}} - \beta_3 \sum_{i\in I}\sum_{j\in R}\sum_{e\in E}\frac{t_{ijp,t,e}.\alpha.o_{ij}.\delta}{N_e(T_{e,t}-T'_{e,t})} \\
& +\beta_4 \sum_{i\in I}\sum_{j\in R}\frac{\sum_{p\in K}\sum_{e\in E} h_{ijp,e}t_{ijp,e} + \sum_{p\in K} w_{ij,p,p-1}d_{ij,p,p-1}}{C_{ij}}\Bigg\} + \sum_{i\in I}\sum_{j\in R}\lambda_1\left(\frac{Q_{ijc}-Q_{ije}}{Q_{ijc}}\right) \\
& + \sum_{i\in I}\sum_{j\in R}\lambda_2\left(\frac{(1+\zeta)t_{ij}-t'_{ij}}{t'_{ij}}\right) + \sum_{i\in I}\sum_{j\in R}\sum_{e\in E}\lambda_3\left(\frac{t_{ijp,t,e}.\alpha.o_{ij}-N_e(T_{e,t}-T'_{e,t})}{N_e(T_{e,t}-T'_{e,t})}\right) + \lambda_4(Z(V)-\theta) \\
& \sum_{i\in I}\sum_{j\in R}\sigma\left\{\left(\frac{Q_{ijc}-Q_{ije}}{Q_{ijc}}\right)^2 + \left(\frac{(1+\zeta)t_{ij}-t'_{ij}}{t'_{ij}}\right)^2 + \left(\frac{t_{ijp,t,e}.\alpha.o_{ij}.\delta-N_e(T_{e,t}-T'_{e,t})}{N_e(T_{e,t}-T'_{e,t})}\right)^2 + (Z(V)-\theta)^2\right\}
\end{aligned}
\tag{14.13}
$$

$$
s.t. \quad : \quad 0 \le W_{ij} \le \sum_{p\in K} W_{ijp}, \quad \sum \beta_h = 1
$$

$$
T_{e,t} > T'_{e,t}, E \ge 0, N_e \ge 0, o_{ij} \ge 0, w_{p,p-1} \ge 0, d_{p,p-1} \ge 0
$$

In order to simplify solving nonlinear problem, variables are set as follows:

$$
x_{ij,1} = \frac{Q_{ije}}{Q_{ijc}}, \quad x_{ij,2} = \frac{t_{ij}}{t'_{ij}}, \quad x_{ij,3} = \sum_{e\in E}\frac{t_{ijp,t,e}\cdot\alpha\cdot o_{ij}\cdot\delta}{N_e\left(T_{e,t}-T'_{e,t}\right)},
$$

$$
x_{ij,4} = \frac{\sum_{p\in K}\sum_{e\in E} h_{ijp,e}t_{ijp,e} + \sum_{p\in K} w_{ij,p,p-1}d_{ij,p,p-1}}{C_{ij}}
$$

Then formula (14.13) is converted to:

$$
\begin{aligned}
f(x,\lambda,\sigma) = \min & \sum_{i\in I}\sum_{j\in R}\left\{-\beta_1 x_{ij,1} + \beta_2 x_{ij,2} - \beta_3 x_{ij,3} + \beta_4 x_{ij,4}\right\} \\
& + \sum_{i\in I}\sum_{j\in R}\lambda_1\left(1-x_{ij,1}\right) + \sum_{i\in I}\sum_{j\in R}\lambda_2\left((1+\zeta)x_{ij,2}-1\right) \\
& + \sum_{i\in I}\sum_{j\in R}\lambda_3\left(x_{ij,3}-1\right) + \sum_{i\in I}\sum_{j\in R}\lambda_4\left(x_{ij,4}-\theta\right) \\
& + \sum_{i\in I}\sum_{j\in R}\sigma\left\{\left(x_{ij,1}-1\right)^2 + \left((1+\zeta)x_{ij,2}-1\right)^2 + \left(x_{ij,3}-1\right)^2 + \left(x_{ij,4}-\theta\right)^2\right\}
\end{aligned}
\tag{14.14}
$$

Combinatorial optimization objective $f(x,\lambda,\sigma)$ is decomposed into high-level production planning (the enterprise or the factory level) optimization $f_{pp}(x,\lambda,\sigma)$ and low-level job shop scheduling optimization $f_{sp}(x,\lambda,\sigma)$ as follows:

$$
f(x,\lambda,\sigma) = f_{pp}(x,\lambda,\sigma) + f_{sp}(x,\lambda,\sigma) \tag{14.15}
$$

$$s.t. \quad : \quad 0 \leq W_{ij} \leq \sum_{p \in K} W_{ijp}, \quad \sum \beta_h = 1$$

$$T_{e,t} > T'_{e,t}, E \geq 0, N_e \geq 0, o_{ij} \geq 0, w_{p,p-1} \geq 0, d_{p,p-1} \geq 0$$

Among them,

$$\begin{aligned} f_{pp}(x, \lambda, \sigma) = & \sum_{i \in I} \sum_{j \in R} \left\{ -\beta_1 x_{ij,1} + \beta_2 x_{ij,2} - \beta_3 x_{ij,3} + \beta_4 x_{ij,4} \right\} \\ & + \sum_{i \in I} \sum_{j \in R} \lambda_1 \left(1 - x_{ij,1}\right) + \sum_{i \in I} \sum_{j \in R} \lambda_2 \left((1+\zeta) x_{ij,2} - 1\right) \\ & + \sum_{i \in I} \sum_{j \in R} \lambda_3 \left(x_{ij,3} - 1\right) \\ & + \sum_{i \in I} \sum_{j \in R} \sigma \left\{ \left(x_{ij,1} - 1\right)^2 + \left((1+\zeta) x_{ij,2} - 1\right)^2 + \left(x_{ij,3} - 1\right)^2 \right\} \end{aligned} \tag{14.16}$$

$$\begin{aligned} f_{sp}(x, \lambda, \sigma) = \min & \sum_{i \in I} \sum_{j \in R} \beta_4 x_{ij,4} + \sum_{i \in I} \sum_{j \in R} \lambda_4 \left(x_{ij,4} - \theta\right) \\ & + \sum_{i \in I} \sum_{j \in R} \sigma \left(x_{ij,4} - \theta\right)^2 \end{aligned} \tag{14.17}$$

Algorithm Design

On nonlinear constrained optimization problem, these have a better global convergence of the algorithm are heuristic algorithm, multiplier penalty function method and sequential quadratic programming method, and so on.

In view of complexity of the research object, it will not obtain the global optimal solution on the basis of single algorithm, according to the practical operation experience of production system, a hybrid algorithm based on rule was designed in this paper which combined the multiplier penalty function method, heuristic algorithm and computer information system. The algorithm design is shown in Fig. 14.2. The iterative rule and basic step are as follows:

Step 1: Select initial point $x^{(1)}$, $\lambda^{(1)}$. $\varepsilon \geq 0$ is expected to small enough. Set $k = 1$.

Step 2: Make $x^{(k)}$ as a initial point to solve the unconstrained problem $f_{pp}(x^{(k)}, \lambda, \sigma)$ and $f_{pp}(x^{(k)}, \lambda, \sigma)$, then obtain: $f(x^{(k)}, \lambda, \sigma)$, $g\left(x^{(k)}\right) = \left[\left(x^{\mathrm{k}}_{ij,\,1} - 1\right), \left(x^{\mathrm{k}}_{ij,\,2} - 1\right),\right.$

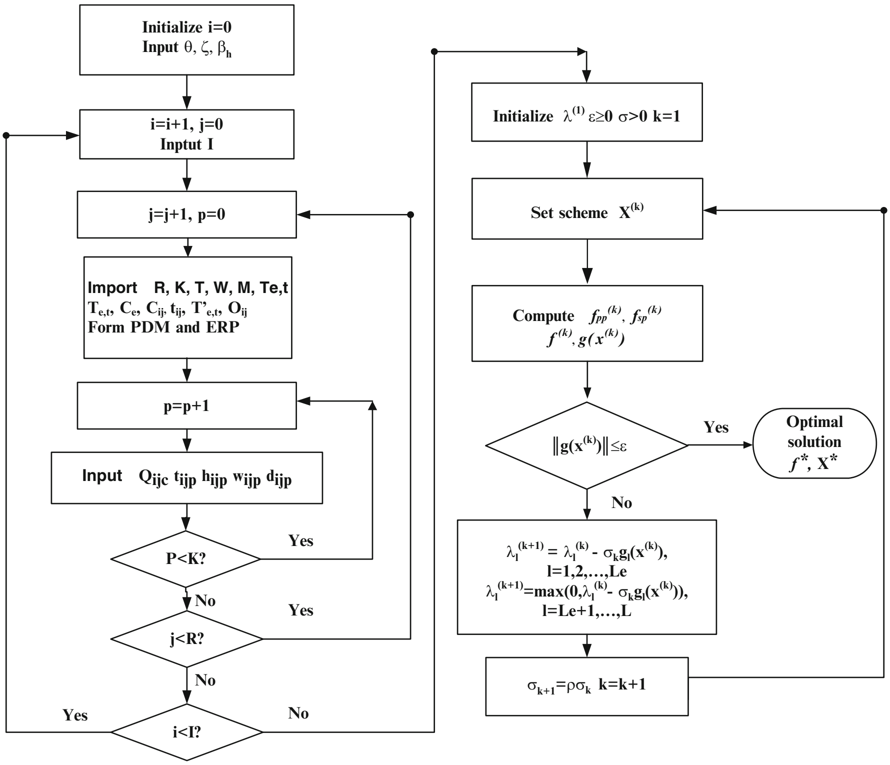


Fig. 14.2 Production planning integration hybrid algorithm

$\left(x^{\mathrm{k}}_{ij,\,3} - 1\right), \left(x^{\mathrm{k}}_{ij,\,4} - 1\right)\Big]^T$, if $\|g(x^{(k)})\| \leq \varepsilon$, then stop and get the optimization solution $f^* = f(x^{(k)}, \lambda, \sigma)$, otherwise, then turn to the next step.

Step3: Compute $\lambda_l{}^{(k+1)} = \lambda_l{}^{(k)} - \sigma_k g_l(x^{(k)}), l = 1, 2, \ldots, L_e$, $\lambda_l{}^{(k+1)} = \max(0, \lambda_l{}^{(k)} - \sigma_k g_l(x^{(k)})), l = L_e + 1, \ldots, L$,

Make $\sigma_{k+1} = \rho\sigma_k, k = k + 1$, here ρ is integer, then turn to step 2.

Conclusion

Production planning is the core task of enterprise production management, which directly related to competition factors such as quality of the product, delivery and cost. In this paper, the large and complex discrete manufacturing system was taken as research object, and some actual survey analysis of the system was also carried out, production planning decision process of whose was combed. Considering the customer satisfaction (quality and delivery) and business efficiency (output and lean production) and other optimization objectives, an integrated optimization model with multiple projects in different parts, process, multi-objective, constraint, random uncertainty and other system characteristics was established by using weighted combination optimization method. Finally, augmented lagrangian relaxation method was adopted in order to effectively solve the nonlinear inequality constrained optimization problems, which is the most widely used method to solve the complex large scale optimization problems, augmented lagrange function was constructed. According to the practical operation experience and heuristic algorithm, a rule based hybrid algorithm was designed. This paper provided a theoretical method to solve the problem of integrated optimization of multilevel production planning. Due to limited space, example validations of the effectiveness of the model and algorithm will do further research in the follow-up article.

References

Argoneto P, Perrone G, Renna P (2008) Production planning in production networks: models for medium and short-term planning [M]. Springer, London

Cai Y, Kutanoglu E, Hasenbein J (2011) Production planning and scheduling: interaction and coordination, in planning production and inventories in the extended enterprise [M]. Springer, London

Gang LCR (2009) A strategy for the integration of production planning and scheduling in refineries under uncertainty [J]. Chin J Chem Eng 17(1):113–127

Guo YW, Li WD, Mileham AR, Owen GW (2009) Applications of particle swarm optimisation in integrated process planning and scheduling [J]. Robot Comput Integr Manuf 25(2):280–288

Iskander SPW (1997) A survey of scheduling rules. Oper Res 25(1):45–61

Kempf KG et al (2011) Planning production and inventories in the extended enterprise: a state of the art handbook [M], International series in operations research and management science 151. Springer, New York/Dordrecht/Heidelberg/London

Kis T, Kovacs A (2012) A cutting plane approach for integrated planning and scheduling [J]. Comput Oper Res 39(2):320–327

Li X, Gao L, Li W (2011) Application of game theory based hybrid algorithm for multi-objective integrated process planning and scheduling [J]. Expert Syst Appl 39(1):288–297

Li X, Gao L, Li W (2012) Application of game theory based hybrid algorithm for multi-objective integrated process planning and scheduling [J]. Expert Syst Appl 39(1):288–297

Luo Chunpeng, Rong Gang (2009) A Strategy for Integration of Production and Scheduling in Refineries under Uncertainty [J]. Chinese Journal of Chem Eng 17(1):13–12

Maravelias CT, Sung C (2009) Integration of production planning and scheduling: overview, challenges and opportunities [J]. Comput Chem Eng 33(12):1919–1930

Nishi T, Konishi M, Ago M (2007) A distributed decision making system for integrated optimization of production scheduling and distribution for aluminum production line [J]. Comput Chem Eng 31(10):1205–1221

Shah NK, Ierapetritou MG (2011) Integrated production planning and scheduling optimization of multisite, multiproduct process industry [J]. Comput Chem Eng 37:214–226

Sortrakul N, Nachtmann HL, Cassady CR (2005) Genetic algorithms for integrated preventive maintenance planning and production scheduling for a single machine [J]. Comput Ind 56(2):161–168

Stadtler H (2005) Supply chain management and advanced planning—basics, overview and challenges [J]. Eur J Op Res 163:563–575

Sugimura N, Hino R, Moriwaki T (2001) Integrated process planning and scheduling in Holonic manufacturing systems [C]. In: Proceedings of IEEE international symposium on assembly and task planning, Soft Research Park

Chapter 15
A Modified Simulated Annealing Algorithm for Optimal Capacity Allocation in Make-to-Order Job-Shops

Liang Huang

Abstract This paper presents a new capacity allocation method to support decisions in the design or redesign of a make-to-order job-shop with stochastic orders and processing times. The solutions for capacity allocation can be adding/ removing machines or work shifts at every work stations. A bi-criteria objective function comprising fixed costs and tardiness penalty is used to evaluate each solution. A simulation model is applied to compute the objective function iteratively in a modified simulated annealing procedure until a feasible and profitable solution is generated. Bottleneck analysis is used as guidance for the neighborhood-generation in the modified simulated annealing procedure in order to accelerate convergence. Consequently, the run time of the procedure is short enough for practical use. Different problems were tested. Solutions from the proposed method were compared to those from the classical simulated annealing and the comparison showed relatively positive results.

Keywords Job-shop • Make-to-order • Capacity allocation • Bottleneck analysis • Simulated annealing

Introduction

Many studies focused on the production scheduling to minimize the tardiness of jobs in a make-to-order job-shop. In these studies, it is generally assumed that the capacity at each work station is determined. However, in practice, it is often needs to be changed dynamically by making use of the numerical or empirical outcomes from production scheduling. For example, when too much tardiness of jobs

L. Huang (✉)
School of Control Engineering, Northeastern University at Qinhuangdao, Qinhuangdao, People's Republic of China
e-mail: huangliang797@yahoo.com.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_15,

repeatedly occur after proper production scheduling, it is necessary to allocate or reallocate capacities at relevant work stations in order to reduce the tardiness in future production (Yeh 1997; Fry and Russell 1993). This paper will address optimal planning for capacity allocation to support medium to long term (several months to years) decisions under a given production scheduling method in a make-to-order job-shop with stochastic orders and processing times.

For capacity allocation, most problems need to allocate multiple work stations' capacity simultaneously. These are complex combinational optimization problems. Arakawa et al. (2000, 2003) presented a simulation model for job-shop scheduling incorporating capacity adjustment. In their study, a backward/forward hybrid simulation method is used for production scheduling at the first step; and based on the result of scheduling, a pattern search method is used to adjust capacity at the second step. Yang et al. (2005) used the particle swarm optimization (PSO) algorithm for integration of process planning and production scheduling in a job-shop. Some studies use simulation models as well as meta-heuristics algorithms in the design of the manufacturing systems similar to job-shops. Seshadri and Pinedo (1999) presented a framework consist of an optimization model and a simulation model to adjust the capacity for assembly and applied an iterative algorithm using CPLEX 10.2 to deal with the optimization. Shahabudee and Krishnaiah (1999) set the parameters of a multi-product Kanban system using genetic algorithm (GA); the parameters include the number of machines at each work station. In another study of Shahabudeen et al. (2003), they set similar parameters of a multi-product Kanban system using simulated annealing (SA). In all these studies, meta-heuristics algorithms usually use neighborhood search to reach the optimum solution from an initial solution. Coupled with simulation models, many alternatives were examined by simulation in the search procedure. For this reason, they often consume too much time in solving large-scale problems.

In this paper, bottleneck analysis is used as approximate discrete gradients of the objective function of the weighted tardiness. A modified simulated annealing is also presented, in which the neighborhood-generation is guided by the gradients in order to accelerate convergence and reduce the run time of the neighborhood search procedure. Our aim is to make the run time short enough for practical use, even if simulation is performed many times in the search procedure.

Optimization Model

In this study, the alternatives for capacity allocation can be adding/removing machines or work shifts. The available operation hours in regular time, such as working 8 h at daytime, is defined as the capacity of a machine. For example, at a work station, five machines can be allocated at most under the plant space availability. In this way, various numbers of machines can provide five discrete alternatives for capacity allocation from 8 to 40 h per day at the work station.

Array these alternatives according to their capacity from low to high. The alternatives can be denoted by the integral values from 1 to 5.

Therefore, it is assumed that in a general job-shop that consists of m work stations, a linear array $s = [c_1\ c_2\ \ldots\ c_m]$ is the solution vector of the optimization model, where c_j is the alternative number of the capacity level at work station j, for $j = 1, 2, \ldots, m$. Then, the feasible region of s is a set of discrete vectors, denoted as S.

For make-to-order production, weighted tardiness is a general performance measure of job-shops. In this study, one of the purposes of capacity allocation is to fulfill the due dates of all jobs as much as possible. Suppose n jobs belong to p product classes will be manufactured in an m work stations job-shop within a q-months period, we can formulate the first object function to measure the performance of the job-shop in the q-months planning period as follow

$$z^{\mathrm{T}}(s) = \sum_{l=1}^{p} w_l^{\mathrm{TP}} \sum_{i \in I_l} n_i^{\mathrm{LS}} \max\left(x_i^{\mathrm{C}}(s) - x_i^{\mathrm{D}}, 0\right), \tag{15.1}$$

where w_l^{TP} is the weight on tardiness penalty per unit product and per unit time of class l, I_l is sets of i when job i belongs to class l, n_i^{LS} is the lot size of job i, $x_i^{\mathrm{C}}(s)$ is the completion time of job i in solution s, and x_i^{D} is the due date of job i. In the capacity allocation tool, each w_l^{TP} is assumed to be a fixed value in the q-months planning period, estimated by the production manager using historical data or practical experience. n_i^{LS}, $x_i^{\mathrm{C}}(s)$ and x_i^{D} are generated by the simulation model.

Another purpose of capacity allocation is to reduce the fixed cost, which mainly consists of the depreciation of machines and the fixed salary of operators in this study. The mean monetary values of the depreciation per month and per machine w_j^{M} at each work station j were provided by the production manager according to the cost accounting of the workshop. Supposing these values in the q-months planning period will be similar to their historical values, we estimated the fixed cost per month of the job-shop for all solutions s according to the number of machines $n_j^{\mathrm{M}}(s)$. Then, the second objective function is

$$z^{\mathrm{C}}(s) = q \sum_{j=1}^{m} w_j^{\mathrm{M}} n_j^{\mathrm{M}}(s). \tag{15.2}$$

The two objective functions are both considered in this study to get a feasible and profitable solution for a practical use. Hence, the optimization model with a bi-criteria objective function is

$$\min z^{\mathrm{T}}(s) + z^{\mathrm{C}}(s) \tag{15.3}$$

$$\text{subject to}: s \in S. \tag{15.4}$$

Gradient-Based Simulated Annealing

Kirkpatrick et al. (1983) firstly presented SA in 1983. In its neighborhood search, SA accepts inferior solutions according to a probability in order to bypass local optimums. Thus, in this study, we couple the gradient-based method with SA and present a hybrid method named GBSA to optimizing capacity allocation. The GBSA has not only the capability of avoiding local minima, but also a higher speed of convergence to approach stationary compared to the traditional SA.

Step 1: Input the control parameters of the GBSA: Initial Temperature T_{i}, Termination Temperature T_{f}, Cooling Rate α, Freeze Limit Φ, and Accept Limit β. Take T_{i} as current temperature T. Generate initial solution s_0. A simulation is performed to compute the object function value z_0 in solution s_0. In this study, the initial solution s_0 was set to be 1.2 times (an empirical value from the practical case) of the mean capacity requirement per day in the tested cases.

Step 2: Detect the bottlenecks in the job-shop. To detect and measure the shifting bottlenecks in a job-shop, a statistical method called the active period method has been presented by Roser et al. (2002). They proposed that at any given time the momentary bottleneck is the machine with the longest uninterrupted active period at this time and in any given period of time the average bottlenecks can be measured by the percentage of the time that a work station. Although this method is not an exact one, it is very robust, easy to apply and has the ability to detect the bottlenecks in steady state systems or non-steady state systems.

Step 3: Suppose there are n_{s} solutions neighbor to the current solution s_0 in the feasible region N^{+}. They are denoted as h_k ($k = 1, 2, \ldots, n_{\mathrm{s}}$). In this step, "neighbor to" means only one element is +1 or -1. If the neighborhood h_k is a solution to add machines to work station j, let $p_k = b_j$; otherwise, let $p_k = -b_j$. Denote the minimum in p_k as $p_{\min}$. We select a new solution s_1 from the neighborhoods of s_0 according to a probability shown as follows:

$$\mathrm{P}(s_1 = h_k) = \frac{(p_k - p_{\min})^{\gamma}}{\sum_{k=1}^{n_{\mathrm{s}}} (p_k - p_{\min})^{\gamma}}. \tag{15.5}$$

Therefore, the neighbor of a better estimated objective-function value has a higher probability to be chosen in order to accelerate convergence. Parameter γ in (15.5) is used to adjust the influence of the bottleneck analysis in the search procedure. Based on pilot experiments, we observe that when the objective-function value has a large improvement in the previous iteration indicating that the guidance of the gradient works well at this stage of the search procedure, γ should be set to a larger value to make full use of the guidance of the gradient, or else γ should be set to a smaller value to have a better chance to move from one local minimum area to another one. For this consideration, in this study γ is set to 1 at the beginning of the search procedure and will be adjusted at each iteration as stated in Step 4.

Step 4: Calculate the objective function value z_1 in the new solution s_1 through a simulation. Let $\Delta z = z_1 - z_0$. If $\Delta z < 0$, the current solution s_0 will be replaced by the new solution s_1; otherwise, apply a probability $\mathrm{P(A)} = \mathrm{e}^{-\Delta z/T}$ to determine whether the replication should be performed. Set $\gamma = |\Delta z|/(|\Delta z|)_{\max}$, where $(|\Delta z|)_{\max}$ is the maximum among all the $|\Delta z|$ values in the past iterations.

Step 5: The current temperature T is adjusted after every Φ iterations according to α. If it's below T_{f} or the solution has not been improved for too many consecutive iterations to overstep β, stop the search produce; otherwise, go to Step 2.

Step 6: Report s_0 and z_0 as the final solution and its objective function value, respectively.

In the proposed GBSA, the neighborhood-generation is not a random produce like that in the traditional SA, but controlled by the results of the bottleneck analysis. And γ will be changed at each iteration according to the improvement of the objective-function value. These modifications speed up the search for a better solution in the area with the most potential while still allows the search to move away from a local area to another. Thus, the neighborhood search may stop earlier as controlled by β and the computing time is reduced.

Computational Experiments

In this paper, three case studies are tested using our proposed GBSA. Case 1 consists of 3 types of orders and 5 work stations, Case 2 consists of 5 types of orders and 10 work stations, and Case 3 consists of 15 types of orders and 30 work stations, respectively. In this paper, only the data of Case 1 to be given in detail for the space constraints.

In Case 1, there are 3–10 machines at each of the five work stations. The scheduling method used in this workshop is a dispatching rule, earliest due date with the tie broken by first come first service (EDD/FCFS), for it is very easy to be applied in a dynamic job-shop with stochastic demand and processing times. Within a work station, the scheduling is complex in this workshop. For we have not enough detailed records about it, according to the production manager's suggestion, we make an assumption that a task can always make full use of the capacity within a work station and the processing time of the tasks processed at the work station will decrease/increase linearly with adding/removing capacity to the work station.

In the simulation model, inter arrival times of the orders and processing times of the tasks are generated in exponential distributions; constraints of lead times, tardiness penalties per hour and depreciation of machines are set to be fixed values. These data is shown in Tables 15.1 and 15.2.

The simulation software was developed in Microsoft SQL2000. In all the cases, the simulation for any given solution was performed in the duration of 25,000 h. The simulations were all performed in a personal Pentium IV computer with 2.4G

Table 15.1 Demand requirements and tardiness penalties in Case 1

Product type	Mean inter arrival time of orders (hour)	Constraints of lead time (hour)	Tardiness penalty (RMB/hour)
1	40	50	20
2	60	60	15
3	80	70	10

Table 15.2 Processing times and depreciation of machines in Case 1

Product type	Work station	Mean processing time (hour)	Depreciation of machines (1,000 RMB)
1	1	2.25	20
	2	2.00	20
	3	2.50	10
2	1	1.25	7.5
	2	1.25	7.5
	3	2.00	15
3	1	1.75	10
	2	1.25	7.5
	3	2.25	10

Table 15.3 Control parameters

		Control parameter values				
	Type	T_i	T_f	α	Φ	β
A1	GBSA	1	0.1	0.9	10	20
A2	GBSA	1	0.3	0.7	5	10
A3	Traditional SA	1	0.1	0.9	10	20
A4	Traditional SA	1	0.3	0.7	5	10

Table 15.4 Results of the computational experiments

	Objective function value (1,000 RMB)			Run time (minute)		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
A1	1,053	1,794	4,250	9.64	14.59	42.37
A2	1,053	1,794	4,287	6.13	12.95	37.08
A3	1,053	1,826	4,420	38.31	76.45	225.54
A4	1,053	1,815	4,587	31.66	52.21	89.40

CPU and 1G memory. The mean simulation time of each simulation (including the time for bottleneck analysis) is 35 s in Case 1.

According to the pilot runs, two groups of control parameters are used to both traditional SA and GBSA. Therefore, there are four kinds of algorithm with different control parameter values or different neighborhood-generation methods applied to Case 1, 2, and 3, which is denoted as A1, A2, A3, and A4. Their control parameter values are shown in Table 15.3. The results of the three cases are shown in Table 15.4.

Conclusions

In this paper, a modified SA, named GBSA, is used as an optimization tool to optimize capacity allocation in make-to-order job-shops. Although the optimums of all the algorithms equip to each other in Case 1, the proposed GBSA used noticeably smaller computing time than the traditional SA. Moreover, with less computing time, GBSA found better solutions in Case 2 and 3 compared to the traditional SA. These results show that the proposed method can often finds better solutions with a shorter computation time compared to the traditional method. These optimal solutions for capacity allocation can be very useful to support decisions in performing tradeoffs between the tardiness penalty and the cost of capacity allocation.

References

Arakawa M, Fuyuki M, Nakanishi H, Inoue I (2000) A simulation-based capacity adjustment method for job shop production scheduling. In: Proceedings of the third Asia-Pacific Conference on Industrial Engineering and Management Systems (APIEMS'2000), Hong Kong, China, pp 84–90

Arakawa M, Fuyuki M, Nakanishi H (2003) An optimization-oriented method for simulation-based job shop scheduling incorporating capacity adjustment function. Int J Prod Econ 85 (3):359–369

Fry TD, Russell GR (1993) Capacity allocation strategies in a hypothetical job-shop. Int J Prod Res 31(5):1097–1115

Kirkpatrick S, Gelatt CD Jr, Vecchi MP (1983) Optimization by simulated annealing. Science 13:671–680

Roser C, Nakano M, Tanaka M (2002) Shifting bottleneck detection. In: Proceedings of the 2002 winter simulation conference, New York, USA, pp 1079–1086

Seshadri S, Pinedo M (1999) Optimal allocation of resources in a job shop environment. IIE Trans 31(3):195–206

Shahabudee P, Krishnaiah K (1999) Design of a bi-criteria kanban system using genetic algorithm. Int J Manag Syst 15(3):257–274

Shahabudeen P, Krishnaiah K, Thulasi Narayanan M (2003) Design of a two-card dynamic kanban system using a simulated annealing algorithm. Int J Manag Syst 21(10–11):754–759

Yang YH, Zhao FQ, Hong Y, Yu DM (2005) Integration of process planning and production scheduling with particle swarm optimization (PSO) algorithm and fuzzy inference systems. In: Proceedings of the ICMIT 2005: control systems and robotics, Chongqing, China, pp 2292–2297

Yeh CH (1997) Schedule based production. Int J Prod Econ 51(3):235–242

Chapter 16
An Optimal Product Mix Decision Model Considering Unit-Batch-Product Level Cost for Steel Plant

Hu-sheng Lu and Guo-qiang Lv

Abstract In recent years, the iron and steel industry's operation condition has been continuously worsening, profitability reducing, thus the product mix decision (PMD) for the iron and steel enterprises became research focus to reduce manufacturing costs and maximize profits. Taking into account unit-level, batch-level and product-level cost, an integrated model conducting product mix decision for steelmaking, continuous casting and hot rolling (SM-CC-HR) process was proposed in this paper. A numerical example was presented to illustrate data input, solution method and result analysis. By comparing the model with two traditional ones, it was showed that the model attained higher profit and smoother implementation, because it traced the cost appropriately and effectively reduced the volume of left slabs in manufacturing processes and that of left steel products after order-delivery.

Keywords Activity-based costing (ABC) • Iron and steel enterprises • Product mix decision model

Introduction

With the increasingly fierce market competition and severe management environment and production process transformation, only by well coordinating product mix can iron and steel enterprises achieve high profit and low cost in current conditions. Whereas the product mix problem is to maximize profit from the mix of manufactured products subject to constraints on the available capacity of resources. Kee and Robert provided a numerical example that integrated activity-based

H.-s. Lu (✉) • G.-q. Lv
School of Economics and Management, Inner Mongolia University of Science and Technology, Baotou, China
e-mail: hushenglu@sina.com; aylvgq@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_16,

costing (ABC) with the theory of constraints (TOC) to illustrate the economic consequences of the production-related decisions. ABC and TOC represented alternative paradigms to traditional cost-based accounting systems. Both paradigms were designed to overcome limitations of traditional cost-based systems (Kee 1995). Later, Kee and Schmidt developed a more general product mix decision model that overcame the stringent requirements of the TOC and ABC and demonstrated that TOC and ABC were special cases of their model (Kee and Schmidt 2000).

On the basis of these studies, there was much work in the literature about deciding which paradigm to select for production-related decisions. Baykasoglu developed a new approach based on digraph theory and matrix algebra to quantify flexibility (Baykasoglu 2009). Balakrishnan and Chun-hung CHENG proved that LP was a useful tool in the TOC analysis by re-examining TOC and linear programming (LP) (Balakrishnan and Chun-hung Cheng 2000). Tsaia and Hung integrated ABC and performance evaluation and established the green supply chain (GSC) model which not only helped decision makers to monitor GSC comprehensive performance but also could facilitate further improvement and development of GSC management (Tsaia and Shih-Jieh Hung 2009). Weeks, Gao, Alidaeec and Rana studied the impact of two reverse logistics business strategies on profitability of the firm through operations management (OM) (Weeks et al. 2010). Souren, Ahn and Schmitz analyzed several examples, which showed that the TOC-based approach may be used within a wide range of product mix decisions and could lead, sometimes with some slight modifications, to optimal or at least acceptable solutions (Souren et al. 2005). Leaa, Fredendallb tested three alternative product-costing systems in a more realistic model of the manufacturing environment than had been used in prior tests (Bih-Ru Leaa and Fredendallb 2002). Karakas, Koyuncu, Erol and Kokangul presented a fuzzy programming for product mix selection in the light of obscure estimation of parameters for the capacities of the activities and the demands of each product (Karakas et al. 2010). Bhattacharya and Vasant used fully fuzzified-LP model to guide decision makers in finding out the optimal product mix with the higher degree of satisfaction with the lesser degree of fuzziness under tripartite fuzzy environment (Bhattacharya and Vasant 2007). Tsaia, Kuob, Linc, Kuod and Shena developed an enhanced general model that incorporated all four factors: capacity constraint, management's degree of control over resources, capacity expansions, and purchase discount to determine the optimal product mix (Wen-Hsien Tsaia et al. 2010). Hu-sheng LU, Sen WU, Bing LIU and Zhen-gang LIU developed a maximum profit flow algorithm for optimizing production planning of steel works (Hu-sheng Lu et al. 2004). Li-xin TANG reviewed the theories and methods of the planning and scheduling on the basis of the stimulation in iron and steel industry (Li-xin Tang 2005). Ren-qian ZHANG and Yi-yong XIAO built a distributed production decision model based on activity processes and the bill of materials (BOM). A heuristic algorithm was proposed to solve the model, which was based on particle swarm optimizer (PSO) (Ren-qian Zhang and Yi-yong Xiao 2007). Bo-xiong LAN, Nan JIANG and Yan ZHENG

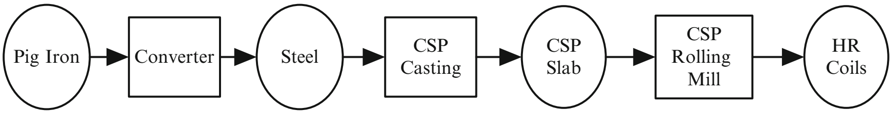


Fig. 16.1 Flow chart of CSP process

developed a heuristic lot-sizing algorithm for large scale lot-sizing problem to optimize enterprise resources (Bo-xiong Lan et al. 2010).

In this paper, the ideas of Kee (1995) and Kee and Schmidt (2000) were integrated and a more integrated model was developed which had taken into account unit-level, batch-level and product-level cost. In addition, this study also considered three-stage global optimization of steelmaking, continuous casting and hot rolling (SM-CC-HR) to help decision makers to find an optimal product mix solution.

To better understand the process, a flow chart is listed as follows:

In Fig. 16.1, circle stands for material; box stands for machine. Between two circles, there are arrows to represent the transition route.

Model Formulation

To model the product mix decision, the following notation will be used:

1. i, m, n, z represent steel product, slab, steel and pig iron index respectively.
2. j_1, j_2, j_3 represent the resource index in HR, CC and SM process respectively.
3. k_1, k_2, k_3 represent the machine index in HR, CC and SM process respectively.
4. r_1, r_2, r_3 represent the transition route index in HR, CC and SM process respectively.
5. P_i: price of product i.
6. D_i: market demand for product i.
7. $X1_i$, $Y1_m$, $Z1_n$, Z0 represent volume of steel product i, slab m, steel n and pig iron produced.
8. UC_{Z0}: unit cost of pig iron.
9. UC_{j1}, UC_{j2}, UC_{j3} represent unit cost of resources in HR, CC and SM process respectively.
10. N_{j1}, N_{j2}, N_{j3} represent quantity of resources can be obtained in HR, CC and SM process respectively.
11. N_{j1}^*, N_{j2}^*, N_{j3}^* represent consumption of resources in HR, CC and SM process respectively.
12. UC_{k1}, UC_{k2}, UC_{k3} represent unit cost of rolling mill, casting machine and converter hours respectively.
13. N_{k1}^*, N_{k2}^*, N_{k3}^* represent consumption of rolling mill, casting machine and converter hours respectively.

14. Qx1, Px1, Qx2, Px2, Qx3, Px3; Qy1, Py1, Qy2, Py2, Qy3, Py3; Qz1, Pz1, Qz2, Pz2, Qz3, Pz3 represent the amounts of resources and hours used to produce a unit of steel product/slab/steel, a batch of steel products/slabs/steels and a kind of steel product/slab/steel respectively.
15. $\rho_{A1}, \rho_{B1}, \rho_{C1}$ represent the volume of transition in HR, CC and SM process respectively.
16. $\rho_{A2}, \rho_{B2}, \rho_{C2}$ represent the number of transition batches in HR, CC and SM process respectively.
17. $\rho_{A3}, \rho_{B3}, \rho_{C3}$ determine if transition in HR, CC and SM process is taken place respectively.
18. AvgX, AvgY, AvgZ represent the average batch sizes in HR, CC and SM process respectively.
19. η_m,η_n,η represent yield in HR, CC and SM process respectively.

The process of selecting an optimal product mix may be expressed as:

Maximized profit = Total revenue-Total costs of pig iron-Total costs of resources and machine hours in SM-CC-HR process- Total fixed costs in SM-CC-HR process.

$$\begin{aligned} Maximized \quad profit = & \sum_i (P_i * X1_i) - \sum_{z0} (UC_{Z0} * Z0) \\ & - \sum_{j_1} (UC_{j_1} * N^*_{j_1}) - \sum_{j_2} (UC_{j_2} * N^*_{j_2}) - \sum_{j_3} (UC_{j_3} * N^*_{j_3}) \\ & - \sum_{k_1} (UC_{k_1} * N^*_{k_1}) - \sum_{k_2} (UC_{k_2} * N^*_{k_2}) - \sum_{k_3} (UC_{k_3} * N^*_{k_3}) - C \end{aligned} \tag{16.1}$$

Subject to

Constraints in Hot Rolling Process

Resources constraints:

$$\begin{aligned} & \sum_{r_1} [(Qx1)_{r_1,j_1} * (\rho_{A1})_{r_1} + (Qx2)_{r_1,j_1} * (\rho_{A2})_{r_1} \\ & \quad + (Qx3)_{r_1,j_1} * (\rho_{A3})_{r_1}] - N^*_{j_1} = 0 \qquad \forall j_1 \end{aligned} \tag{16.2}$$

$$N^*_{j_1} \le N_{j_1} \qquad \forall j_1 \tag{16.3}$$

Transition level constraints:

$$(\rho_{A1})_{r_1} - AvgX_{r_1} * (\rho_{A2})_{r_1} \le 0 \qquad \forall r_1 \tag{16.4}$$

$$(\rho_{A2})_{r_1} - M\,^{*}(\rho_{A3})_{r_1} \leq 0 \qquad \forall r_1 \tag{16.5}$$

Sales constraint:

$$X1_i \leq D_{\mathrm{i}} \qquad \forall i \tag{16.6}$$

Machine Constraints:

$$\sum_{r_1} [(Px1)_{r_1,k_1} * (\rho_{A1})_{r_1} + (Px2)_{r_1,k_1} * (\rho_{A2})_{r_1} + (Px3)_{r_1,k_1} * (\rho_{A3})_{r_1}] - N^*_{k_1} = 0 \qquad \forall k_1 \tag{16.7}$$

$$N^*_{k_1} \leq N_{k_1} \qquad \forall k_1 \tag{16.8}$$

Constraints in Continuous Casting Process

Resources constraints:

$$\sum_{r_2} [(Qy1)_{r_2,j_2} * (\rho_{B1})_{r_2} + (Qy2)_{r_2,j_2} * (\rho_{B2})_{r_2} + (Qy3)_{r_2,j_2} * (\rho_{B3})_{r_2}] - N^*_{j_2} = 0 \qquad \forall j_2 \tag{16.9}$$

$$N^*_{j2} \leq N_{j2} \qquad \forall j2 \tag{16.10}$$

Transition level constraints:

$$(\rho_{B1})_{r_2} - AvgY_{r_2} * (\rho_{B2})_{r_2} \leq 0 \qquad \forall r_2 \tag{16.11}$$

$$(\rho_{B2})_{r_2} - M * (\rho_{B3})_{r_2} \leq 0 \qquad \forall r_2 \tag{16.12}$$

Machine constraints:

$$\sum_{r_2} [(Py1)_{r_2,k_2} * (\rho_{B1})_{r_2} + (Py2)_{r_2,k_2} * (\rho_{B2})_{r_2} + (Py3)_{r_2,k_2} * (\rho_{B3})_{r_2}] - N^*_{k_2} = 0 \qquad \forall k_2 \tag{16.13}$$

$$N^*_{k_2} \leq N_{k_2} \qquad \forall k_2 \tag{16.14}$$

Constraints in Steelmaking Process

Resources constraints:

$$\sum_{r_3} [(Qz1)_{r_3,j_3} * (\rho_{C1})_{r_3} + (Qz2)_{r_3,j_3} * (\rho_{C2})_{r_3} + (Qz3)_{r_3,j_3} * (\rho_{C3})_{r_3}] - N^*_{j_3} = 0 \qquad \forall j_3 \tag{16.15}$$

$$N^*_{j_3} \le N_{j_3} \qquad \forall j_3 \tag{16.16}$$

Transition level constraints:

$$(\rho_{C1})_{r_3} - AvgZ_{r_3} * (\rho_{C2})_{r_3} \le 0 \qquad \forall r_3 \tag{16.17}$$

$$(\rho_{C2})_{r_3} - M * (\rho_{C3})_{r_3} \le 0 \qquad \forall r_3 \tag{16.18}$$

Machine constraints:

$$\sum_{r_3} [(Pz1)_{r_3,k_3} * (\rho_{C1})_{r_3} + (Pz2)_{r_3,k_3} * (\rho_{C2})_{r_3} + (Pz3)_{r_3,k_3} * (\rho_{C3})_{r_3}] - N^*_{k_3} = 0 \qquad \forall k_3 \tag{16.19}$$

$$N^*_{k_3} \le N_{k_3} \qquad \forall k_3 \tag{16.20}$$

Mass Balance Constraints

Output constraints:

$$X1_i = \sum_{r_1} \rho_{A1} \qquad \forall i \tag{16.21}$$

$$Y1_m = \sum_{r_2} \rho_{B1} \qquad \forall m \tag{16.22}$$

$$Z1_n = \sum_{r_3} \rho_{C1} \qquad \forall n \tag{16.23}$$

Consumption constraints:

$$Y1_m \geq \sum_{r_1} \rho_{A1}/\eta_m \qquad \forall m \tag{16.24}$$

$$Z1_n \geq \sum_{r_2} \rho_{B1}/\eta_n \qquad \forall n \tag{16.25}$$

$$Z0 \geq \sum_{r_3} \rho_{C1}/\eta \tag{16.26}$$

Pig Iron's Upper Bound

$$Z0 \leq L \tag{16.27}$$

Where:

$\rho_{A2}, \rho_{B2}, \rho_{C2}$ are integer variables.
$\rho_{A3}, \rho_{B3}, \rho_{C3}$ are binary variables.

M stands for a very big number. L stands for the upper bound of pig iron. C stands for the facility-level cost (fixed cost). All variables are greater than or equal to zero.

A Numerical Example

This paper adopts the actual production data of B Iron and Steel enterprise in March 2012 to test and analyze the performance of the above model. Time horizon is 1 month. The data of this example are described as follows.

The CSP rolling mill produces nine products (Hot rolling coils), using six kinds of slabs and three kinds of steels. Table 16.1 shows the details of steel products' information and resources and machine hours' usage in the hot rolling process.

Based on the actual production data, the unit costs of pseudo-resource in SM, CC and HR are RMB 2.0, 1.7 and 1.5 respectively. Unit costs of machine hours in SM, CC and HR are RMB 0.8, 0.7 and 0.5 respectively. The average batch sizes in SM, CC and HR are 210, 5,250 and 26 t respectively.

In ABC models, the hierarchy of company activities is composed of the following categories: unit-level activities (performed one time for one unit of product or service, e.g., machining, finishing); batch-level activities (performed one time for a batch of products or services, e.g., setup, scheduling); product-level activities (performed to benefit all units of a particular product or service, e.g., product

Table 16.1 Steel products' information and resources and machine hours' usage in hot rolling process

ID	Material	Dimension	Price	Demand	Qx1	Qx2	Qx3	Px1	Px2	Px3
1	Q235AB,SS400	$\geq 2.5 < 4.0$	3623.93	18,124.25	68.401	444.606	2,171,882	0.055	1.417	0.000
2	Q235AB,SS400	<2.5	4209.40	2,028.180	82.572	536.715	238,682	0.050	1.417	0.000
3	Q235AB,SS400	≥ 12	4081.20	2,645.748	33.948	220.659	308,462	0.071	1.417	0.000
4	Q235AB,SS400	$\geq 4.0 < 12$	4038.46	100,115.6	48.310	314.016	11,741,076	0.063	1.417	0.000
5	Q345	$\geq 4.0 < 12$	4166.67	36,969.42	49.712	323.130	4,309,901	0.065	1.417	0.000
6	Q345	≥ 12	4252.14	1,154.316	39.904	259.378	134,003	0.071	1.417	0.000
7	Q345	$\geq 2.5 < 4.0$	4252.14	139.224	90.811	590.271	16,601	0.056	1.417	0.000
8	SPHC,SPHD	$\geq 2.5 < 4.0$	4294.87	60,039.08	39.405	256.130	7,117,176	0.057	1.417	0.000
9	SPHC,SPHD	<2.5	4380.34	638.808	65.837	427.938	77,045	0.051	1.417	0.000

Table 16.2 Resources and machine hours' usage in continuous casting process

Slab	Qy1	Qy2	Qy3	Py1	Py2	Py3
Y1	163.765	214,942	872,508	0.148	30.000	0.000
Y2	163.765	214,942	271,611	0.148	30.000	0.000
Y3	163.765	214,942	430,724	0.148	30.000	0.000
Y4	167.859	220,315	894,321	0.148	30.000	0.000
Y5	167.859	220,315	278,401	0.148	30.000	0.000
Y6	167.859	220,315	441,492	0.148	30.000	0.000

Table 16.3 Resources and machine hours' usage in steelmaking process

Steel	Qz1	Qz2	Qz3	Pz1	Pz2	Pz3
Z1	149.483	7,848	1,612,996	0.152	6.000	0.000
Z2	208.066	10,923	698,908	0.152	6.000	0.000
Z3	152.308	7,996	811,324	0.152	6.000	0.000

design); and facility-level activities (performed to sustain the manufacturing or service facility, e.g., plant guard and management). ABC uses these four categories of activities to facilitate the identification of costs and drivers. Furthermore, appropriate activity drivers should be chosen for different kinds of activity costs. As indicated in Tables 16.1, 16.2 and 16.3, the unit-level, batch-level and product-level resources and machine hours' usage are presented.

Based on the information provided in Tables 16.1, 16.2 and 16.3, this section runs the proposed model, which is 0–1 mixed integer linear programming model and is solved by software 'LINGO 11.0 LGSL2-112164'.

First, we name the model I considering unit-level, batch-level and product-level cost. Second, we name the model II considering unit-level and batch-level cost. And then we name the model III only considering unit-level cost. Three models are solved one by one.

A comparison between the optimal solutions of the three models is shown in Table 16.4. In that table, an income statement for the product mix selected with each model is given. The product mix selected with model III produces all the products, leading to the highest income. However, the product mix selected with the model I leads to the highest profit though products 1, 2 and 7 are not produced, because product-level cost of those three products will be reduced to zero and less fixed cost of the firm will be deducted from revenue.

Comparing model I with model II, it can be seen that profit of model II is RMB 59,283,465.45, RMB 1,360,194.00 lower than that of model I, though products 1 and 2 are produced in model II. When some products are not produced, the product-level cost of those products will be reduced to zero. As to the example, RMB 50,840,094 is declined when products 1 and 2 are not produced.

Comparing model I with model III, it can be seen that model III is not the least acceptable solution. However, both continuous casting and hot rolling are batch production process, batch size is almost constant, and batch number is integer. Extra slab (WIP) and extra steel product (finished product) will be produced if we follow the product mix plan of Model III which relaxes the integer constraints of batch number. As to the example, 133.374 t of extra steel products, 11,587.114 t of

Table 16.4 A comparison between the optimal solutions of the three models

	Model I	Model II	Model III
X1	0.000	18,080.340	18,124.250
X2	0.000	2,028.000	2,028.180
X3	2,645.748	2,645.748	2,645.748
X4	100,115.600	100,115.600	100,115.600
X5	36,969.420	36,969.420	36,969.420
X6	1,154.316	1,154.316	1,154.316
X7	0.000	0.000	139.224
X8	60,039.080	60,039.080	60,039.080
X9	638.808	638.808	638.808
Revenue	102,240,100.000	151,720,000.000	152,305,100.00
Fixed cost	41,596,440.546	92,436,534.546	92,436,534.546
Profit	60,643,659.454	59,283,465.454	59,868,565.454

Table 16.5 Left slabs in model III

Slab	Produced volume	Batch number	Left slabs
Y1	104,062.100	20	937.900
Y2	38,606.310	8	3,393.690
Y3	0.000	0	0.000
Y4	20,407.520	4	592.480
Y5	140.986	1	5,109.014
Y6	61,445.970	12	1,554.030
Batch size 5,250.000; Total left slabs 11,587.114			

extra slabs are left. Table 16.5 shows the details of left slabs. Left steel products follow the same principle.

In short, the model I can get optimal and operable solutions, and it can be used in production planning and control.

Summary and Conclusion

In this paper, a product mix model was presented with its numerical example based on the expanded ABC approach proposed by Kee (1995) and Kee and Schmidt (2000) and considered three ABC's cost levels: unit-level, batch-level and product-level for steelmaking, continuous casting and hot rolling process.

The comparisons of optimizing results with that of model considering unit-level and batch-level cost and with that of model only considering unit-level cost showed that the model not only attained higher profit, but also could be implemented smoothly. The model traced the cost appropriately and effectively reduced the volume of left slabs in manufacturing processes and that of left steel products after order-delivery.

References

Balakrishnan J, Chun-hung Cheng (2000) Theory of constraints and linear programming: a re-examination. Int J Prod Res 38(6):1459–1463

Baykasoglu A (2009) Quantifying machine flexibility. Int J Prod Res 47(15):4109–4123

Bhattacharya A, Vasant P (2007) Soft-sensing of level of satisfaction in TOC product-mix decision heuristic using robust fuzzy-LP. Eur J Oper Res 177:55–70

Bih-Ru Leaa, Fredendallb LD (2002) The impact of management accounting, product structure, product mix algorithm, and planning horizon on manufacturing performance. Int J Prod Econ 79:279–299

Bo-xiong Lan, Nan Jiang, Yan Zheng (2010) A heuristic lot-sizing algorithm for large scale lot-sizing problem (in Chinese). Chin J Manag Sci 18(2):81–88

Hu-sheng Lu, Sen Wu, Bing Liu, Zhen-gang Liu (2004) Maximum profit flow algorithm for optimization of production planning of steel works (in Chinese). Iron Steel 39(3):74–77

Karakas E, Koyuncu M, Erol R, Kokangul A (2010) Fuzzy programming for optimal product mix decisions based on expanded ABC approach. Int J Prod Res 48(3):729–744

Kee R (1995) Integrating activity-based costing with the theory of constraints to enhance production-related decision-making. Account Horiz 9(4):48–61

Kee R, Schmidt C (2000) A comparative analysis of utilizing activity-based costing and the theory of constraints for making product-mix decisions. Int J Prod Econ 3(63):1–17

Li-xin Tang (2005) Intelligent optimization-based production planning and scheduling in iron and steel industry (in Chinese). Chin J Manag 2(3):263–267

Ren-qian Zhang, Yi-yong Xiao (2007) A research on agent-based heuristic production planning of product mix considering build-to-order (in Chinese). Syst Eng Theory Pract 10:54–62

Souren R, Ahn H, Schmitz C (2005) Optimal product mix decisions based on the theory of constraints? Exposing rarely emphasized premises of throughput accounting. Int J Prod Res 43(2):361–374

Tsaia W-H, Shih-Jieh Hung (2009) A fuzzy goal programming approach for green supply chain optimisation under activity-based costing and performance evaluation with a value-chain structure. Int J Prod Res 47(18):4991–5017

Weeks K, Gao H, Alidaeec B, Rana DS (2010) An empirical study of impacts of production mix, product route efficiencies on operations performance and profitability: a reverse logistics approach. Int J Prod Res 48(4):1087–1104

Wen-Hsien Tsaia, Kuob L, Linc TW, Yi-Chen Kuod, Yu-Shan Shena (2010) Price elasticity of demand and capacity expansion features in an enhanced ABC product-mix decision model. Int J Prod Res 48(21):6387–6416

Chapter 17
Development of Free Gift Based on People-Oriented Concept

Ying Zhao

Abstract Free gift is one of important sales promotion artifices which will influence the brand image, and many companies use it. But there're some problems about giveaway in market nowadays. This paper present people-oriented concept is significant in development and innovation of free gift. It should formulate market strategy in accordance with customers and specific conditions. As an important link in market strategy, design for gift needs comprehensive consideration of various factors and rational innovation.

Keywords Free gift • Market strategy • Innovation • Design

Value and Effect of Free Gift

Free gift is a kind of common and important sales promotion, which is free for customers with the main product. Otherwise, in commercial activities, products that company provides to customers or business partners for free are all called free gift. It is age-old, effective and widely used in the commerce areas. Dan Ariely said attraction of free is irresistible, and it can bring great energy (Dan Ariely 2010). Free gift attract consumer's attention to stimulate consumption, encourage consumer to buy new product, otherwise it also will help to keep consumer's brand loyalty to a certain extent (Fengyun Wang 2005). Nowadays, in a competitive market, there're lots of company use free gift. So it needs to pay more attention on design and develop.

There're many kinds of promotion gifts, it can be classified by nature: gift in kind and Non-physical gift. Gift in kind includes the same product of the same

Institute Level Projects Funded by Beijing Institute Graphic Communication. E-b-2012-21

Y. Zhao (✉)
Department of Industrial Design, Beijing Institute of Graphic Communication, Beijing, China
e-mail: wuyue8656@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_17,

brand; different product of the same brand; special gift of the same brand; related gift of different brand and other forms. Non-physical gift usually consist of coupon, recharge card and other forms. Company should choose proper method depending on the specific circumstances. This paper deals mainly with gift in kind, which is fairly common in market.

People-Oriented Concept in Design for Free Gift

As many gifts are daily article or some may be displayed at a very visible place, such as stationery, kitchen supplies, ornaments etc. So the quality, appearance and function will affect directly the attitude of customers to the brand and product. People-oriented concept is one of the most important elements for product design. In spite of giveaway is free for customer, it is still a part of product and represent the image of brand. So the company must pay enough attention, fully consider and analyze the characteristics and need of customers before development and design.

The Main Problem of Free Gift in Current Market

In the current Chinese market, a lot of enterprises use free gift in promotion sales. But it doesn't always have good effect, even growing worse. There're some common problems in market.

Bad Quality

Based on research, we found many free gifts are bad quality in present market, which maybe can save cost. However, the image of brand in customs' heart will deteriorate as well. For example, some household electrical appliances enterprises give poor quality tableware with product; it appears to bring tangible benefits to customers, while actually it maybe brings trouble when they use the gift, which may lead to customers do not believe in the brand any more.

Monotonous Gift

Lots of companies choose an existing product with other brand or stick on their own trademark as the free gift. For the similar product, many companies always select similar even same gift and propaganda method, which are lack of innovation and looked monotonously alike. Such as some stationery, electronics and daily supplies which are lack of characteristics. Under the similar product and the price, that kind of gift is hard to achieve the desired effect and make customers to remember (Yaqin et al. 2009).

The Accessories Are Better than the Main Part

In the current market, some free gifts are more expensive than the main product. It looks to bring huge benefit to customers, but this distracting behavior may make people wonder the value of the main product. For example, some enterprises give very precious gift with moon cake. This kind of promotion will guide customers to ignore the moon cake, while only concern about the gift. It maybe will going against long-term development of brand and company.

The Main Marketing Strategy of Free Gift

To avoid the above question, company shouldn't take selecting free gift slightly. Using a suitable marketing strategy is very significant. The strategy is not only selecting a gift, but overall consideration of various factors.

Analyze the Main User

1. *Making clear the main user group*: Almost every successful product must have a clear target user group, as well as the free gift. Analyzing target user' characteristics, hobbies, life style and consider about what kind of product they will like is very important.
2. *Fully taken into account of "80/20 rule"*: The "80/20 rule" is one of the rules in marketing, which means 20% customers will bring 80% profit. So company should fully consider the demand of those 20% customers (Qi Lei and Xiaojiang Xu 2006). This paper provides "people-oriented concept" in free gift design, which doesn't mean think over all the customers, but the group who always like to buy the product of a brand. After make clear the main users, company should find out the target group-the "20% customers", and try to service their needs about giveaway. They have a certain loyalty to the brand, and won't change easily to other brand.
3. *Analyze the customers' attitude toward free gift and the motivation of purchase*: Although some customers don't pay much attention on giveaway, as a part of product, successful free gift will activate the motivation of customers' attitude towards main product. There're three level of giveaways' positive effect: First, after getting gift by purchasing product, customers feel like getting benefit from

Fig. 17.1 The "red cup" of Nestlé (http://www.yihaodian.com/product/detail.do?productid=950941&tracker_u=5089558&tracker_type=1&merchantid=1)

it; Second, when there are many possible choices, customers choose the product for preferring its gift; Third, Customers buy the product because of loving the gift.

We can know this information through users' survey or other data, and then know the users' attitude to giveaway, for the customers who favor giveaway, we should know their motivation. In the science of consumer behavior, when activating the customers' need of wanting, there will be a kind of intensive mood that impelling customers to alleviate or eliminate the need, which will be beneficial to sale (Solomon 2009). So evaluating and analyzing the detail reasons of the attitude and the motivation of purchase is very helpful to formulate the marketing strategy.

The "red cup" of Nestlé is a classic case As Fig. 17.1. Instant coffee of Nestlé entered into Chinese market in the 1990s. Instant coffee is fresh for most Chinese. The target users of instant coffee are college student. They are easy to accept new things and full of energy. Buying a certain amount of instant coffee will get the "red cup" as free gift. The color of the gift cup is red and white, which is dynamic. And the appearance is simple, which meet the youth preference. The red cup becomes a symbol of fashion life in the youth in 1990s. Some youth so love the red cup that buying coffee for free gift. And the slogan "the taste is great" is also deeply rooted among the people. The red cup of Nestlé had become a kind of culture at one time.

Make Clear the Main Objective

There're various objective of promotions, such as increasing sales, capturing the market share, replying to the competition, developing new market, or establishing the image of company and so on. Before making the decision, the company should make clear the main objective of promotion. Different objective will decide to use different methods of marketing strategy.

Fig. 17.2 "Red packet" for DOVE in spring festival promotion

Overall Consider About the Place and Time of Promotion

Company shouldn't use one kind of gift all the time. In supermarket, shop, exhibition or road show, they require free gift with different price and feature. Since it need to offer lots of free gift in the exhibition, Epson corp. selects gifts which comparatively cost less, such as USB wire, cell phone charm. For common sale, they will choose shaver, earphone and other fashionable products with higher price and better quality (Liang Liu 2005). This strategy will help to save cost and promote effect.

Different seasons or festivals need different free gift. Giveaway with features of season or festival will let customers feel friendlier than the normal one. For instance, many companies make promotion in festival. The free gift should show element of the festival, which will increase appreciation for customers. We have ever designed a gift for DOVE chocolate, which was used in spring festival, as Fig. 17.2. We innovatively combined Dove package with red packets (the elder give children money packed with it at China in spring festival). It is very suitable for spring festival with festive and prosperous element.

Control Costs but Keep Quality

Most free gift is free for customers, so company must calculate the cost. Meanwhile, the quality of the gift is also very important, which will influence the brand image in customers. According to a survey about the attitude of customers towards free gift, customers think the top three key of giveaway in order is practicality, quality and attraction (Ying Kang and Qinru Huang 2009). It means customers the good quality is very important.

Design Principle of Free Gift

Design is one of the important links in market strategy; this paper provides some design principle of giveaways through design practicing and research.

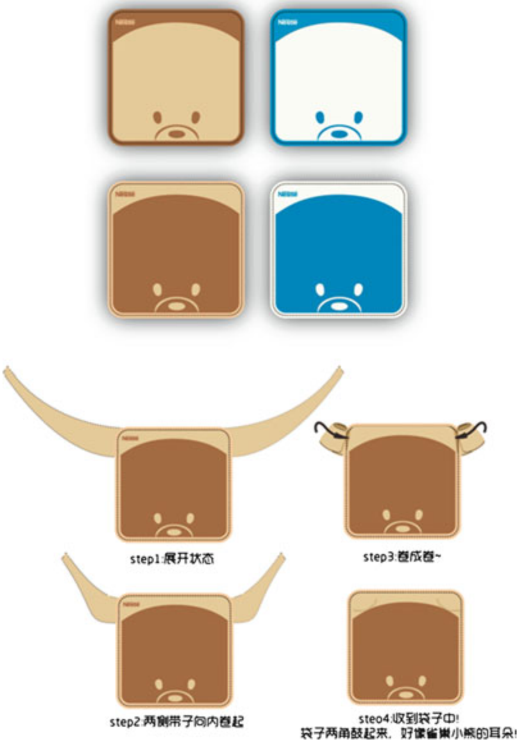
Relevance

1. *Free gift should be associated with the main product*: Free gift have a very important function, which is promoting the sale of main product. Successful giveaway should help customer think of the main product. So it would be better that free gift having relationship with the main product. E.g. selling cosmetics could offer cosmetic bag.
2. *Free gift should have relevance with the brand*: Successful free gift can promote the brand, and it will make customers think of the brand when they using it. There're some companies stamp the trademarks on the gift, and also some companies use their own special image to design new product (Bo Zhu 2004).

For example, According to image of Nestlé baby milk powder-blue bear, as Fig. 17.3, we have designed a baby bib as the free gift for Nestlé milk powder, as Fig. 17.4. Baby bib is very useful for most babies, especially when they using the bib, Parents will easily to remember of the powder.

Fig. 17.3 The image of Nestlé baby milk powder (http://www.nipic.com/show/4/79/a815f321a89b9499.html)

Fig. 17.4 Baby bib designed for Nestlé baby milk powder



Appropriate Innovation

Innovation is one of the most important keys for the sustainable development of enterprise. But usually for design of free gift, totally inventing a product is not necessarily appropriate. It doesn't copy others, but "Appropriate Innovation". It means to choose the appropriate exiting product that is familiar to customers, and base on it to innovate.

There're two reasons to do that. Firstly, invention needs to spend plenty of time and money; however, giveaway is free for customs, invention new product means increasing the cost for the company. Secondly, free gift should be easy and simple for customers to get and use, if offering a totally new product may make customs confused.

We have ever design a photo frame as free gift for HP E-Print series printer. Photo frame is a common and useful on desk, but we creatively use the "e" shape in design. Our innovation is mainly on using way and style (Fig. 17.5).

Fig. 17.5 "E" shape photo frame

Using Suitable Material and Package

For cost reasons, not all of material is appropriate for making free gift. On account of the differences of process technology and package, relatively speaking, the same product which using plastic, rubber costs less, while metal and glass costs more.

When designing the package of gift, except for considering the collocation with the main product and the gift, designers should also think over the sale process. Using independent packing is flexible but hard to keep when sold in market, and will cause loss. Packing with the product has limitation, while easy to manage. So company should choose a suitable package for free gift.

Conclusion

Free gift is a minor point, but it must not be overlooked. In the fierce competition, giveaways are one of an important promotional methods and it will influence the image of brand in customers. Company should pay enough attention on it. Not only concern the free gift itself, but also the users' need, and the whole promotional strategy and process from the concept to sale after synthetical study the concrete condition.

References

Bo Zhu (2004) Principle of free gift-How to choose the free gift of household appliances. Mod Househ Appl 19:48–49 (in Chinese)

Dan Ariely (2010) Predictably irrational: the hidden forces that shape our decisions. pp 42–51 (in Chinese)

Fengyun Wang (2005) Free gift can develop the market. Market Obs 4:37–38 (in Chinese)

Liang Liu (2005) The free gift's strategy of Epson. Advert Mark Obs 4:28–39 (in Chinese)

Solomon MR (2009) Customer behavior, ch. pp 106 (in Chinese)

Qi Lei, Xiaojiang Xu (2006) Analyzing promotion from the case. Mark Modernization 87:134–135 (in Chinese)

Yaqin Xia, Jiaxin Du, Liyao Li, Xiang Wu (2009) Design strategy for promotion-gifts development in the context of market segmentation. In: Tsinghua international design management symposium, Beijing, pp 55–59

Ying Kang, Qinru Huang (2009) Research on the need of design and application for free gift. Cai Zhi 13:263 (in Chinese)

Chapter 18
The Impact of Shop Window Design on the Development of Modern Time Visual Merchandising in China

Ling Miao

Abstract The establishment of China's shop window design industry is based on its unique historic opportunity and background. Its emergence has refashioned the manner of traditional visual merchandising which makes too much use of the shop signs. The development of design style covers the importation of the western design and the domestic innovation of design in China. In the first half of the twentieth century, the shop window design reached its first developmental climax. The concepts and modalities of China's modern time visual merchandising have been developing in tandem with the birth of shop window design industry. And this has contributed to the ceaseless progress of China's commercial civilization.

Keywords Visual merchandising • Birth of shop window design industry • China in modern times

Introduction

In the 1840s, the industrialized countries in the west had finally achieved the mass production of transparent glass, which had realized shop-owners' dream of displaying commodities in the shop windows so as to attract consumers. This has contributed to the fast improvement and development of visual merchandising concepts. China's shop window design industry during the modern times possesses its own unique development history and has as always exerted influences upon the dissemination and application of visual merchandising concepts throughout the commercial activities of the country.

L. Miao (✉)
School of Design, Shanghai Institute of Visual Art, SIVA, Shanghai, China
e-mail: miao19781227@yahoo.com.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_18,

Relationship Between Visual Merchandising and Shop Window Design

As a special terminology, visual merchandising has been universally adopted in the current commercial activities. In this trade, “VMD” has been frequently used to stand for the term directly. Visual merchandising aims to maximize commercial interests, combining demonstration, visual display techniques and commodity marketing philosophy (Tony Morgan 2008). Although the idea has just made its debut in recent years, the application of visual merchandising concepts in commercial activities has existed for quite a long time. Thanks to their features for staging display, shop windows play a key role in the success of visual merchandising. Regarding the shop windows as fixed areas, shop window design seeks to arrange the commodities in practical and artistic ways so as to facilitate consumers’ appreciation and reference of the goods. Its function lies in boosting the purchasing desire of consumers and raising market sales. As a result, shop window design is viewed as a crucial method in commercial visual merchandising strategies (Wen-jie Pan 2011).

Traditional Mode of Visual Merchandising in China

The formalities of commercialism determine the corresponding modes of visual merchandising. Prior to the introduction of a vast number of overseas commodities into China, old-style shops possessed no shop windows. The traditional shop promotions were dominated by a decorated signboard called “the shop sign” (Xiao-jian Shu 2011). In terms of visual merchandising, “the shop sign” is regarded as combination of “signboard” and “front cover”. The shop sign is usually set on the shop façade or in its front. The sign can be suspended, inlayed or bricked up. The shop’s “front cover” makes use of vivid visuals, bright colors, exaggerated decorations or its unique symbols to display the design or words featuring the store (Xing-gong Wang 1994). It creates a powerful visual impact. The shop sign constitutes a major device in the traditional competition of visual merchandising. But it remained quite difficult to display the tangible commodities outside the shop. On one hand, it was due to the shortage of commodities and product varieties. Upon seeing “the shop sign”, customers became aware of the major commodities sold in the shop. On the other hand, glass had not been used widely so that outside display of commodities is devoid of necessary security.

Positive Effects of China's Shop Window Design on Visual Merchandising

Negative Effects of Overseas Shop Window Design on Visual Merchandising

The need for shop window design stems from the emergence of department stores where a greater variety of goods are sold. In the later period of nineteenth century, foreign-funded department stores began to emerge in Shanghai. Ever since the later period of Qing dynasty, four foreign-funded departments stores such as Whiteaway, Laidlaw & Co., Ltd., Hall, Haltz & Co., Ltd., Weeks & Co., Ltd., Lane, Crawford & Co., Ltd. moved to the Bund area of Nanjing road. They are called the "Four Major Companies in the Early Period". The most prestigious one is the world-renowned English-owned department store – Whiteaway, Laidlaw & Co., Ltd. Established in London in 1882, the company set to construct its high-rise headquarters over a land area in the northeast of the crossroad between Nanjing road and Sichuan road in December 1904. The company entrusted the building design to architect Scott of Morrison Matheson. The ground floor of the building is a shopping mall with large French windows used for goods display. The "Four Major Companies" followed the uniform style of display design adopted across the world. So the earliest shop window design in China was graced with the international style but devoid of any Chinese elements. At that time, the major function of shop windows was to show off the glamour of the foreign-funded companies. The commodities on display had nothing to do with the majority of Chinese people. The costumes and especially the models in display had become a hot topic during that time. Ever since the establishment of foreign-funded department stores, they had always adopted the marketing principle of selling upper scale goods catered for foreigners living in China. Being confronted with the accelerating consumption ability in Shanghai during the early period of twentieth century and the ever increasing middle class, they failed to grasp the consumption capacity and mentality of Chinese people, though they enlarged their market later. And they simply followed the visual merchandising strategies in the west, which included the design of shop windows. Consequently, their leading position in the commercial realm had been gradually supplanted (Figs. 18.1 and 18.2).

Domestic Shop Window Design Industry Paying Attention to Visual Merchandising

The birth of China's shop window design industry stems from the development of its domestic retail industry. During the early twentieth century, the capital of overseas Chinese investors began to flow into Shanghai from Hong Kong and Guangzhou. And it had brought about a period of prosperity in Shanghai. On the 20th of October 1917, Sincere Co., Ltd. first set up its business. The company building takes on a baroque style. The façade is arranged according to the classical three sections. The ground floor is surrounded by an arcade veranda with built-in

Fig. 18.1 Western civilization in shop windows of Shanghai (by Austria painter Schiff)

Fig. 18.2 Westernized shop window design of Whiteaway, Laidlaw & Co., Ltd.

Fig. 18.3 Sincere Co., Ltd.

Fig. 18.4 “Single display” and “Multiple display” shop window

shop windows (KIkuchi Toshio 2012). Sincere Co., Ltd. is the first large-scale international department store run by Chinese in Shanghai. It designed the earliest shop window advertisement in China. Shop window design during this period was dominated by “single display” featuring one type of commodities and “multiple display” featuring a variety of commodities. Crepe paper, color paper and cloth strips were the popular decorations. And the design is devoted to commodity display. The usual design is to construct a crepe paper backdrop for the commodity. The more complex design, for example, is to festoon the shop window with cloth strips. The mapping of strips serves to attract customers and set off the commodity (Figs. 18.3 and 18.4).

Upon entering into the 1930s, Shanghai had become the Number One Metropolis in the Far East. Its modernization and internationalization surpassed Hong Kong and Tokyo. Not only was Shanghai the political enter of China, but it also became the cultural center, leading the whole country in industry and commerce, finance and security, international trade and municipal developments (Feng Li 2010). With the birth of shop window design industry, the brand new visual merchandising method greatly boosted the retail sale of the time. All businesses invested significantly in shop window construction and design. As the “Four Leading Companies” (Sincere Co., Ltd., Wing On Co., Ltd., Sun Sun Co., Ltd., and Da Sun Co., Ltd.) frequently received commodity catalogues together with introductions about shop window design and costumes for display while they were importing goods from overseas. Adopting overseas design, these domestic companies took into great consideration the aesthetic standards of Chinese people and managed to create the traditional Shanghai style for shop window design, which was rich in unique local features.

Flourishing Shop Window Design Industry Promoting Competition in Visual Merchandising

Making use of shop windows to conduct commercial competitions demonstrates how visual merchandising promotes commercial progress. It is the importance attached by domestic department stores to visual merchandising that ushered in a development climax for the modern time retail business in China. Wing On Co., Ltd. department store had made the most important contribution to the modern time shop window design in China. Opening in 1918, the company specialized in about 10,000 varieties of commodities. With a façade covered with tiny pebble mingled cement, the shop windows were installed with huge imported panes, which set the precedent for shop window design in Shanghai. The shop façade was decorated with Roman columns, which bestowed it with an ambience of renaissance. They were the first one to bring about “the situational” shop window display, using the shop window to tell a story. The shop window display would be rearranged according to different seasons. This had constituted a characteristic attraction along Nanjing road. Shortly before the Mid-autumn Festival, the shop window design would focus on the story of the “Legend of Chang Er, the Moon Goddess”. On the background of the shop window was a big full moon towards which Chang Er, the Moon Goddess, flew gracefully. All kinds of moon-cakes were displayed behind the window (Qi-wen Xu 1934). Drawing on the festive atmosphere, the design aimed at arousing people’s wish for family reunion. In this way, it intended to promote the sale of commodities. Influenced by the foreign culture in the concession areas, quite a few fashionable people in Shanghai began to celebrate Christmas. It became very popular for senior relatives to bring gifts to their minors. Several weeks before Christmas, the company would place in the middle of the shop window a gorgeously dressed Santa Claus with white hair and beard. Surrounding him were all kinds of toys. By changing the shop window design in different festivals, the company aimed at gaining the markets for foreigners and those overseas Chinese who had adopted the way of life in the foreign country. During the winter time, the shop window would display a snow scene. The snow flakes were made of cotton. They fluttered in the air with the aid of machine power, creating a snowing scene. This has become the first dynamic shop window display in China (Guan-chang

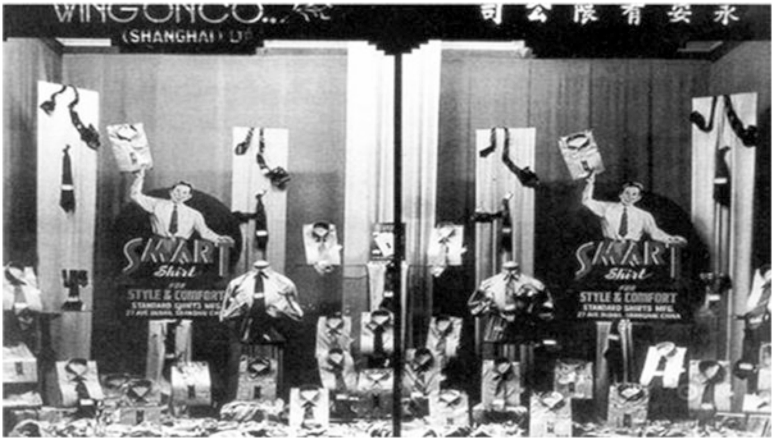


Fig. 18.5 Wing On Co., Ltd.'s shop window displaying the shirts of "SMART"

Guo 1936). In 1934 when Da Sun Co., Ltd. was set up, it invited the famous American architect John Graham (1873–1955) as its adviser who was reputed for his design of department stores. He believed that shop windows were the most valuable features for advertising, suggesting that the ground floor should be circled with continuously connected shop windows. Responding to the smoothness of the internal walls, the outside window façade would fit quite well with the internal design. Graham's advice was adopted by the company. Eighteen shop windows were installed around the ground floor, making the company the one with the largest number of shop windows and the largest shop window space in China (Fig. 18.5).

More and more companies begin to regard shop windows as the best platform for the publicity of the company image and the commodities. Passing by the shop windows, busy pedestrians are able to see the commodities promoted by the company. Good shop window design can lead customers into the shop (Guan-nan Liu 2007). In terms of space, shop windows provide the department stores with a great extension of marketing area. Because shop windows will not close when the stores close, they maximally extend the marketing time for the commodities. It is fair to say that shop windows have become strategic tactic for "magnifying time and space" in the visual merchandising competitions among stores. During the early period of the People's Republic of China, Qi-wen Xu, an expert in visual merchandising, pointed out: "whenever I approach various department stores, grand shop window advertisements always come into my sight. They are designed in such a beautiful way that I become quite reluctant to leave. At the very beginning, there is no wish for purchase. By and by, I become absorbed in the display when a purchasing desire wells up in my heart. Driven by the desire, few people will never enter and bargain unless one carries not a single penny. And this has yielded many successful purchases."(Qi-wen Xu 1934) His words demonstrate the positive function of visual merchandising in commercial promotions. The "Four Major Companies" are located along Nanjing road. The four bosses are all from Xiang Shang. They are engaged in the same business in Shanghai. The fierce competitions among them have produced many interesting stories of

Fig. 18.6 Nanjing road with busy transportation and shop windows on both sides in the 1930s

business wars. The shop windows became the most direct channel to conduct competitions. Various companies constantly updated their shop window design, furnishing Nanjing road with beautiful decorations. Overseas media called it "the most global and culturally diverse avenue in the world" (Tian Li 2010). During the heydays of the "Four Major Companies" in the 1920s and 1930s, shop window displays became part of the street scene. People in Shanghai regarded window shopping as a goal-oriented activity. Department stores had become a must for travelers from outside the city to visit. According to a Tour Guide in Shanghai published in 1935, the department stores on Nanjing road always topped the list of visits on the first day. And the shop windows provided the travelers with the first impression of modern Shanghai (Zong-fu Sun 1935). At that time, the evolution of shop window design in Shanghai's department stores largely followed the trend of the western countries. But it lagged behind them for about two decades. From then on the overseas expertise on shop window design began to enter into China and had become a major inspiration for the shop window design of the "Four Major Companies". For example, in order to make reference, Wing On Co., Ltd. had subscribed to some foreign magazines such as *Look, Life* and *Window Display*. With the aim of gaining more market share, they even interchanged design staff with Hong Kong Wing On Co., Ltd. so as to bring about more creative ideas and cater to customers' demands for visual aesthetics (Fig. 18.6).

Conclusion

The establishment of shop window design industry in China is different from western countries. It is dependent upon China's unique history of modern time development. The business prosperity brought about by the competitions of shop window design demonstrates the universal applicability of visual merchandising. The commercial progress does not merely depend upon shop window design. Nevertheless, all successful retailers cannot afford to ignore shop window design. At the same time, the development of retailing industry has enhanced the progress of shop window design. Historically, commercial prosperity has always been accompanied with excellent shop window design. Up till now, visual merchandising has always been regarded as the barometer of retailing industry. Businesses have attached more importance to its functions in commercial activities.

References

Feng Li (2010) Discussion on the ideas of modernism design in Chinese window advertisement design in the first half of 20th century (in China). Packag Eng 31(22):116–118

Guan-chang Guo (1936) The origin and business status quo of the “Shanghai Yongan Company” (in China). New Bus Quart (02):43–44

Guan-nan Liu (2007) The sleeping business window of China (in China). MEIYUAN (02):75–76

KIkuchi Toshio (2012) Department stores and urban culture in modern Shanghai, SPPH. Four morgan department store

Qi-wen Xu (1934) Study on commercial advertisements (in China). Bus Mon 14:2

Tian Li (2010) Shanghai window and Shanghai culture (in China). Shanghai Bus (08):42–43

Tony Morgan (2008) Visual merchandising-window and in-store displays for retail, London, China Textiles Press Mar. 2009, 11

Wen-jie Pan (2011) The analysis on commercial window design from the perspective of consumer psychology and behavior (in China). Mark Res (10):25–27

Xiao-jian Shu (2011) The art of the ancient shop window advertising medium (in China). Cont Lit Art (08):89–91

Xing-gong Wang (1994) Chinese traditional market signs, Taipei, pp 13–23

Zong-fu SUN (1935) Shanghai Tour Guide (in China), Zhonghua Publishing House, pp 195–202

Chapter 19
The Creative Design Research of Personalized Furniture

Fan Bei and Yang Jing

Abstract With the worldwide industrial restructuring, the creative industries have become the new direction of China's economic development. In the economic background of the growing demand for creative products and artworks, as the focus of the creative industries, personalized furniture design has become the focus of China's creative industries. With the emergence of personalized furniture, it brought a new challenge in the furniture industry. Designers should not only meet the reasonable structure and function of the furniture, but also to maximize meet the needs of consumers' pursuit of individual, and thus formed a strong conflict. In this paper, on the one hand, from the analysis of creative personalized furniture cases to extract specific personalized furniture creative development approach, on the other hand, study to find a personalized design method, and provide a new research direction for the design theory of the creative methods, provides a new idea for the designers that seeking the design inspiration. For the learners of art and design, it is a new method of pioneering and creative thinking. Contribute to industrial development for the future of personalized furniture (Fanbei, Furniture design. China Water Power Press, Beijing, 2010).

Keywords Personalized furniture • Development path • Personality and creative method

F. Bei (✉)
Wuhan Institute of Technology, Wuhan, Hubei 430073, People's Republic of China
e-mail: bei317@163.com

Y. Jing
South China University of Technology, Guangzhou,
Guangdong Province 510641, People's Republic of China
e-mail: 541478892@qq.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_19,

Introduction

The increasingly fast pace of life, and a variety of images continue to impact our eyes. In the furniture industry, the era of personalized design is quietly coming, and there are many distinctive art and design furniture, they articulate the feelings of the owner. The style is novel and unique, very dynamic. Their style has advanced design ideas, exaggerated variation, and is the avant-garde of the furniture world. These bizarre, odd color splendor of personalized furniture become the eye-catching furniture on the modern market. Cutting-edge designers are standing in the forefront of furniture design and using their boundless creativity, design the furniture that shinning the light of creative idea and full of personalized design. The use of creative thinking and the attempt of new design methods become very important in the design process. At present, explore the theory of creative thinking and product design methods, there are a lot of more mature research. However, it is seldom mentioned that the practice of personalized design method to be introduced to the design of innovative. The design innovation is both the eternal theme and the eternal problem. How to design a more beautiful shape, easier to use the features of the product, designers seem to never be able to really solve the problem. However, these problems also lead to the ongoing research on the method of design creativity (Hu jingchu et al. 2008).

From a theoretical point of view, the theoretical research on design methods at home and abroad, often to explore from two directions. On the one hand, the designer through an objective description of the design process, to research the design procedures and methods. On the other hand, from the perspective of the thinking brain, research the ways of thinking of design. Exploratory books on the theory of the thought processes of the human brain after another, seldom discussed to make the system lead to creative thinking.

Some people think that good design is a system strict size-fits-programmed system, this view seems to ignore the diversity and variability of the design issues, as well as its own pursuit of innovative world is not a static method can deal with all kinds of problems, especially in design methods.

Existing furniture design methods can be broadly divided into two categories, one is rational reasoning out the new products according to market research, and the other is rely on non-rational inspiration to innovative products. Most design firms are more common is the first approach to design, the design process as follows: market research – concept – design – design samples – feedback – feedback from the market. It is the collection and analysis of the target product and user targeted materials, there are products, or a breakthrough. Designers will find the problem to be resolved, and thus to improve the function or shape of the original product. This method is commonly used in the product design industry, it can be summarized into two steps: ask questions, solve problems. This method is very direct and very effective, targeted, there is often an immediate effect (Liang qifan 2001).

However, with several improvements of furniture products, it is increasingly difficult to find the new problems of the products. In this case, the designers try to irrational flash of inspiration to seek a breakthrough in the design. Because of preconceptions rather than accept the limitations of the design process, designers are freedom to use their imagination and creativity, which became another direction of development of the creative design methods.

How to discover a source of creative thinking, alternative state of waiting for flashes of inspiration, has become a very difficult problem to be solved by many designers. In this paper, with the help of personalized lifestyle, mobilize the initiative of the thinking brain, to seize a wonderful source of inspiration, innovative design thinking to a certain degree of inspiration and guiding role, but also import a new innovative design method for furniture designers, provide a new and interesting creative thinking training method for the design students. Explore design ideas, exercise creative thinking, and inspired design inspiration, to enhance the design capability is the starting point of the research (Li Feng and Thant 2005).

Personalized Furniture Product Design and Creative Development Approach

Thinking Innovation

Any innovation, their thinking is fundamental, no innovative thinking, no innovative design. After systematic and deliberate training, the people can form a thinking pattern. Someone said: innovation is opposed to some fixed thinking mode. As everyone knows, trying to break some antiquated way and establish a new thinking mode is a kind of innovative thinking.

With the development of society, the furniture design needs to grasp the pulse of the times, the public spotlight into the design theme. Such as the human environmental concerns into the system of ecological design, and then evolved into "ecological design"; designer in the choice of materials can try to use recycled materials or renewable materials, to suppress the use of waste wood materials or wood pulp sculpture new furniture for more design sense (He Songfei 2007) (Figs. 19.1, 19.2, 19.3 and 19.4).

Function Innovation

The furniture is a kind of product. Its functionality is beyond doubt. The main indicator of social development is one of the people's lifestyle and behavior change and progress. Social development will continue to put forward the functional requirements of the new furniture. Function innovation has become the primary means and methods of furniture design innovation.

The ideas of personalized furniture design are also come from the furniture features and usage. A lot of furniture design masters in the design of a chair, in fact, not a chair, but a pattern of sit, the design of a function. Function is not a physiological system or a

Fig. 19.1 Chairs made of newspaper

Fig. 19.2 Pebble stool

Fig. 19.3 Human-shaped armchair

Fig. 19.4 Foldable wooden bench

Fig. 19.5 Sofabeds with new functions

physical system, but a cultural system. A chair, a table, has been completely according to ergonomic principles to the design is complete, why there are still people feel comfortable, some people feel uncomfortable? Ergonomics cannot explain the meaning of "comfortable", the designer responsibility is not to achieve, but to discover the function. The design is a positive modification of human behavior. The new features are the new freedom and the new usage (Li wenbin 2001) (Fig. 19.5).

Technological Innovation

The design of technological innovation is the invention and creativity in science and technology level. Technical innovations include a wide range of materials, structures, production technology, production process innovation (Zhang tong 2004) (Fig. 19.6).

Compared to other industries, furniture design and manufacture is not the so-called "high-tech" industries, but it is not mean that the high-tech have nothing to do with the design and manufacture of furniture, although it is not a high-tech areas, but it can become the master applications battlefield of high-tech. Science and

Fig. 19.6 Chairs carrying LED lights

technology are the ultimate power to promote the development of furniture design, new technology, new materials open up a new world of products for the power the dominant factor. The use of a new properties materials new features and even the birth of the accessories, the use of new manufacturing technology, a new structure type, are a reflection of the new technology in furniture design.

Personalized furniture creative also come from the use of new materials. New materials, new technology applications, often the precursor form of the new product development. The change of new lifestyle and the impact of contemporary cultural thought, is the new characteristics of the new form of motivation. Expansion of new materials to give the material basis of the furniture design, you can take full advantage of the texture characteristics of the different materials to design, so you can get the ever-changing the effect of different styles of art. Designers in material selection is eclectic, to break the fixed mode to try to use new materials. For the materials, the designer not only seen as the material guarantee of the design, but also the medium of a positive exchange of feelings and designers to express themselves mirror, given the material to the cultural meaning and combinations of features to make our products become a harmonious complexity system, an expressive world. The designers are adept at using new materials, bright colors and innovative patterns, showing the design of the double meaning, for the public, for the history, is masterpieces, and is arbitrary. Focus on the surface of the visual effects. Design of all kinds, arbitrary and display. The attitude of their material sometimes is emotional rather than rational, material for the designer does not matter, it is important to the texture of the material itself, texture, color, transparency, luminosity, reflective rate, and they have expressive. For materials, there is no limit.

Fig. 19.7 Furniture made of GRP (fibre glass reinforced plastics)

Innovation of Forms

Furniture in the form of innovation, the basic point is that the new style and the style of furniture design. Forms of innovation with new visual features, it brings the effect of "new, odd, different", make personalized furniture in the form of innovative furniture design to the main manifestations (Fanbei 2010).

Personalized creative furniture, mostly from the shape of an exaggeration, variation, the pursuit of the furniture itself is modeling his lines from the designer. The green modeling, ecological modeling, personification modeling, humor modeling, high-tech modeling. People accustomed to the vitality of nature "green" to describe the "green" design of the furniture in the shape refers to furniture shape of naturalization. Nature is always the main line of green furniture design, combine the image of beauty and dynamic, which reflects the eco-style. Such as flowery type sofa, peacock chair, and shells stool, reflects the shape of the green ecological concepts. The Aiello agno (EerOAornio), claiming that the furniture design can have a variety of inspiration from the animals in the 1970s, more styling of the furniture also use vinegar foam constructed of polyurethane, upgrade the production of furniture to the art level. Shape melodious cantabile, the flow line, and thinking constantly. Smooth shape of the curve, the function is no longer important. Cartoon-like shape, humorous shape, by the simple geometry of the rounded form, and reflect the designer's unique design creativity (Figs. 19.7 and 19.8).

Personalized Furniture Design Method

Creative personalized furniture, mostly from the shape of an exaggeration, variation, comes from the pursuit of designer furniture styling and lines. The modeling of green, eco, personification, humor, high-tech.

Fig. 19.8 Anemone Chair

"Building Block" Modular Game Design

In the process of product innovation, the modular design can make more possibilities of communication between products and people, and more flexibility. The modular design is a more effective method of communication between corporate and users. According to the user's needs, they can flexible combination the final shape. The initiative of the personality into the design, individuality and differences will become the design-oriented, combination of modular components provide a variety of products to the people, standard design patterns was terminated, consumers directly involved in product design and the environment , as if the game , modular game design is a very effective and innovative ways (Fig. 19.9).

Division of Thinking Design Method

Division of thinking design method is object decomposition or in combination, in order to generate new ideas or new ways of thinking of the program. Division and thinking in the product design process is generally as follows: judgment – decomposition and – combination- recombination and break down – and then decomposition and combination. In life, the multifunctional personalized furniture design is ideal for use this way of thinking (Chris Leif terry 2004) (Figs. 19.10 and 19.11).

Layout Print Design Method

Reference to the page printing, we can easily think of calligraphy and painting, drawings, decorative furniture and industrial products, surface decoration and

Fig. 19.9 Block designing like piling up toy tricks

Fig. 19.10 Armchair and Bench

traditional practices. But now, modern furniture to give it a new meaning and form of expression, personalized furniture design also reflects the cutting process, carving, weaving form. To break the traditional furniture style (He Songfei 2007) (Figs. 19.12 and 19.13).

Assembled Combination

Assembled combination is the intersection of same elements or different elements, so that each element contradict each other and colliding with each other, to get an

Fig. 19.11 A-shaped multi-functional chair

Fig. 19.12 Child wardrobe with alphabet decorating on drawers

Fig. 19.13 Furniture with the layout of printing designs

Fig. 19.14 Patch-up furniture

Fig. 19.15 Bookshelf

unexpected ideas and innovative appearance and structure (Figs. 19.14 and 19.15) (He Songfei 2007).

Select a larger vocabulary with the goal of designing products typically conceptual difference, leading the expansion of the design direction of the designer. Such as chair design, assuming the same time the two terms of the "timber" and "light bulb", then we need to give priority to elements of the "light bulb". This is because the usual concept of the timber is more commonly used in making chairs and other furniture materials. This word is difficult to have a strong stimulus for designers, and even bring the designer's ideas back to the normal mode of thinking. However, if we choose the word "light bulb" that the result will be very different. Bulb

Fig. 19.16 bookshelf

regardless of what angle do not feel associated with the chair in place, but just such a leap of inspiration will bring us more and more innovative ideas: Can a chair made of light as bulbs ? Numerous bulb combination can out of a chair? Or the chair of the material is replaced by a transparent material like bulbs? This association at once opens the designer's idea, so from the innovative design will bring new and interesting feelings to us (Zhu dan and Guo liangyu 2004).

Reverse Thinking

Reverse thinking that the reversal of the direction of thinking, it seems unlikely that the coexistence of two ideas form of thinking to seek solutions to problems with the original idea of opposition, or on the surface it seems. Popular is to think "Why not . . .?"(Fanbei 2010).

Such as: the shelves used for? The answer is to put the book. You must think I asked this question very strange. Then the shelves must be empty to put the book go? However, it was the opposite happens, put shelves in advance filled with books, where our own book? Do not worry, when you put the book into the bookcase shelves above false book will bounce back, so usually we do not have so many books on the shelves when the shelves will not be empty (Fig. 19.16).

Similarly, the world-famous chain stores IKEA's product design also use this way of thinking. Generally, we are the first to design the product produced, the pricing of sales. But IKEA does not do so. It is to give the product price, then the designer to design the appropriate product according to the price of the product. That is the reason of why IKEA is so popular in the world especially in China.

Fig. 19.17 Funny Children furniture designing

Fig. 19.18 Cactus chair

A very modern design sense of products, the price is not expensive, and everyone can afford to spend the same amount of money consumers are more willing to choose IKEA products.

Humorous Series Design

Humor is an attitude toward life. Such as to give the furniture to some human characteristics, enlarge common items, irony or warm attitude to deal with the design, can produce a humorous effect (Fanbei 2010) (Figs. 19.17 and 19.18).

Conclusion

The pursuit of an alternative personality creative furniture design is rooted in the head of the designers. Materials, processes, and other constraints can't be bound to the designer's creativity. We should constantly be freed from the monotonous and stale design patterns, design is not arbitrary, not to transform in a simple way of thinking (Jim Lescaut 2005). There are new thinking and new ideas to argue in the design community. Reasonable idea to develop an intellectual, to be explored in this trend of thought, resulting in a new furniture design concept and this concept is applied to modern design space, personalized furniture industry. Continue to guide China's furniture design and production development as a world power country.

References

Chris Leif terry (2004) Top 5 material creative in the European and American industrial design. Shanghai People's Fine Arts Publishing House, Shanghai

Fanbei (2010) Furniture design. China Water Power Press, Beijing

He Songfei (2007) Industrial design content of creative thinking. China Youth Publishing House, Beijing

Hu jingchu, Fang hai, Peng liang (2008) The development history of world modern furniture. Central Compilation & Translation Press, Beijing

Jim Lescaut (2005) Industrial design materials and processing manual. China WaterPower Press, Beijing

Li Feng, Thant U (2005) From the composition to product design. China Building Industry Press, Beijing

Li wenbin (2001) Building interior and furniture design ergonomic. China Forestry Publishing House, Beijing

Liang qifan (2001) Environmental art and design furniture design. China Light Industry Press, Beijing

Zhang tong (2004) Product system design. Shanghai People's Fine Arts Publishing House, Shanghai

Zhu dan, Guo liangyu (2004) Furniture design. Shanghai People's Fine Arts Publishing House, Shanghai

Chapter 20
Comparative Analysis of Luxury Market in China and India Based on PEST Model

Chen Zhao and Shu-jie Diao

Abstract The desire for luxury goods has been released in China due to its open economic environment and international lifestyle. The same trend exists in India—another emerging market of Oriental culture, which cannot be underestimated. This paper focuses on the market circumstances and conducts comparative analysis on political and legal element, economic, social-cultural factors and technological environment with the help of the PEST model. The findings lie in identifying similarities and differences between prospects of both markets from internal and external perspectives in this paper, which lays foundation for branding strategies in China and India.

Keywords China • India • Luxury market • PEST model

Introduction

The perception of "luxury" evolves from "prodigality" and "extravagance" to a more neutral and scientific term advocating human freedom and natural desire (Berry 1994). Luxurious living attitude can be represented in luxury goods, whose appeal is a result of perceived premium quality, recognizable style, reputation, and exclusivity (Hung et al. 2011). Based on the benefits for consumers, luxury brand perception can be divided into three dimensions, namely, functional, experiential and symbolic value (Berthon et al. 2009). Apart from material embodiment the functional value conveys, which also exists in common commodity, pleasurable feeling and sensory satisfaction may be evoked by brand-related marketing mix. Furthermore, owners seek symbolic meaning from luxury brand (Kapferer 1997). Luxury brand encompasses functional and experiential utilities, signifies aesthetics

C. Zhao (✉) • S.-j. Diao
Department of Management, Dalian Polytechnic University, Dalian, China
e-mail: zhaochen989@163.com; dsj8922@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_20,

and artistic taste, thus playing a role as a badge in transmitting the information of owners. There is a deep involvement with consumers when conceptualizing luxury brand (Kapferer 1997). That is to say, no generic concept can specify its accurate meaning within the varying context.

Research on Luxury Market

Nowadays, considerable attention has been paid to the emerging markets represented by Brazil, Russia, India and China ("BRIC") instead of mature and saturated ones. Current analysis can be clustered into two categories. On one hand, experts compare different markets on economic status quo according to the level of development. It has been estimated that Chinese luxury market will be valued at 180 billion Yuan, more than 20%of the global market by 2015 (Mckinsey & Co 2011), while Indian market share will rise to 8–10% with remarkable annual growth rate of 20%. On the other hand, academic literature focuses on cross-cultural comparison. Cultural differences breed diverging self-concepts (Wong and Ahuvia 1998), dependent self-concept in western culture and interdependent one in Oriental culture, manifesting themselves in individualism and collectivism respectively (Shu-pei Tsai 2005). Individualist consumers are motivated by their own preference, needs and rights (Hofstede 1991), in pursuit of practicality of luxury goods (Shukla 2011). Conversely, collectivist identifies the self more by relationship with members of extended environment including family, relatives, and co-workers (Wang and Waller 2006).

China and India have been identically labeled as "the emerging country" and "of the Oriental origin" in light of growth speed and cultural background. However, Chinese luxury market developed ahead of Indian, and the latter is still in the ascendant level with limited market scale. Also, from a cultural perspective, Chinese scholar Liang Shu-ming divided global cultures into three types, that is, western, Chinese and Indian culture, highlighting the unique characteristic of Indian culture. As a consequence of the above, clarifying the similarities and differences is the prerequisite to effective luxury brand strategy. Thus, this paper will reveal some of these similarities and differences based on PEST Model what provides political, economic, social and technological perspectives for market research.

Comparative Analysis on Chinese and Indian Luxury Markets

Political and Legal Factors

China and India have witnessed momentous transition in the political and economic policy. Economic progress is gradually driven by technology and free market mechanism known as "an invisible hand", hence less dependent on interference of administrative power. In 2011, the World Luxury Association and Chinese Council for Promotion of International Trade Cooperation established the "Chinese

Luxury Trade Committee", aiming to expand domestic imports, promote upgrading of consumption and establish supervision mechanism. Moreover, increasingly complete protection of intellectual property rights is the guarantee of a great economic leap. In 2012, the World Luxury Association announced cooperation with China to set up the first institution in order to curb counterfeit luxury product and safeguard the interests of consumers and companies.

Indian economy was liberalized following China. After two-decade reform for marketization, India mapped out the 12th Five Year Plan, hoping to achieve an average growth rate of 9% annually. As a part of reform, luxury industry is regarded as the booster of consumption. It encouraged Confederation of Indian Industry (CII) and Economic Times (EI) to organize CII- EI Dialogue on Luxury in November 2011. The conference attempted to assess Indian luxury industry comprehensively covering the feasibility, opportunities and challenges. There is a tendency that India will display an open image to attract foreign capital, in turn, to strengthen country competitiveness.

Economic Factors

The luxury market economic environment in India and china is proposed (see Fig. 20.1).

Similarities in Economic Factors

China demonstrated a higher economic growth speed than India in 2011. But then, Indian growth rate is expected to reach 8.7% in 2012, exceeding 8.4% in China, which makes India the fastest-growing economy country in the global market.

Demographic dividend and an increasingly large affluent population also contribute to the strategic position of Indian and Chinese markets. Chinese extreme wealthy group who gains annual income of more than RMB one million sees growth rate of 20%, increasing to one million by 2015. This group will drive 38%of growth in the Chinese luxury market over the next 5 years (Mckinsey & Co 2011). Similarly, the number of Indian rich class is soaring, particularly the high net worth individuals (HNIs) whose net worth is greater than US$1 million. India had around 127,000 HNIs in 2010, whose total wealth increased by more than 50% than the previous year. The rise of high-end consumers brings out incremental disposable income, making China and India promising "gold mine" for marketers.

The other drive for the boom of luxury market comes from the rapid urbanization and resulting concentration of wealth and prosperity in second-tier cities. Goldman Sachs predicted that by 2015, Chinese second-tier cities will be the dominant power in that 75% of rich people will reside in second-tier cities like Chengdu, Wenzhou. In the case of India, one in four luxury stores are set up outside metropolises like Mumbai, Delhi and Bangalore. Low operational costs and huge developing consumer markets spotlight their significance in the next round of fierce competition.

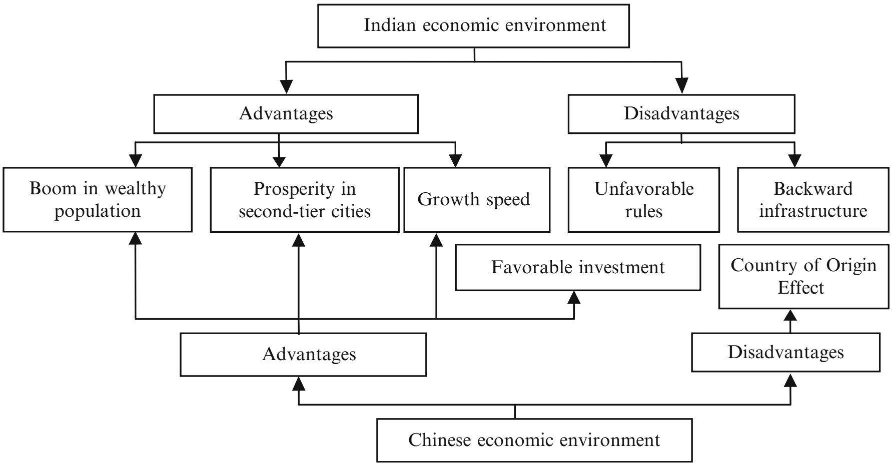


Fig. 20.1 Economic environment in India and China

Differences in Economic Factors

Relatively incomplete infrastructure, high rent and unfavorable foreign direct investment (FDI) policies in India hinder the development of luxury market. The number of luxury malls is inadequate to meet the growing demand for builders fail to follow the international format about infrastructure and ambience. Furthermore, India has the third heaviest taxation burden in the world. Import taxes on luxury goods range from 30 to 40%, accompanied with 12.5% value added tax(VAT), making the price much higher than those in European market. The limitation on foreign ownership also works as a hurdle for the sake of interest of domestic companies. FDI has been barred beyond 51%, what is a threat to current brand image and business model.

China has advantage of abundant human resources and lower labor cost, appealing to international brands who attempt to reduce cost and promote profit margin. However, brand is at the risk of damaging its value because of the emphasis on the country of origin by consumers (KPMG 2011). "Made in China" has long been equivalent with low quality, a preconceived idea that still poses a threat to the time-cherished brand.

Social Factors

Analysis on the Route of "cultural values—purchase intention—consuming behavior"

Concept delivered by luxury brands coheres with Asian values. However, cultural differences affect consumer's judgment which in turn impacts the importance degree of motivations, rather than the motivations themselves. As a result, consuming behavior and pattern mirrors cultural differences (see Fig. 20.2).

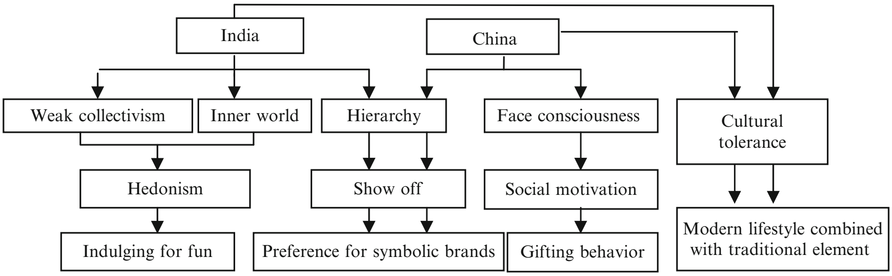


Fig. 20.2 Analysis on route "Cultural values—purchase intention—consuming behavior"

Sense of hierarchy is rooted in Chinese and Indian traditional cultures. In India, caste society and its established strict rules indicate the significance of inequality and hierarchy. As for china, feudal rituals in Confucian culture also claim consistence within consuming behavior and social class. In modern society, liberty and democracy provide a platform for modern consumers, especially the new rich, to show wealth and indicate their status. Public consumption intensifies personal image (O' Cass and MeEwen 2004), helping consumers associate brand with social recognition, reputation, and profession.

The second similarity presented in long history is the strong cultural tolerance. From the traditional great debate in Buddhism to Satyagraha Movement, the character of rationality, openness and contending enables Indian to accept and take in foreign culture. In China, from civilized Tang Dynasty to the May Fourth Movement, cultural exchange never ceased. Indian and Chinese consumers on one hand accept western luxurious notion, conforming to international lifestyle, on the other hand, yearn for ethnic element and improve sense of identity in the process of spiritual enjoyment.

Motivation and performance in consumption is derived from culture. India is a multiethnic and religious country, whose values and religions are inseparable. The description of physical and inner world leads to the tendency of seeking spiritual gratification. The emphasis on mind demonstrates weaker collectivism than Chinese values. Luxury goods are overwhelming in quality and aesthetics. Consequently, the need for implying social position and pursuing inner satisfaction can be met by owning luxury brand.

Face awareness is a unique cultural phenomenon in China, which results in distinctive function for luxury goods as gift (Hong-ji Guo 2009). According to Bain & co, half of the luxury items are purchased for gifting in China. Face consciousness is knitted with Confucian ritual and human relationship. Confucian ritual that is not only the external rules of etiquette, but internal evaluation criteria, demands that personal behavior should be in accordance with social status. Contrary to the general social exchange, Chinese social intercourse attempts to build social network via reciprocal exchange. Therefore, the value of gift is the principal factor determining whether the "face" will be maintained. Luxury brand is in high-end positioning and completely suitable for representing social roles.

Young Tendency in Luxury Market

The growing enthusiasm of young consumers on luxury goods is the noteworthy. It is estimated that 73% Chinese luxury consumers are under the age of 45, and 45% in the group of 18–34. Indian consumers are younger than their counterparts, with more than half of the total number less than 35. In Japan and UK, this proportion is respectively 37 and 28%. Young consumers mainly refer to as 1980s generation in China and BPO group (young generation seizing opportunities in the heat of business process outsourcing) in India. Their consumption characteristics can be reduced to four points: (1) Desire for consumption exceeds capacity; (2) Preference for paying in advance; (3) Willingness to take risk of credit consumption; (4) Low repayment pressure and high-degree acceptance of overdraft consumption. Young consumers identify with consumerism and may economize on food and clothing to realize "dream of luxury brand" in order to acquire satisfaction from the social recognition.

Technological Environment

In the face of dispersive population, it is a tough job for entities shops getting used to traditional marketing strategies to make potential customers involved. The Internet bridges between brand and customers through transmission and communication of diverse information, showing striking achievement in the second or lower tier cities.

The Internet is outstanding in promoting product and implementing favorable policy, but feeble in brand loyalty and brand construction. The invalid supervision of online shopping may even weaken the brand image and damage the brand competitiveness. When opening network channel, brand operators must make full use of it as a transmitter of information, for one thing maintaining brand image, for another realizing "viral marketing" to foster the potential customers via active human network.

Branding Strategies

"Pure blood" Versus "do as Romans do"

Western aesthetics and brand culture is admired and pursued by Orientals who regard consumption as a process of learning the connotation deep in the band. Therefore, brand should safeguard the inherent "cultural genes" and ensure its "pure blood", so that consumers can fully recognize cultural charm of brand. Nevertheless, the insight of standardization will never eliminate the respect and love for traditional culture, which seems to put luxury brand in a dilemma. Adhering to the original design and the fine processing work, policymakers should also take into account the cultural differences and distinct taste.

Symbolization and "cult of luxury brand (Chadha 2007)"

Consumers in both countries attach importance to brand's social value. Operators can signify and create iconic brand in order to express image whereby cultivating the cult of luxury brand. However, the Indian-style pursuit of the spiritual world and China's gifting behavior asks for focused strategies. In India, cultural transmission and experiential marketing will be efficient. As for china, elegant appearance merged into the brand image conforms to social etiquette, assisting consumers to perform well in social circle.

Catering to the Young Generation

Young customers are passionate in chasing luxury brands. Although financial situation and work pressure keep them from being customary buyers, they are keen on luxury brands indicative of future potential. It suggests that embodying the characteristics of the times not only in the brand connotation but in the media selection to attract young group may make far-reaching meaning for brand.

Conclusion

International luxury brands are vying for burgeoning markets like China and India as traditional ones have shown signs of plateau. Based on the PEST model, market demand in China and India is rising rapidly with uncertainty. As two representatives of the Oriental civilization, China and India display strong collectivism in contrast of western nations. However, different degree of collectivism is demonstrated in luxury consumption. The industry implication of this paper is that the complex similarities and differences within two nations necessitate distinctive strategies for marketers to seize the momentous opportunity, rather than simple replication of the "Chinese model" or "Indian way".

References

Berry CJ (1994) Berry, the idea of luxury: a conceptual and historical investigation. Cambridge University Press, Cambridge

Berthon PR, Pitt L, Parent M, Berthon J-P (2009) Aesthetics and ephemerality: observing and preserving the luxury brand. Calif Manag Rev 20(6):457–467

Chadha R (2007) Cult of the luxury brand: inside Asia's love affair with luxury. Nicholas Brealey Publishing, London

Hofstede G (1991) Cultures and organizations: software of mind. McGraw Hill, New York

Hong-ji Guo (2009) Analysis of the Indian democracy and Indian values (in Chinese). Soc Sci Res 9(5):61–66

Hung K-P et al (2011) Antecedents of luxury brand purchase intention. J Prod Brand Manag 20(6):457–467

Kapferer J-N (1997) Managing luxury brands. J Brand Manag 20(6):457–467

Klynveld Peat Marwick Goerdeler (2011) Luxury experience in China (Report style). KPMG, Hongkong

Mckinsey & Co (2011) Understanding China's growing love for luxury (Report style). Mckinsey & Co, China

O' Cass A, MeEwen H (2004) Exploring consumer status and conspicuous consumption. J Consum Behav 4(1):25–39

Shukla P (2011) Impact of interpersonal influences, brand origin and brand image on luxury purchase intentions: measuring interfunctional interactions and a cross-national comparison. J World Bus 46(2):242–252

Shu-pei Tsai (2005) Impact of personal orientation on luxury-brand purchase value. Int J Mark Res (4):177–206

Wang PZ, Waller DS (2006) Measuring consumer vanity: a cross-cultural validation. Psychol Mark 23(8):665–687

Wong NY, Ahuvia AC (1998) Personal taste and family face: luxury consumption in Confucian and western societies. Psychol Mark 15(5):423–441

Chapter 21
A Multi-stage and Parallel-Machine Scheduling Problem for Solar Cell Industry

Li-chih Wang, Chen-yang Cheng, Tzu-li Chen, Yin-yann Chen, and Chung-chun Wang

Abstract This paper studies a multi-stage and parallel-machines scheduling problem which is similar to the traditional hybrid flow shop scheduling (HFS) in the solar cell industry. The multi-stage and parallel-machines scheduling problem in the solar cell industry simultaneously determines the optimal production sequence, multiprocessor task scheduling and machine configurations through dynamically allocating all jobs to multiple machines. We formulate this problem as a mixed integer linear programming model considering the practical characteristics and constraints. A hybrid-coded genetic algorithm is developed to find a near-optimal solution. Preliminary computational study indicates that the developed algorithm not only provides good quality solutions.

Keywords Hybrid flow shop scheduling • Genetic algorithm • Solar cell industry

Introduction

Hybrid flow shop scheduling (HFS) was first proposed by Salvador (1973). Under this type of production environment, not only the process sequence of a job (also called work order) needs to be considered, dispatch problems, such as job allocation to machines, must also be considered, which increase the corresponding

L.-c. Wang (✉) • C.-y. Cheng • C.-c. Wang
Department of Industrial Engineering and Enterprise information,
Tunghai University, Taichung 40704, Taiwan, ROC
e-mail: wanglc@thu.edu.tw

T.-l. Chen
Department of Information Management, Fu Jen Catholic University,
New Taipei City 24205, Taiwan, ROC

Y.-y. Chen
Department of Industrial Management, National Formosa University,
Yunlin County 632, Taiwan, ROC

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_21,

complexity (Salvador 1973; Ribas et al. 2010). Chen and Lee (1999) highlighted that past studies of HFS were commonly based on a one-job-on-one-machine type. However, their study was unable to run each job on multiple machines in simultaneous operation for industrial applications. Therefore, they proposed the so-called multiprocessor task scheduling architecture. Under the HFS production environment, the number of machine resources for each job had to be established or known and then the optimal multiprocessor task scheduling in each stage could be determined. Ribas et al. (2010) believed that in a production environment of this type, not only did the processing sequence require consideration, but the dispatch issue of how to allocate jobs to multiple machines should also be scrutinized. HFS problems have evolved from the earliest use of one-job-on-one-machine to subsequent production environments with one-job-on-multiple-machines. However, the premise remains the same, namely that the machine resource allocation (or machine configuration) of each job must be established in advance before a planning approach can be implemented. Currently, a realistic problem in the solar cell industry arises from the unknown decisions of the job production sequence, machine resource configuration, and resource allocation, which will increase the difficulty and complexity of production scheduling.

In recent years, the popular solar cell industry has employed a similar production structure to HFS environments using multiprocessor task scheduling architecture. The production planners in the solar cell industry not only determines the multiprocessor task scheduling but also address the optimal machine configuration through dynamically allocating all jobs to multiple machines. Each job can be arranged with the largest number of machines during this production process. Additionally, the number of machines can be dynamically allocated to complete the job within the shortest possible time. The job production sequence only employs the traditional dispatching rules for job arrangement. Therefore, when the machine resource allocation and job production sequence are unknown, the complexity of the entire production scheduling will be increased considerably, as examined in the previous studies.

Therefore, this study conducts a case study on a company to explore the scheduling characteristics of crystalline silicon solar cell production. The characteristics include parallel processing, dedicated machines, sequence-independent setup time, and sequence-dependent setup time. A mixed integer linear programming (MILP) considering these practical characteristics is proposed to simultaneously generate the optimal job production sequence, machine configurations and parallel-machine scheduling in each stage to achieve the minimization of the maximum makespan. Due the computational complexity of the model, a hybrid-coded genetic algorithm (HCGA) was used to design the configuration of the production sequence and machine resource of each job to obtain the near-optimal scheduling configuration. Our preliminary computational study shows that the developed HCGA not only provides good quality solutions within a reasonable amount of time but also outperforms the classic branch and bound method and the current heuristic practiced by the case company.

Multi-stage and Parallel-Machine Scheduling Problem

The manufacturing of crystal silicon solar cells comprises six processes, and each process has its own characteristics that influence the production schedule. Therefore, these manufacturing process characteristics should be included in the production scheduling. The characteristics are detailed below:

Parallel Machine Processing

Identical parallel machines are used in the manufacturing process of crystalline silicon solar cells. When the job demand is high, a job must be allocated to more than one machine, increasing the capacity and reducing the makespan required to complete the job. There are three approaches to execute parallel machine scheduling.

Dedicated Machines

Crystalline silicon solar cells can be divided into single-crystal silicon solar cells and polysilicon solar cells. The manufacturing of both types uses the same machine and the same production process. The biggest difference is the dedicated machine used in first texturing process, with the polycrystalline silicon solar cells using an acid texturing method and single-crystal silicon solar cells using an alkaline texturing method. Therefore, the machines in these processes cannot be mixed. Thus, when the number of dedicated machines used for polysilicon differs from those of single crystalline silicon due to capacity variances, the subsequent scheduling method for the processes is influenced.

Sequence Independent Setup Time

During the printing process, the required electrode patterns are printed on both sides of the chip. In a crystalline silicon solar cell, the two wider electrodes of the cell are called busbars, and the extensions to the left and right sides contain numerous small electrodes called fingers. There are numerous screen printing design styles. However, for practicality, simplified symmetrical designs are typically used. Therefore, customers require various patterns for screen printing such as a sparse distribution (large distance) and a denser grid distribution (small distance). The density depends entirely on the customer's need to set a different screen pattern with extremely minor similarities. Thus, the order sequence of the network printing process for the job does not affect the duration of the setup time, which is referred to as sequence independent setup time. Conversely, independent setup time affects the performance of the entire scheduling. When the duration of setup time is effectively controlled, the overall makespan is reduced, improving planning results.

Sequence Dependent Setup Time

Due to the appearance of busbars on the crystalline silicon solar cell surface, the testing/sorting process is categorized as: 2 busbars and 3 busbars. Because the two busbars have a varying number of electrodes, for machines in the testing process, the measurement probe must be adjusted according to the number of electrodes in both busbar types. Therefore, when the batch of operations for the measuring machines is the 2-busbars product form and the next batch of operations is of the same (2 busbars) product form, then the number of measuring machine probes does not need adjustment. However, if operation is a 3-busbar form, then the setup for the number of machine probes must be adjusted. The probe adjustment time will be affected by the product sequence, which influences the setup time. This is referred to as sequence dependent setup time.

Problem Description

The production of silicon solar cells belongs to an HFS environment. In addition to the process characteristics mentioned previously, the number of products of the job is very high. The production cannot be completed in a short time. The method of lot splitting must be considered to evenly split the job into several jobs. Then various similar jobs can be processed simultaneously on a number of machines within the same process, thereby reducing the production time. In stage n, job 1 is divided into two sublots, with batch plan 1 operating on machine 1 and batch plan 2 operating on machine 2. In the next phase of stage $n + 1$, job 1 is not splitted but directly configured to operate on machine 4 to determine various combinations as required to minimize the overall planning completion time. Therefore, in addition to considering the production sequence of a job, into how many lots a job should be splitted, and which machines the jobs should be assigned to, are the problems examined by this study, which are described as follows.

1. Determine the production sequence of all work orders
2. Split each order into various sublots
3. Configure the machines after lot splitting

Methodology

In this section, we formulate the mixed integer programming model for the addressed HFS scheduling problem in the solar cell manufacturing, which is based on the standard form of the HFS problem. The indices, input parameters and decision variables of the optimal multi-stage and parallel-machine scheduling model are defined as follows.

Indices

$i, u =$ Work order index, $i, u = 1,2,\ldots, I$
$j =$ Processing stage index, $j = 1,2,\ldots, J$
$k =$ Machine index, $k = 1,2,\ldots, M_j$, M_j is the number of machines at stage j
$l =$ The index of the way of lot splitting, $l = 1,2,\ldots, L_j$, L_j is the number of ways of lot splitting at stage j

Parameters

$d_i =$ The demand quantity of work order i
$p_{i,j} =$ The processing time for work order i at stage j
$r_{j,l} =$ The production ratio factor at stage j when applying the lot-splitting way l
$s_i^{SI} =$ The sequence independent setup time for work order i
$b_i =$ The required number of the busbar for work order i (this value equals two or three)
$s_{b_i,b_u}^{SD} =$ The sequence dependent setup time when work order i is a direct predecessor of work order u
$e_{i,k} =$ The specialized machine constraints. If the work order i can be processed in machine k, $e_{i,k} = 1$; and otherwise, $e_{i,k} = 0$
$M =$ A large enough number

Decision Variables

C_{max} The makespan
$C_{i,j,k}$ The completion time of work order i in machine k at stage j
$X_{i,j,k}$ The production ratio of work order i in machine k at stage j
$Y_{i,j,k}$ $Y_{i,j,k} = 1$, if work order i is processed in machine k at stage j; $Y_{i,j,k} = 0$, otherwise
$W_{i,j,k,l}$ $W_{i,j,k,l} = 1$, if work order i is processed in machine k at stage j with applying the lot-splitting way l; $W_{i,j,k,l} = 0$, otherwise
$S_{i,u,j,k}$ $S_{i,u,j,k} = 1$, if work order i is processed in machine k at stage j before work order u; $S_{i,u,j,k} = 0$, otherwise

Objective Function

$$Minimize \;\; Z = C_{\max} \tag{21.1}$$

The objective function in Eq. (21.1) is to minimize the makespan of the schedule which is equal to the completion time of the last sublot processed in the system.

Constraints

The makespan constraint

$$C_{max} \geq C_{i,J,k} \quad \forall i,k \tag{21.2}$$

Processing sequence constraints

$$C_{i,j-1,k} + d_i \times X_{i,j,k} \times p_{i,j} \leq C_{i,j,k} \quad \forall i,j,k \tag{21.3}$$

Lot-splitting and specialized machine constraints

$$X_{i,j,k} = \sum_{l=1}^{L_j} r_{j,l} \times e_{i,k} \times W_{i,j,k,l} \quad \forall i,j,k;\ j = 1 \tag{21.4}$$

$$X_{i,j,k} = \sum_{l=1}^{L_j} r_{j,l} \times W_{i,j,k,l} \quad \forall i,j,k;\ j>1 \tag{21.5}$$

$$\sum_{l=1}^{L_j} W_{i,j,k,l} \leq 1 \quad \forall i,j,k \tag{21.6}$$

$$\sum_{k=1}^{M_j} e_{i,k} \times X_{i,j,k} = 1 \quad \forall i,j;\ j = 1 \tag{21.7}$$

$$\sum_{k=1}^{M_j} X_{i,j,k} = 1 \quad \forall i,j;\ j>1 \tag{21.8}$$

Work order sequencing constraints (for stage 1–4)

$$C_{u,j,k} \geq C_{i,j,k} + d_u \times X_{u,j,k} \times p_{u,j} - M(2 - Y_{i,j,k} - Y_{u,j,k}) - M(1 - S_{i,u,j,k}) \quad \forall i,u,j,k;\ i;\ j = 1,\ldots,4 \tag{21.9}$$

$$C_{i,j,k} \geq C_{u,j,k} + d_i \times X_{i,j,k} \times p_{i,j} - M \times (2 - Y_{i,j,k} - Y_{u,j,k}) - M \times S_{i,u,j,k} \quad \forall i,u,j,k;\ i<u;\ j = 1,\ldots,4 \tag{21.10}$$

Work order sequencing and independent setup time constraints (for stage 5)

$$C_{u,j,k} \geq C_{i,j,k} + d_u \times X_{u,j,k} \times p_{u,j} + s_u^{SI} \times Y_{u,j,k} - M(2 - Y_{i,j,k} - Y_{u,j,k}) - M(1 - S_{i,u,j,k}) \quad \forall i,u,j,k;\ i<u;\ j=5 \tag{21.11}$$

$$C_{i,j,k} \geq C_{u,j,k} + d_i \times X_{i,j,k} \times p_{i,j} + s_i^{SI} \times Y_{i,j,k} - M(2 - Y_{i,j,k} - Y_{u,j,k}) - M \times S_{i,u,j,k} \quad \forall i,u,j,k;\ i<u;\ j=5 \tag{21.12}$$

$$C_{i,j,k} \geq d_i \times X_{i,j,k} \times p_{i,j} + s_i^{SI} \times Y_{i,j,k} \quad \forall i,j,k;\ j=5 \tag{21.13}$$

Work order sequencing and dependent setup time constraints (for stage 6)

$$C_{u,j,k} \geq C_{i,j,k} + d_u \times X_{u,j,k} \times p_{u,j} + s_{b_i,b_u}^{SD} - M(2 - Y_{i,j,k} - Y_{u,j,k}) - M(1 - S_{i,u,j,k}) \quad \forall i,u,j,k;\ i \neq u;\ j=6 \tag{21.14}$$

$$C_{i,j,k} \geq C_{u,j,k} + d_i \times X_{i,j,k} \times p_{i,j} + s_{b_u,b_i}^{SD} - M(2 - Y_{i,j,k} - Y_{u,j,k}) - M \times S_{i,u,j,k} \quad \forall i,u,j,k;\ i<u;\ j=6 \tag{21.15}$$

Others and domain constraints

$$X_{i,j,k} \leq M \times Y_{i,j,k} \quad \forall i,j,k \tag{21.16}$$

$$Y_{i,j,k} \in \{0,1\} \quad \forall i,j,k \tag{21.17}$$

$$W_{i,j,k,l} \in \{0,1\} \quad \forall i,j,k,l \tag{21.18}$$

$$S_{i,u,j,k} \in \{0,1\} \quad \forall i,u,j,k \tag{21.19}$$

$$X_{i,j,k} \geq 0 \quad \forall i,j,k \tag{21.20}$$

$$C_{i,j,k} \geq 0 \text{ (integers)} \quad \forall i,j,k \tag{21.21}$$

Equation (21.2) states that the makespan of the schedule, C_{max} is greater than or equal to the completion time of any sublot on the last stage. Equation (21.3) indicates that the completion time for work order i in machine k at stage j is greater than or equal to the completion time on the preceding stage $j - 1$ plus the processing time on the current stage j. The processing quantity demanded of each sublot depends on the number of machines. For example, the processing quantity demanded of a certain work order is 900 units. If applying any two machines to process this order, it will be splitted into two sublots, the quantity of which is 450 units each. In this case, the production ratio ($X_{i,j,k}$) is 1/2. Equations (21.4) and (21.5) determine the production ratio ($X_{i,j,k}$). Because the number of processing machines at every stage is given in advance, all possible ways of lot-splitting at any stage are also known. For instance, there are three identical parallel machines at a certain stage, and then it has three lot-splitting ways in this situation, with applying one, two, or three machines to process orders. The production ratio factor ($r_{j,l}$) is 1, 1/2, or 1/3, respectively. Equations (21.4) and (21.5) are similar except for the specialized machine consideration for single-crystalline or poly-crystalline silicon at the first stage in Eqs. (21.4) and (21.6) ensures that the production ratio ($X_{i,j,k}$) only equals one of all possible production ratio factors at any stage or zero. In other words, when the work order is split ($W_{i,j,k,l} = 1$), its lot-splitting way is one of all possible lot-splitting ones. The sum of the sublot size in all machines at a certain stage must equal the processing quantity demanded. Therefore, Eqs. (21.7) and (21.8) state that the sum of the production ratio ($X_{i,j,k}$) of the order i in each machine k at stage j equals 1.

Sequencing constraints must be imposed on a pair of work orders i and u only if they are allocated to the same machine k. If work order i is run earlier than u, then $S_{i,u,j,k} = 1$ and Eq. (21.9) is enforced to guarantee that work order u will begin after completing the work order i. Moreover, the other sequencing constraint Eq. (21.10) becomes redundant. On the other hand, if work order i is run later than u ($S_{i,u,j,k} = 0$) at the same machine k, then constraint Eq. (21.10) must hold to prevent from starting i before ending u. In addition, Eq. (21.9) will become redundant. Otherwise, such a pair of work orders (i and u) is not carried out at the same machine ($Y_{i,j,k} + Y_{u,j,k} < 2$) and, consequently, Eqs. (21.9) and (21.10) become both redundant and the value of the sequencing variable $S_{i,u,j,k}$ is meaningless. Besides, it is worth mentioning a significant saving in sequencing variables is achieved by $i < u$ as follows from Eqs. (21.9) and (21.10). The number of sequencing variables $\{ S_{i,u,j,k} \}$ is reduced by half.

Equations (21.11) and (21.12) are similar to Eqs. (21.9) and (21.10) except for adding the sequencing independent setup time in the "*Printing*" stage. Equation (21.13) ensures that the completion time for work order i in machine k at "*printing*" stage is greater than or equal to the processing time plus the sequencing independent setup time. Equations (21.14) and (21.15) are similar to Eqs. (21.9) and (21.10) except for adding the sequencing dependent setup time between two work orders in the "*Testing/Sorting*" stage.

In Eq. (21.16), it is shown whether the work order i is processed in machine k at stage j. $Y_{i,j,k}$ equals 1 if work order i is processed in machine k at stage j ($X_{i,j,k} > 0$); otherwise ($X_{i,j,k} = 0$), $Y_{i,j,k}$ equals 0. Equations (21.17), (21.18), (21.19), (21.20) and (21.21) are the domain restrictions on the decision variables.

Hybrid-Coded Genetic Algorithm(HCGA)

In this section, a novel hybrid-coded genetic algorithm (HCGA) is designed to find the near-optimal solution through the evolutionary process because of the computational complexity of the proposed MILP model. Figure 21.1 shows the flow chart of the HCGA algorithm.

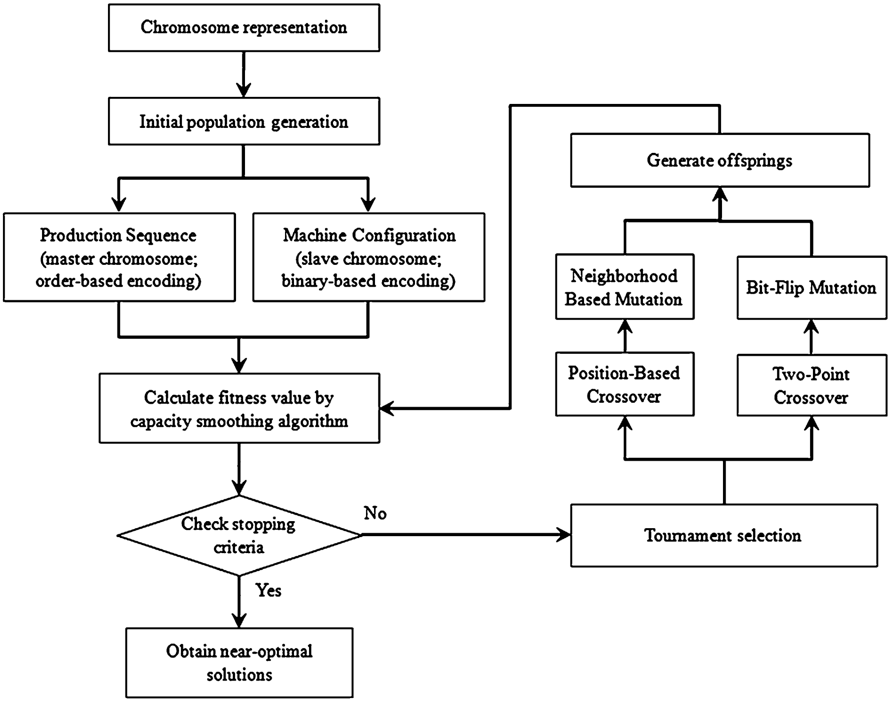


Fig. 21.1 The flow chart of the proposed HCGA

Results

Ten samples of different sizes shown in Table 21.1 are collected and modified from the solar cell manufacturing industry for this computational study. The MILP model of hybrid flow shop scheduling is formulated by using the ILOG CPLEX and solved by traditional B&B algorithms. The proposed hybrid-coded genetic algorithm is implemented by Visual C++ programming language. A personal computer with an Intel Core 2 Quad 2.5 GHz processor and 2 GB RAM is used to execute and test the algorithms. In order to determine the suitable control parameters of the HCGA, we conducted the full factorial design of experiments to identify the optimal settings for the control parameters of the proposed HCGA. The best settings of GA control parameters are found in Table 21.2 and they will be used in the following computational study.

We compared objective value and solution gap (%) between the developed hybrid-coded genetic algorithm and the B&B algorithm. The minimal, average, maximal solution gaps and objective value of all solved problems are shown in Table 21.3. The row with symbol * means that its optimal solution computed by the MILP model is an estimated value since CPLEX optimizer runs out of memory. From this table, we can observe that the value of average solution gaps between

Table 21.1 Ten testing samples with different sizes

Data Size	Problem number	Problem size (order, machine, stage)	No. of continuous variables	No. of binary variables	No. of integer variables	No. of total variables	No. of constraints
Small	1	(3, 3, 4)	36	180	37	253	770
	2	(3, 5, 4)	60	420	61	541	1,604
	3	(3, 8, 4)	60	360	61	481	1,522
	4	(5, 5, 6)	150	1,200	151	1,501	4,632
	5	(5, 8, 6)	240	2,640	241	3,121	9,431
Large	6	(10, 8, 6)	480	6,480	481	7,441	23,662
	7	(10, 10, 6)	600	9,300	601	10,501	32,962
	8	(20, 10, 8)	1,600	31,280	1,601	34,481	117,322
	9	(20, 15, 8)	2,400	61,200	2,401	66,001	214,962
	10	(50, 15, 8)	6,000	243,000	6,001	255,001	699,626

Table 21.2 The best settings of HCGA control parameters

The GA parameters	Value
Population size	700
Offspring size	700
Crossover rate	0.8
Mutation rate	0.1
Selection strategy	Tournament selection

Table 21.3 The objective value and solution gap (%) between B&B and HCGA

			CPLEX Optimizer (B & B)	Hybrid-coded genetic algorithm		
Data size	Problem number	Problem size (orders, machines, stages)	Solution	Min. solution (solution gap %)	Average solution (solution gap %)	Max. solution (solution gap %)
Small	1	(3, 3, 4)	76,500	76,500,(0)	76,530 (0.0392)	76,800 (0.3922)
	2	(3, 5, 4)	25,200	25,200 (0)	25,260 (0.2381)	25,800 (2.3810)
	3	(3, 8, 4)	103,500*	99,300 (−4.0580)	102,210 (−1.2646)	10.3,500 (0)
	4	(5, 5, 6)	64,800*	60,570 (−6.5278)	63,645 (−1.7824)	66,480 (2.5926)
	5	(5, 8, 6)	98,100*	45,900 (−53.211)	49,439.2 (−49.603)	55,285 (−43.644)
Large	6	(10, 8, 6)	–	69,750	77,286	79,650
	7	(10, 10, 6)	–	59,640	71,386.9	74,031
	8	(20, 10, 8)	–	115,200	129,192.5	135,540
	9	(20, 15, 8)	–	150,701	155,553.1	165,954
	10	(50, 15, 8)	–	360,000	367,008	374,400

*Branch and bound method in CPLEX runs out of memory

Table 21.4 The comparison of CPU times between B&B and HCGA

			CPLEX optimizer (B & B)	Hybrid-coded genetic algorithm		
Data size	Problem number	Problem size (orders, machines, stages)	CPU time (second)	Min. CPU time (second)	Average CPU time (second)	Max. CPU time (second)
Small	1	(3, 3, 4)	58.00	6.49	6.70	6.90
	2	(3, 5, 4)	1,257	9.47	9.79	10.06
	3	(3, 8, 4)	>2,334.69*	75.27	79.28	81.49
	4	(5, 5, 6)	>5,140.52*	351.79	367.46	384.60
	5	(5, 8, 6)	>977.22*	263.17	272.99	283.90
Large	6	(10, 8, 6)	>2,087.50*	385.25	397.68	408.74
	7	(10, 10, 6)	>1,531.16*	476.65	498.59	526.7
	8	(20, 10, 8)	>3,107.84*	1,393.76	1,424.00	526.7
	9	(20, 15, 8)	>2,098.42*	1,806.99	1,853.44	1,913.32
	10	(50, 15, 8)	–	2,338.27	2,438.58	2,600.66

*Branch and bound method in CPLEX runs out of memory

these two algorithms lie between 0 and 1% in problem #1 and problem #2. The proposed HCGA can also reach the optimization solution since minimal solution gap equals to zero under the best case. This shows that the hybrid-coded genetic algorithm can find the near-optimal solution.

Moreover, the value of average solution gaps between these two algorithms is "negative" from problem #3 to problem #5. It means that the solution provided by the hybrid-coded genetic algorithm is better than the one generated by the terminated B&B algorithm. In these samples, the B&B algorithm uses up the memory and has little distance with the optimal solution. The hybrid-coded genetic algorithm, on the other hand, can still find the near-optimal solution and even outperform the terminated B&B algorithm. In the large samples (from problem #6 to problem #10), we further observed that the B&B algorithm not only spends more time but cannot obtain any feasible solutions. The developed GA still generates better solutions for the large samples in the reasonable time. Consequently, from above analysis, our results claim that the proposed hybrid-coded genetic algorithm not only provides the near-optimal solutions irrespective of the size of the sample data; it also generates the better solutions for large scale samples in which B&B algorithm cannot found any feasible solutions.

The minimal, average and maximal CPU time of all solved problems are shown in Table 21.4. The row with symbol * means that the real CPU time of the specific problem is greater than the estimated CPU time since CPLEX optimizer runs out of memory. From this table, we observed that the computational speeds of the hybrid-coded GA outperform the traditional B&B algorithm and the B&B algorithm grows exponentially with the problem sizes. Even the B&B algorithm is not executable in problem #10 due to the more requirements in the memory space. Thus, it is not feasible for solving realistically large size problems. However, the hybrid-coded GA only needs fewer CPU time and memory to generate the near-optimal solution compared with the terminated B&B algorithm and have best performances in large size problems. From the above analyses of the solution quality and computational time, it can be deduced that the hybrid-coded genetic algorithm can provide better quality solutions within a reasonable amount of time as data size increases. Thus, this heuristic is more suitable for solving realistically large size problems of hybrid flow shop scheduling problems.

Conclusion

In this paper, we present a multi-stage and parallel-machine scheduling problem which is similar to the traditional hybrid flow shop scheduling (HFS) in the solar cell industry. The multi-stage and parallel-machines scheduling problem simultaneously determines order production sequence, multiprocessor task scheduling and optimal machine configuration through dynamically allocating all jobs to multiple machines under the minimization of the maximum makespan. A mixed integer linear programming model has been proposed, in consideration of many practical characteristics including hybrid flow shop, parallel machine system, specified machines, sequence-independent setup time, and sequence-dependent setup time. Because of the computational complexity, a hybrid-coded genetic algorithm has been developed for finding a near-optimal solution. The computational study shows that the proposed algorithm could be more suitable and efficient for solving large size problems than the conventional B&B algorithm.

Acknowledgment The authors gratefully acknowledge the National Science Council, Taiwan, R.O.C., for support under contract NSC 98-2221-E-029-018-MY3 and NSC 100-2221-E-029-011.

References

Allahverdi A, Mittenthal J (1994) Scheduling on M parallel machines subject to random breakdowns to minimize expected mean flow time. Nav Res Logist 41(5):677–682

Chen J, Lee CY (1999) General multiprocessor task scheduling. Nav Res Logist 46(1):57–74

Engin O, Ceran G, Yilmaz MK (2011) An efficient genetic algorithm for hybrid flow shop scheduling with multiprocessor task problems. Appl Soft Comput 11(3):3056–3065

Garey MR, Johnson DS (1979) Computers and intractability: a guide to the theory of NP-completeness. San Francisco W.H. Freeman & Co. New York, USA © 1990

Jin ZH, Ohno K, Ito T, Elmaghraby SE (2002) Scheduling hybrid flow shops in printed circuit board assembly lines. Prod Oper Manag 11(2):216–230

Ribas I, Leisten R, Framin JM (2010) Review and classification of hybrid flow shop scheduling problems from a production system and a solutions procedure perspective. Comput Oper Res 37:1439–1454

Ruiz R, Vázquez-Rodríguez JA (2010) Invited review. The hybrid flow shop scheduling problem. Eur J Oper Res 205(1):1–18

Salvador MS (1973) A solution to a special class of flow shop scheduling problems. In: Elmaghraby SE (ed) Symposium on the theory of scheduling and its applications. Springer, Berlin, pp 83–91

Chapter 22
The Research of Creative Design of Green Equipment for Caring Outdoor Activities

Ming-Tang Wang, Rain Chen, Jenn-Yang Lin, and Chang-Tzuoh Wu

Abstract According to the four stages of iNPD, the green equipment for outdoor activities is designed. Its description is as follows: (1) Lifestyle impact: internet technology transforms for leisure of special group to become customized mobile products, (2) Ergonomics: green energy (solar) as power supply with electrical storage devices which can track sunshine direction, and easy to close and carry. (3) Feature: a tree structure for outdoor activities, and can integrate with existing WiMAX equipment for LAN.

Keywords iNPD • Caring design • Green equipment • Outdoor activities

Introduction

In the history of human beings, there is a tendency to live together for purpose. Thus, they live in a style from families, tribes to cities, and have been particularly influential in contributing to communication of each other. The continuing improvements in communication difficulties arisen from the obstacles of different tribes or cities have led to many fascinating applications from carrier pigeons, letter dogs, and smoke of flame. However, it is difficult to communicate

M.-T. Wang (✉) • C.-T. Wu
Department of Industrial Design, National Kaohsiung Normal University, Kaohsiung, Taiwan, Republic of China
e-mail: mtwang2000@gmail.com

R. Chen
Department of Creative Product Design, Southern Taiwan University, Tainan, Taiwan, Republic of China

J.-Y. Lin
Department of Creative Product Design, Nanhua University, Chiayi, Taiwan, Republic of China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_22,

effectively because there are obstacles of mountains and water. The increasing usage of requirements for transferring and exchanging information among human beings has become more critical. In order to overcome the barriers of terrain and distance and to create more efficient solutions, the scientists invented the telegraph and telephone for voice communication after the discovery of electricity.

Although the development of wired communication technology has made great progress, the connected devices cannot efficiently build the wired cable to fit needs and the subsidiary needs to connect related products for information communication. The use of technology in the voice communication has been increasing the objects from wired to wireless in recent years. Many transmission technologies have been made use of electrical appliances in livelihood simultaneously, and have influenced consumers' social behaviors. The reason the wireless transmission has naturally become a main trend is that it relies on base station to own characteristics of infinite direction of the limited range for information communication. There are LAN (Local Area Network) and WLAN (Wireless Local Area Network) of wireless transmission services which can provide indoor (within a distance of 100 m) low-mobility and high-speed. Unfortunately, there are many standard agreements for requirements in the WLAN and LAN. The main usages are the band of 2.4 GHz: IEEE 802.11(b/g) and band of 5 GHz: IEEE 802.11a, HIPERLAN-2 and other specifications. The other wireless personal area network (WPAN) also has an emerging development trend of wireless access. It can be applied in short-range and low-power wireless transmission technology to connect home appliances (printers, cell phones, PDA, etc.).

In common, the mobile internet facilities (NB or smart phone, pad, etc.) do not have better application with a convenient wireless AP (Access Point). The Wifi and WiMAX (Metropolitan Area Network) work for the general area network in public. However, the greatest disadvantage of WiFi is the transmission distance which is about 10–100 m. In contrast, the WiMAX technology has better transmission distance which is over 10 km with the fastest transmission (70 Mbps). It is not only solve the problem of inadequate Wifi Internet coverage in wireless cities, but also connect as the last mile in a network for business or home application.

The process of research innovates wireless product opportunities for meeting consumers' needs, it is always meet the fuzzy front end of opportunities. Cagan and Vogel (2002) proposed that a process of the integrated New Product Development (iNPD) is not just a set of methods that can be plugged into an existing company structure. It is a way of thinking that combines three key elements: (1) A truly horizontal and interdisciplinary structure. (2) A commitment to maintain a focus on what customers and other stakeholders value. (3) A system that begins with an emphasis on qualitative methods of discovery and development and evolves toward quantitative methods of real methods of refinement and manufacture. It is a good way to transfer and combine the marketing research, engineering and design of products to explore the complex and comprehensive research. Therefore, a number of studies have investigated this question since the process of iNPD. Xin et al. (2007) have applied this way to use motion capture as a quantitative tool to study dynamic ergonomics, physical ability both in two dimensions and in motion and to

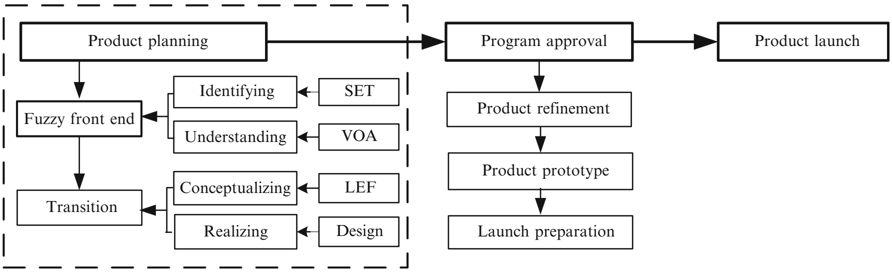


Fig. 22.1 The process of product development (Cagan and Vogel 2002)

provide insights for understanding the physical limitations of users and the usability of products. Metzler and Shea (2011) put lessons learned from a project-based approach for teaching new cognitive product development to multi-disciplinary student teams. In order to deepen our understanding of the method, Xu et al. (2010) have investigated Industrial design rationally through the iNPD process of high-tech industrialization by two actual projects through the use of these methods. Rothstein said managing integrated development, cross-functional teams and strategic planning are the challenges that many of today's business and design leaders face. Several studies have suggested the benefits of iNPD, but there has been relatively little research (Fig. 22.1).

The internet application technologies have great progress whereas the exploration of application of wireless network become crazy because the infrastructure is still in progress. Although the lack of frequency has been complained, the important point is only the application. In order to explore the concepts of application, the major purpose of the present study was to investigate the fuzzy front end of wireless communication and coordinate the possible ways of using wireless equipment in outdoor activities.

Methodology

The process of iNPD consists of four stages: (1) identifying opportunities, (2) understanding opportunities, (3) conceptualizing opportunities, (4) realizing opportunities (Rothstein 2012; Clarkson and Eckert 2005; Sun 2006) (Fig. 22.2).

1. The first stage – identifying opportunities
   In this stage, it is way to collect the SET factors (Social change, Economic trends and Technological innovation) for locating a better position of innovative planning as the product opportunity gaps (POGs). According to Akman and Mishra (2010), the age has a positive impact on average daily use of the Internet in general and a negative impact on the use of the Internet for information access. The main target groups of using the wireless communication equipment are the young and the highly educated whose ages are between 18 and 35. In this study, there are eight participants whose age are from 20 to 24. They own the

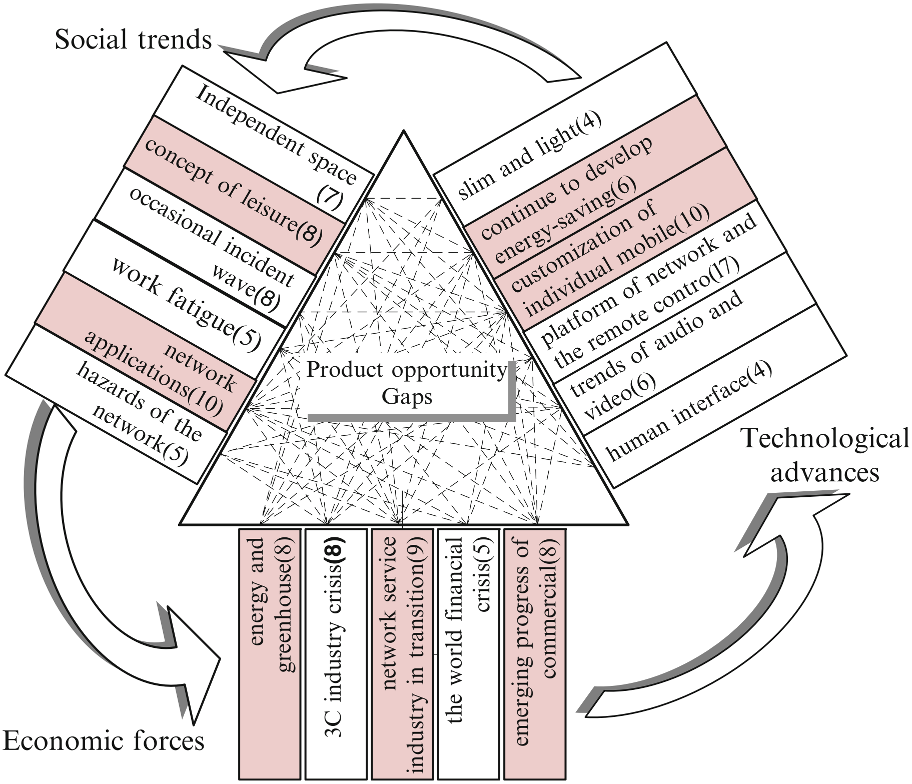


Fig. 22.2 The POGs from SET

basic knowledge of designing the wireless transmission products and major in product design, visual communication design, information and communication, information engineering and electronic engineering design. In order to collect the factors of all issues of SET, they will have brainstorming and then verify related issues of SET to be grouped as POGs.

2. The second stage – understanding opportunities
   In order to recognize the POGs of SET after the first stage, they continue to understand the opportunities of possible products. The values of opportunities will be divided into seven composite values: emotion, ergonomics, aesthetics, identity, impact, core technology and quality. Afterwards, value opportunities analysis (VOA) is used to make the descriptions of POGs clear. The five steps need to be followed: (A) Opportunities modification: adjust and increase several values to fit for possible products. (B) Quantitative survey: It is for identifying the significant values that have a semantic survey of products from the questionnaire which is with seven segments of Likert scale, and all examinees' age is between 20 and 29 with high using rate of network. (C) Reliability and validity analysis: The reliability of each sample of opportunity values will be verified the coefficient of

Cronbach α by scale analysis. It means credible when the coefficient is higher than 0.4, and the higher is the better. The other validity can be checked from factor analysis, and someone will be deleted to ensure validity because its factor loading is under 0.5. (D) Descriptive statistics: Each average of descriptive statistics of requirement is less than 1.5 which is deemed as 'low'. 1.5–4 is deemed as 'moderate' requirements, and more than 4 is deemed as 'high'. Some of the values will be pointed to describe. (E) Find the fuzzy front end: Integrations of the high average of descriptive statistics and GOPs are seemed as the direction of product design.

3. The third stage – conceptualizing opportunities
   In this stage, the pictures will be simulated the preferred orientation of significant value opportunities for target groups which will focus on the LEF (Lifestyle, Ergonomics, Figure): (A) set up the users' lifestyle to conceptualize product design direction, (B) be oriented from users, and center on caring human and earth to concentrate direction.
4. The fourth stage – realizing opportunities
   In order to realize the opportunities, the green direction of the concept should be consistent with the result of the study and care the outdoor activities. It will be proposed by sketch as first presentation.

Results

Identifying Opportunities

In order to identify opportunities, relevant issues of social trends, economics forces, and technological advances by eight participants in brainstorming as SET exploration were collected. Then, relevant issues of each factor groups by KJ method were converged. Thus, 25 issues of social trends were categorized into 6 topics, 24 issues of economic forces into 5 topics, and 24 issues of technological advances into 6 topics (Table 22.1). In order to synthesize GOPs, the cross-correlation of SET topics was linked and then the frequencies (X) of topics was calculated, and all convergent topics in a value (Y) between 1 and 3 was weighed. The sorting scores (Z) were multiplied from the values of frequencies and weighed (Table 22.1), which has ranked the higher ones as the possible POG. Finally, the wireless communications design directions were synthesized as follows: (1) a personal customized mobile products with internet technology and (2) a concept for leisure activities from convenient and unlimited solar energy.

Understanding Opportunities

Value opportunities (VO) can be classified into specific attributes that contribute to the usefulness, usability, and durability of a product, and connect the features of a product to those values. There are seven categories: emotion, ergonomic, aesthetic,

Table 22.1 Evaluation of the factors of set

Social trends	X	Y	Z	Economic forces Item	X	Y	Z	Technological advances Item	X	Y	Z
1. Independent space	7	1	7	1. Energy and greenhouse	8	3	24	1. Slim and light	7	3	21
2. Concept of leisure	8	3	24	2. 3C industry crisis	8	1	8	2. Continue to develop energy-saving	10	3	30
3. Occasional incident wave	8	1	8	3. Network service industry in transition	9	3	27	3. Customization of individual mobile	7	3	21
4. Work fatigue	5	2	10	4. The world financial crisis	5	1	5	4. Platform of network and remote control	6	1	6
5. Network applications	10	3	30	5. Emerging progress of commercial	8	2	16	5. Trends of audio and video	4	2	8
6. Hazards of network	5	2	10					6. Human interface	7	3	21

Table 22.2 The adjustment of product opportunities

	original	Modification
1. Emotion	Adventure, independence, security, sensuality, confidence, power	Excitement, fresh, creativity, security, deluxe, excellence, confidence, reliability, authority, controlling
2. Ergonomic	Comfort, safety, ease of use	Comfort, safety, ease of use
3. Aesthetics	Visual, auditory, tactile, olfactory, taste	Visual, auditory, tactile, olfactory, taste
4. Identity	Point in time, sense of place, personality	Point in palace, characteristic, personality
5. Impact	Social, environmental	The self, others, environmental
6. Core tech	Reliable, enabling	Reliable, enabling, effectiveness
7. Quality	Craftsmanship, durability	Appropriateness, craftsmanship, durability

identity, impact, core tech and quality. Each of the seven VO classes contributes to the overall experience of the product which have 23 original items, and have adjusted to be 30 items by 8 participants for fitting possible direction (Table 22.2).

Those 30 items had made questionnaire with 7 segments of Likert scale and taken quantitative survey in Internet Survey from 5/23/2011 to 6/23/2011. There were 728 examinees to participate in this internet survey and 639 valid questionnaires were received. The distributive regions of questionnaires in Taiwan: north, central, south and east. The examinees were men (52.9%) and women (47.1%). Through the correlation analysis of the 30 values, there were two pairs of two variables. The results of inter-correlation were lower than all values that were suitable for further analysis.

Firstly, we held a scale survey for reliability analysis of 30 items of opportunity values. The value of Cronbach's Alpha of all items was 0.886 which indicated a high credibility of the survey sample. Secondly, principal component analysis and equamax shaft method were selected to run factor analysis. All values of Cronbach's Alpha were over than 0.5 indicated the validity, and all items can be retained for subsequent descriptive statistics.

The descriptive statistics of questionnaire surveys found more important values of opportunities that were the creativity (5.05) on emotion, the ease of use (4.86) on ergonomics, the visual (5.42) on aesthetics, the point in place (5.42) on identity, the environmental (5.24) on core tech, the enabling (5.41) on identity, and the durability (5.45) on quality (Fig. 22.3). A structure for fitting upper opportunities, was proposed and described in the next stage.

Conceptualizing Opportunities

Nevertheless, considering the conceptualization of opportunities, we opted the empirical data and major items to recognize the fuzzy front end of opportunities.

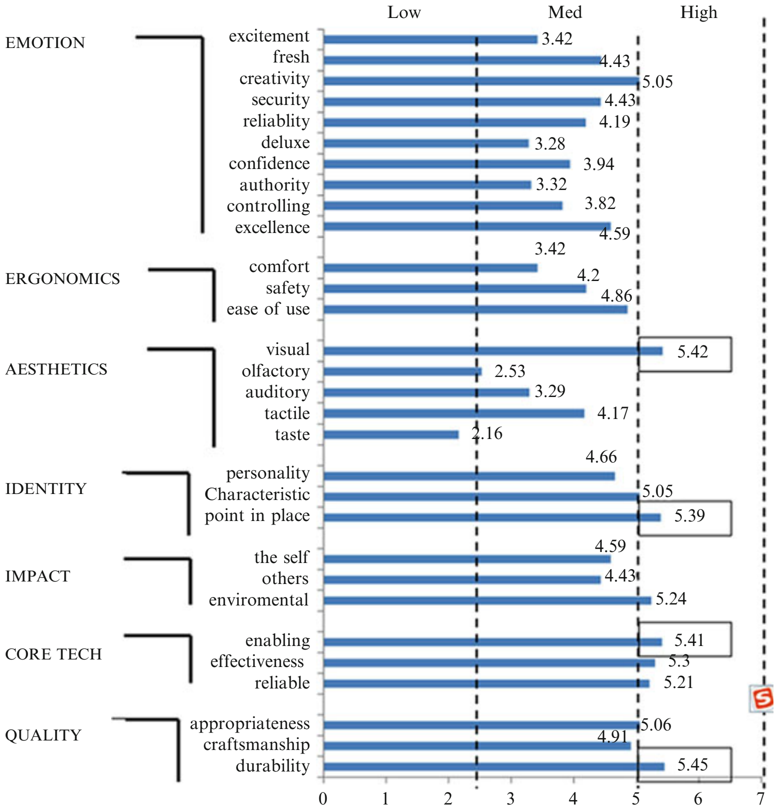


Fig. 22.3 The value of product opportunities

It is better to create a structure of solar energy power supply for wireless equipment than a green router unit.

1. User life style
   Exploring a feasible and potential wireless product which can be constructed for outdoor space: temporary camping area, golf course, the mobile caravan, and the needs for external communications for regional communication network. Nevertheless, people in outdoor leisure activities are difficult to receive signal or use the temporary network facilities to overcome point in place (Fig. 22.4).
2. Moving to first quadrant
   The product should approach the first quadrant and thus can be a green equipment for accessing wireless facility (Fig. 22.5).
3. Integration of style and technology
   It depends on LEF: (1) Lifestyle impact: become customized mobile products with internet technology for leisure special group (2) Ergonomics: a green energy (solar)

Fig. 22.4 The lifestyle of user

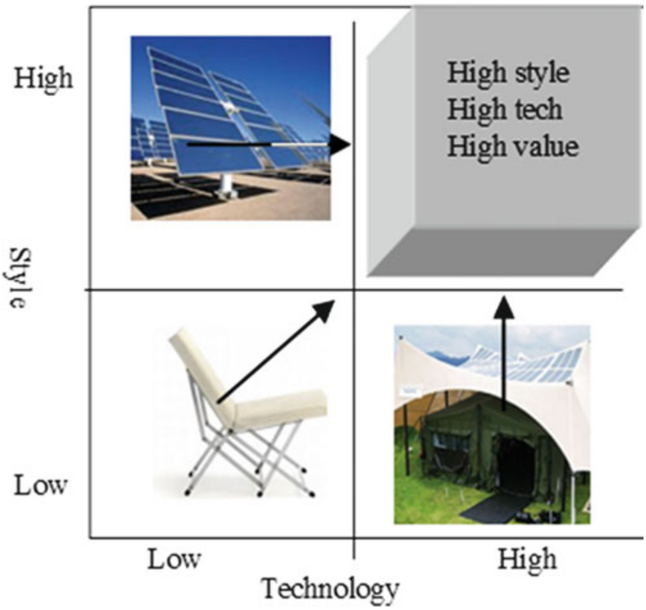
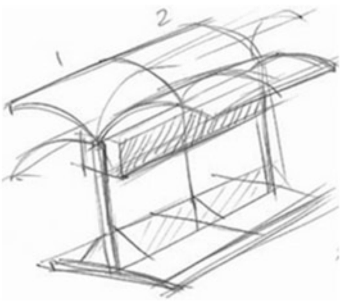
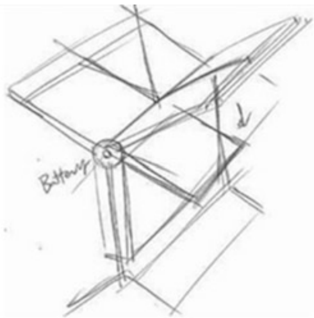


Fig. 22.5 The style and technology go in the first quadrant (Casual folding chair 2012; Solar energy 2012; Solar tent for USA army 2012)

Table 22.3 The creative design for green equipment

LEF	Collected factors	Direction
L	Environmental impact	Become customized mobile products with internet technology for leisure special group
	Customized personal mobile	
	Leisure activities	
E	Easy operation	To use solar as power supply, can track sunshine direction, and easy to close and portability
	The point in place	
	Durability	
	Unlimited energy	
F	Creativity	Outdoor green tree structure with the existing WiMAX equipment for LAN
	Visual attention	

Table 22.4 Idea sketch of structure

Idea-1	Idea-2
	

power supply with electrical storage and portability (3) Feature: outdoor environmental tree structure can integrate the existing WiMAX equipment for LAN (Table 22.3).

Realizing Opportunities

The design created from investigated concept is a foldable tree structure with solar light panel which could assemble the solar light panel (670*816*40(m/m)) with battery and the router with DC 5 V = 1.2 A to construct a sustainable changeable product. There are several idea sketches and two are selected (Table 22.4). Finally, we design the adjustable solar light panel with wireless router of Wimax which can fold for portable, and have a heavy battery as base (Fig. 22.6).

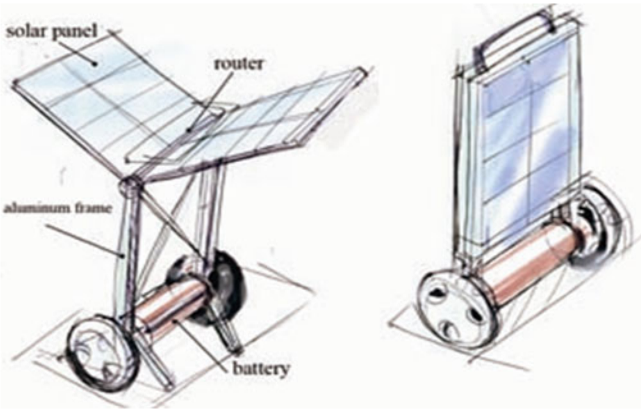


Fig. 22.6 Sketch for proposal: using and folding

Conclusion

Finally, we are responsible for the following process of iNPD to propose the design of green wireless equipment for caring outdoor activities. We are aware of a foldable solar energy supply with tree structure for customized mobile internet product because the energy supply is a main obstacle in outdoor activities. This creative concept is a structure for integrating the existing WiMAX equipment for LAN that is a less expensive and less complicated product for outdoor activities.

References

Akman I, Mishra A (2010) Gender, age and income differences in internet usage among employees in organizations. Comput Hum Behav 26:482–490

Cagan J, Vogel MC (2002) Breakthrough products: innovation from product planning to program approval. Pearson Education, Inc., Upper Saddle River, p 108

Casual folding chair, 2012/4/2. http://www.topchair.cn/blog/post/303.html

Clarkson J, Eckert C (2005) Design process improvement: a review of current practice. In: Cagan J, Vogel CM (eds) Integrated new product development. Springer, pp 389–403

Metzler T, Shea K (2011) Lessons learned from a project-based approach for teaching new cognitive product development to multi-disciplinary student teams. In: Proceedings of the ASME 2011 international design engineering technical conferences & computers and information in engineering conference, Washington, DC, USA, pp 1–10, 29–31 Aug 2011

Rothstein P, Closing the gap between practice and education: a case study. Arizona State University, 2012/4/2, from http://www.idsa.org

Solar energy, 2012/4/2. http://www.conserve-energy-future.com/SolarEnergy.php

Solar tent for USA army. 2012/4/2. http://www.patent-cn.com/tag/%E5%A4%AA%E9%98%B3%E8%83%BD/page/2

Sun ZX (2006) Application of user-centered iNPD method. Packag Eng 27(5):255–267

Xin X, Vogel C, Ma H (2007) Motion capture as a user research tool in Dynamic Ergonomics. In: Proceedings of the 15th conference international association of design research, pp 1–8

Xu L, Zong GH, Zhang R (2010) The research and application of industrial design method based on iNPD. J Eng Gr 31(4):130–139

Chapter 23
Mean Shifts Identification in Multivariate Autocorrelated Processes Based on PSO-SVM Pattern Recognizer

Chi Zhang and Zhen He

Abstract In multivariate statistical process control, interpretation of a signal issued by multivariate control charts is very useful to find source(s) of variation that result in the out-of-control condition. This paper develops a support vector machine(SVM) based model for multivariate autocorrelated processes to diagnose abnormal patterns of process mean changes, and to help identify abnormal variable (s) when residual T^2 control chart issue an alarm. Particle swarm optimization (PSO) method is adopted to determine the values of penalty parameter and kernel parameter of the model to improve the performance of the SVM pattern recognizer. The results demonstrate that the proposed method provides an excellent performance in terms of accuracy of classifying patterns of out-of-control signals.

Keywords Multivariate autocorrelated processes • Support vector machine • Particle swarm optimization • Quality diagnosis

Introduction

In many industries, multivariate control charts are a widely used tool of quality control, which are applied to monitor process abnormalities and minimize process variations. However, traditional multivariate control charts will give too many false alarms if apply in some process industries because data from these facilities are autocorrelated. A common approach for monitoring multivariate autocorrelated processes is to remove the autocorrelation from the data using time series model then apply multivariate control charts to the residuals, as in Yang and Sun (2006), Sun and Yang (2007), Pan and Jarrett (2007), Jarrett and Pan (2007). Besides time series models, data mining models are also used to predict and obtain the residuals of the

C. Zhang (✉) • Z. He
Department of Management Science and Engineering, University of Tianjin, Tianjin, China
e-mail: zhangchi123060@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_23,

processes. Neural network regression based model can be used to obtain residuals and construct residuals Cumulative Sum chart for multivariate autocorrelated processes, see Arkat et al. (2007). Also support vector regression method can be used to obtain and construct residuals Multivariate Cumulative Sum (MCUSUM) control chart for monitoring mean shifts in multivariate autocorrelated processes, see Issam and Mohamed (2008). Because these residuals are not the original observations of the process, it may not be easier for operators to interpret the out-of-control signal issued by residual-based control chart. Thus, some original observations-based methods are proposed. One class classification-based control charts was proposed to monitor multivariate autocorrelated processes, see Kim et al. (2010). Some works considered modified control charts scheme for original multivariate autocorrelated processes observation, as in Kramer and Schmid (1997), Bodnar and Schmid (2007, 2011). All the above-mentioned researches can handle multivariate autocorrelated process monitoring problems but they can't interpret the source of variations when control charts issue an alarm.

There are only very few existing researches focusing on the problem of identifying variables that result in the out-of-control condition in multivariate autocorrelated processes. A Z-chart method was firstly proposed which can both detect an out of control status and identify variable(s) result in the out of control situation in Kalgonda and Kulkarni (2004). Neural networks are used to monitor mean shift and identify variables that give rise to the out-of-control condition in Fountoulaki et al. (2011), Hwarng and Wang (2010). Though support vector machine (SVM) has proved effective in identifying abnormal variable(s) in independent multivariate processes in Cheng et al. (2010), it hasn't applied in identifying abnormal variable(s) in multivariate autocorrelated processes. In this paper, we propose a SVM based model to help identify abnormal variables when residual T^2 control chart issue an alarm, we use particle swarm optimization (PSO) to determine the proper setting of the SVM parameters to improve the performance of the model.

The rest of the paper is organized as follows. Section "Methodology" briefly describes the time series based residual control chart, SVM and parameters selection using PSO. Section "Proposed Approach" proposes a PSO-SVM based Monte Carlo approach for identifying variable(s) result in out of control situation. An example is presented in section "Results" to demonstrate the performance of proposed approach.

Methodology

Residual Control Chart

We use vector autoregressive model(VAR) to simulate a multivariate autocorrelated processes. The n-dimensional VAR model with p-lag autocorrelation has the follow expression:

$$Y_t = (I - \Phi_1 - \ldots - \Phi_p)\mu + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \varepsilon_t, \quad (23.1)$$

where Φ_i are coefficient matrices, $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{nt})^T$ is white noise process (serially uncorrelated or independent) vector which has (n $\times$ 1) zero mean and time invariant covariance matrix Σ. The best linear predictor $\hat{Y}_t$ of $Y_{\mathbf{t}}$ in terms of $Y_1, \ldots, Y_{t-1}$ is

$$\hat{Y}_t = (I - \Phi_1 - \ldots - \Phi_p)\mu + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} \ldots + \Phi_p Y_{t-p}. \tag{23.2}$$

The residual vector R_t is the one-step prediction errors, i.e. $R_t = Y_t - \hat{Y}_t$. R_t will be normally and independently variables if an appropriate time series model is fitted to the process. Suppose the process parameters are known, when the process is in control,

$$R_t = Y_t - \hat{Y}_t = \varepsilon_t. \tag{23.3}$$

When a process shift δ occur at time $t = q$, we can obtain

$$R_t = \begin{cases} \varepsilon_t & t < q \\ \varepsilon_t + \delta & t = q \\ \varepsilon_t + (\mathrm{I} - \Phi_1 - \Phi_2 - \ldots - \Phi_\mathrm{i})\delta & t = q + i, 1 \le i < p \\ \varepsilon_t + (\mathrm{I} - \Phi_1 - \Phi_2 - \ldots - \Phi_\mathrm{p})\delta & t \ge q + p \end{cases} \tag{23.4}$$

Thus, conventional multivariate control charts, like Hotelling T^2 control chart, could now be applied to the sequence of the residuals.

Support Vector Machines

SVM is a kind of statistical learning algorithm proposed by Vapnik, see Vapnik (1995). It has been widely used for classification as well as regression problems. The main advantage of the SVM embodies its very good generalization ability, and it has a global and unique solution.

For simplicity, we will illustrate SVM using a supervised binary classification problem. Suppose the training dataset consists of l vectors $x_i (i = 1, 2, \ldots, l)$ from the n-dimensional feature space X, we label each vector x_i a target $y_i \in \{-1, +1\}$. For the linearly separable case, the SVM classification approach looks for an opportune hyperplane to separate the two classes in X. The optimal separator can be obtained by a constrained optimization formulation

$$\begin{aligned} \min \quad & \frac{1}{2}\|\omega\|^2 \\ s.t. \quad & y_i((\omega^T \cdot x_i) + b) \ge 1, i = 1, \ldots, l. \end{aligned} \tag{23.5}$$

For the non-separable cases, we can't find a hyperplane with a class separation band without any data points inside it. One can deal with this problem by relaxing the constraints. We can do it by introducing positive slack variables $\xi_i \geq 0,\ i = 1, \ldots\ , l$, which becomes:

$$\begin{aligned} &\min \quad \frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{l}\xi_i \\ &s.t. \quad y_i((\omega^T \cdot x_i) + b) \geq 1 - \xi_i \quad i = 1, \ldots, l \\ &\xi_i \geq 0, \quad i = 1, \ldots, l\ . \end{aligned} \tag{23.6}$$

Here the constant C is a regularization parameter that balances model complexity and empirical risk. The Lagrangian formulation for this dual problem of formulation is as follows:

$$\begin{aligned} &\min \quad \frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l} y_i y_j \alpha_i \alpha_j (x_i \cdot x_j) - \sum_{j=1}^{l}\alpha_j \\ &s.t. \quad \sum_{i=1}^{l} y_i \alpha_i = 0 \\ &0 \leq \alpha_{\mathrm{i}} \leq C, \quad i = 1, \ldots, l. \end{aligned} \tag{23.7}$$

Where α_{i} represents Lagrangian multiplier of x_i. The discriminant function is

$$f(x_i) = \mathrm{sgn}\left(\sum_{j=1}^{l} \alpha_j y_j x_i \cdot x_j + b\right). \tag{23.8}$$

For non-linear SVM, the decision function becomes a nonlinear function of the training data. The decision function for new x_i can be obtained through substituting $x_i \cdot x_j$ with kernel function. The kernel function is defined as the inner product of vector functions $K(x_i, x_j) = \Phi(x_i) \cdot \Phi(x_j)$. One of the most commonly used kernel function is the radial Gaussian basis

$$k(x_i, x_j) = e^{-\|x_i - x_j\|^2/2\sigma^2}. \tag{23.9}$$

In this paper, Gaussian radial basis function is selected as the kernel function of the SVM classier. Finally, note that although we only describe binary SVM classifiers, the main concepts can be easily extended to handle the multi-class case if combined some strategies (one-versus all, one versus one). In this paper, we adopt one-versus-one approach to handle multiclass classification problem.

Parameter Optimization Using PSO

Particle swarm optimization (PSO) is a stochastic optimization algorithm proposed by Kennedy and Eberhart in 1995, see Kennedy and Eberhart (1995). It is a kind of global search algorithm which simulates the behavior of bird flocking in finding food. In this algorithm each individual is called a particle and the given population is called a swarm. Each particle will adjust its flying velocity and position according to its own experience and experience of its neighboring particles in the swarm during each iterative process. This new algorithm is easy to implement, and have fast convergence rate. It has been successfully applied in many areas like function optimization, artificial neural network training, and the parameters optimization of support vector machine. The main concepts of the basic PSO algorithm can be shown as follows:

Suppose z_i represents the i-th particle, p_i is the best previous position of any particle, the symbol g represents the index of the best particle among all the particles in the swarm. v_i is the current velocity for the i-th particle. The velocity and position of the i-th particle at the k-th iteration are updated as follows:

$$v_{id}^{k+1} = w \cdot v_{id}^{k} + c_1 \cdot r_1 \cdot (p_{id} - z_{id}^{k}) + c_2 \cdot r_2 \cdot (p_{gd} - z_{id}^{k}) \tag{23.10}$$

$$z_{id}^{k+1} = z_{id}^{k} + v_{id}^{k+1}, \tag{23.11}$$

where c_1 and c_2 are two positive constants, r_1 and r_2 are two positive random numbers drawn from a uniform distribution between 0 and 1, and w represents the inertia weight. Note that a large inertia weight w facilitates a global search while a small inertia weight facilitates a local search, thus we can balance the global search and local search by tuning the parameter w. In addition, because PSO has a tendency to explode as oscillations become wider and wider, a limit on the particle velocity is required to damping the velocity, which is represented as the maximum allowed velocity $v_{\max}$.

Proposed Approach

In an independent multivariate process monitoring environment, when an out-of-control signal is issued by Hotelling T^2 control chart or other multivariate procedures, the problem of identifying source(s) that caused the signal is considered as a pattern classification problem, as in Niaki and Abbasi (2005), Yu and Xi (2009), Guh (2007). This idea can be extended to autocorrelated multivariate process monitoring and diagnosing situation. In order to identify and locate the abnormal variable(s) for the multivariate autocorrelated process mean vector, this paper proposes to construct a multivariate autocorrelated process diagnosis model based on residual Hotelling T^2 control chart and PSO-SVM pattern recognizer, and

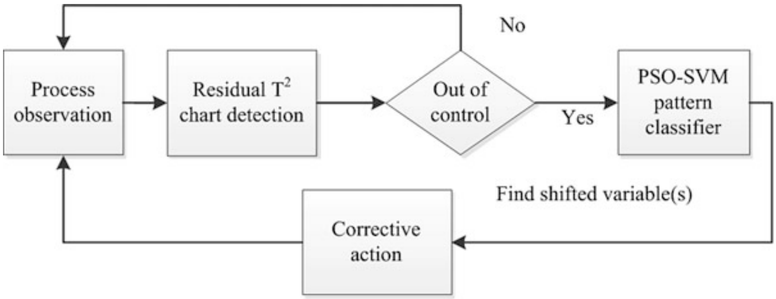


Fig. 23.1 Process diagnosis model by residual T^2 chart and PSO-SVM pattern classifier

the model structure is schematically shown in Fig. 23.1. When residual Hotelling T^2 control chart signal an alarm, the SVM classier can classify the out-of-control signal into several classes of patterns. Take the bivariate case for example; there are three different abnormal patterns: (1) process shift only occurs in first variable, (2) process shift only occurs in second variable, and (3) process shift occurs in both the first and the second variables. It is obvious that the pattern of mean shift that caused the abnormal signal must be one of them.

In this paper, we use the Matlab software to generate data for training and testing, and we use Libsvm for Matlab as the SVM tool. We take two bivariate autocorrelated cases as examples for simplicity. Assume the processes have known parameters. Say, the mean vector (μ_1, μ_2), the covariance matrix of the error term Σ, and the autocorrelaion coefficient matrix $\begin{bmatrix} \Phi_{11} & \Phi_{12} \\ \Phi_{21} & \Phi_{22} \end{bmatrix}$. The non-shifted process is considered as normal pattern, and the output should be (0,0). We shift the mean vector as the following three patterns, $(\mu_1 + k\sigma_{11}, \mu_2)$, $(\mu_1, \mu_2 + k\sigma_{22})$ and $(\mu_1 + k\sigma_{11}, \mu_2 + k\sigma_{22})$, $k = 1,2,3$. The target output of the SVM classier should be (1,0), (0,1), and (1,1), respectively. In SVM classier, these four classes of normal/abnormal process patterns (i.e., (0,0), (0,1), (1,0), (1,1)), can be labeled with, lable1 = 1, lable2 = 2, label3 = 3, label4 = 4 respectively. At the step of generating training and testing data, the residual T^2 statistic is used as a constraint to guarantee that the generated data meet the demand of the corresponding patterns of the process mean vector.

Results

We will demonstrate the effectiveness of the proposed model through an example. Consider the diagnostic of abnormal signal in a 1-lag vector autoregressive multivariate autocorrelated process which has two process variables. Suppose the mean vector, the autocorrelation matrix and the variance-covariance of the

Table 23.1 Classification accuracy of proposed approach

		Patterns of classification				Classification percentage
K		(0,0)	(0,1)	(1,0)	(1,1)	Accuracy
1	(0,0)	257	16	27	20	0.8031
	(0,1)	10	253	1	56	0.7907
	(1,0)	11	0	282	27	0.8813
	(1,1)	23	31	21	245	0.7656
2	(0,0)	310	4	0	6	0.7313
	(0,1)	4	310	0	6	0.9688
	(1,0)	4	0	278	38	0.8688
	(1,1)	22	23	8	267	0.8344
3	(0,0)	315	2	1	2	0.9844
	(0,1)	0	318	0	2	0.9938
	(1,0)	2	0	310	8	0.9688
	(1,1)	2	13	0	305	0.9531

error term for a bivariate autocorrelated process are $\mu = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$, $\Phi = \begin{bmatrix} 0.7 & 0.1 \\ 0.2 & 0.5 \end{bmatrix}$, and $\Sigma = \begin{bmatrix} 1 & 0.5 \\ 0.5 & 1 \end{bmatrix}$, respectively. The simulation experiment is conducted according to the above descriptions. We set $\alpha = 0.05$, the control limit for the residual T^2 control chart is calculated by $UCL = \chi^2_{2,\alpha}$. For each patterns described above, we generate 400 dataset. The first 80 are used as the training dataset, and the rest 320 are used as the testing dataset. K is set to 1, 2, and 3. In the process of carrying out our experiment, the PSO method was introduced to optimize the values of penalty parameter and kernel parameter to improve the performance of the SVM pattern recognizer, Simulation results are presented in Table 23.1.

The results of Table 23.1 show that the PSO-SVM model is able to classify the signals in an acceptable accuracy, even for a small shift, say one times of standard deviation shift in each of the two variables or in both of them, the accuracy of the classification is nearly 80%. The accuracy improved as the shift magnitude K increased. For a large shift, say three times of standard deviation, the accuracy will be more than 95%.

Conclusion

In modern complex manufacturing scenario, finding source(s) of abnormal signals has been a challenging task for multivariate autocorrelated process monitoring scheme. There have been only very few researches on this scheme. In this paper, we propose a PSO-SVM based model to classify and identify the variable(s) that corresponding to the mean shift of autocorrelated process.

The performance of the model for identification accuracy of mean shift patterns is evaluated through the use of a numerical example. Since the parameters of the

SVM have significant effect on the performance of our model, we introduce Particle Swarm Optimization algorithm to improve the performance of the diagnosis model. The experiment result demonstrates the effectiveness of the proposed approach.

Acknowledgment The authors thank the editor and the anonymous referees for their comments and suggestions.

References

Arkat J, Niaki STA, Abbasi B (2007) Artificial neural networks in applying MCUSUM residuals charts for AR(1) processes. Appl Math Comput 189:1889–1901

Bodnar O, Schmid W (2007) Surveillance of the mean behavior of multivariate time series. Statistica Neerlandica 61(4):383–406

Bodnar O, Schmid W (2011) CUSUM charts for monitoring the mean of a multivariate Gaussian process. J Stat Plan Inference 141(6):2055–2070

Cheng ZQ, Ma YZ, Bu J (2010) Mean shifts identification model in bivariate process based on LS-SVM pattern recognizer. Int J Digit Content Technol Appl 4(3):154–170

Fountoulaki A, Karacapilidis N, Manatakis M (2011) Using neural networks for mean shift identification and magnitude of bivariate autocorrelated processes. Int J Qual Eng Technol 2 (2):14–128

Guh RS (2007) On-line identification and quantification of mean shifts in bivariate processes using a neural network-based approach. Qual Reliab Eng Int 23:367–385

Hwarng HB, Wang Y (2010) Shift detection and source identification in multivariate autocorrelated processes. Int J Prod Res 48(3):835–859

Issam BK, Mohamed L (2008) Support vector regression based residual MCUSUM control chart for autocorrelated process. Appl Math Comput 201:565–574

Jarrett J, Pan X (2007) The quality control chart for monitoring multivariate autocorrelated processes. Comput Stat Data Anal 51:3862–3870

Kalgonda AA, Kulkarni SR (2004) Multivariate quality control chart for autocorrelated processes. J Appl Stat 31:317–327

Kennedy J, Eberhart R (1995) A new optimizer using particle swarm theory. In: Proceedings of the sixth international symposium on micro machine and human science, IEEE service center, Nagoya, Japan, pp 39–43

Kim SB, Jitpitaklert W, Sukchotrat T (2010) One-class classification-based control charts for monitoring autocorrelated multivariate processes. Commun Stat Simul Comput 39(3):461–474

Kramer HG, Schmid W (1997) EWMA charts for multivariate time series. Seq Anal 16 (2):131–154

Niaki STA, Abbasi B (2005) Fault diagnosis in multivariate control charts using artificial neural networks. Qual Reliab Eng Int 21:825–840

Pan X, Jarrett J (2007) Using vector autoregressive residuals to monitor multivariate processes in the presence of serial correlation. Int J Prod Econ 106:204–216

Sun J, Yang M (2007) Residual-based T2 control chart for monitoring multivariate auto-correlated processes. J Tsinghua Univ (Sci Technol) 47(12):2184–2187 (in Chinese)

Vapnik V (1995) The nature of statistical learning theory. Springer, New York

Yang M, Sun J (2006) Residual-based T2 control chart for bivariate autocorrelated processes. J Tsinghua Univ (Sci Technol) 46(3):403–406 (in Chinese)

Yu JB, Xi LF (2009) A neural network ensemble-based model for on-line monitoring and diagnosis of out-of-control signals in multivariate manufacturing processes. Expert Syst Appl 36:909–921

Chapter 24
Direct Control-Chart of Substandard Products Control

Chun-yun Yu and Zhi-min Guan

Abstract In this paper, direct Control-Chart of substandard is put forward. In the Control-Chart, the usual way of deciding the control limits according to sample datum has been eliminated and the shortage of small-scale single-piece production datum has been overcome. It doesn't need sample datum as its basis. Its purpose is not to keep the process stable but to control the occurrence of substandard products, which is more suitable for process quality control of small-scale production. The structure, control rules, statistical principles identifying, capacity, functions, characteristics application of the direct Control-Chart are discussed.

Keywords Multi variety small batch • Quality control • Direct Control-Chart • Statistical process control

Introduction

The statistical tool that is most widely used in the control of process quality is the Control-Chart. Many of the accepted control charts are suitable for mass production. Besides, the charts are based on certain amounts of samples. Grant (1992), Duncan (1986) believe that when the sample size n = 5, the number of sample group m = 20–25, the reliable control chart limits can be establish. While in small-scale single-piece production it is difficult to collect datum. Hillier (1969) first presented $\bar{X} - R$ control charts for short production runs In1969. Quesenberry (1991) proposed the Q control chart, the Q control chart using Fisher's classic

C.-y. Yu (✉)
Northeastern University at Qinhuangdao, Qinhuangdao 066004, China
e-mail: yuchunyun@yahoo.com.cn

Z.-m. Guan
School of Business Administration, Northeastern University, Shenyang 110819, China
e-mail: guanzm168@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_24,

probability integral transformation theorem and OReilly conditional probability integral transform method. The observed value is converted to the Q statistic to obey the standard normal distribution in quality control. Castillo and Montgomery (1994) found that when the process shift, if the process mean is known and variance is unknown, the application effect of the Q control chart is less than ideal. At the same time, the Q control chart is not sensitive enough for monitoring small shifts. Page (1954) proposed cumulative sum control chart (CUSUM). Roberts (1959) proposed exponentially weighted moving average control chart (EWMA). CUSUM and EWMA control chart is sensitive to the slight offset of the process, and is suitable for small batch production quality control, however, these two control chart does not reflect the true quality characteristics. Miao Rui et al. (2005) analyzed the problems occurred in the statistical process quality control in the low volume manufacturing. When process quality char act eristic data followed normal distribution, a standard control chart was provided to monitor process mean and process variance based on the probability integral transform theory. This algorithm has realized real-time control of process quality in the low volume manufacturing. Wang Li-ying et al. (2006) constructed Classified coding system and applied analogical manufacturing theory to classify procedures with same codes into same virtual procedure, thus virtual batch was composed and data shortage problem was resolved which laid foundation for procedure quality control applying SPC technology . However, the application of these methods is more complicated. Today, there is still an effective method to solve the problem of quality control for short production runs.

In the control chart to be discussed in this paper, the usual way of deciding the control limits according to sample datum has been eliminated and the shortage of small-scale single-piece production datum has been overcome. This chart not only applies to mass producing process control but also to unstable control of small scale production.

The Basic Idea

The basic ideas of the direct control-chart are first to determine the process quality standard, that is to say, to set the control limit; and then to check and measure according to control rules in order to find out if the process meets the standard. If the standard is not met, the process must be improved and adjusted. The direct Control-Chart doesn’t need sample datum as its basis. Its purpose is not to keep the process stable but to control the occurrence of substandard products, which is more suitable for process quality control of small-scale production.

Table 24.1 The process capacity index and the rate of substandard products

Standard deviation δ	Process capacity index Cp	The rate of substandard products (%)
T/4	0.67	4.56
T/6	1	0.26
T/8	1.33	
T/10	1.67	

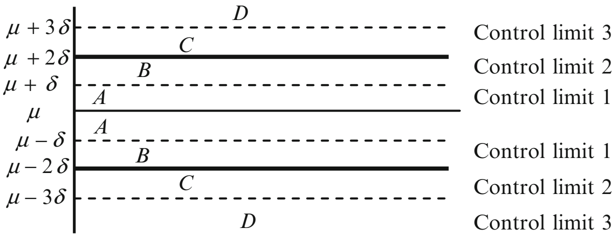


Fig. 24.1 The direct Control-Chart

Making Way and Control Rules

Making way of the direct control-chart is as follow.

1. Determine the process quality standard, that is, standard deviation. Generally, in determining the quality standard, the history of the process should be considered and connected with tolerance T. If the standard deviation is $\delta = T/4$, the process capacity index is 0.67.
   The process capacity index and the rate of substandard products according to different quality standards are shown in the following Table 24.1:
2. Making process Control-Chart (see Fig. 24.1.)
   The space between limit 1 is called area A. The space between limit 1 and limit 2 is called area B. The space between limit 2 and limit 3 is called area C. The part outside limit 3 is called area D.

Control rules of the direct control-chart:

1. At the beginning, take three pieces as samples to be measured. If they all fall into area A, then actually start the operation. Otherwise, readjust until the three pieces all fall into area A when taken as samples continuously.
2. When the operation starts, continue according to the following principles, with three pieces as a group:

   (1) Take one piece as a sample to be measured. If it falls into Area A, It is unnecessary to take a second and a third piece. If it falls into Area D, it is considered abnormal and then adjustment and improvement should be made. If it falls into Area B or Area C, then a second piece should be taken and measured.

Table 24.2 The distributions of the different cases under the control rules

	Area A	Area B	Area C	Area D	Distribution probability (%)
Normal	1				68.26
	2	1			21.48
	2		1		
	3	1, 2			6.61
	3	1	2		
	3	2	1		
Abnormal		1, 2, 3			3.35
		1, 2	3		
		1, 3	2		
		1	2, 3		
		2, 3	1		
			1, 2, 3		
Rather abnormal				1	0.3
				1, 2	
				1, 2, 3	

Note: 1 is the first piece. 2 is the second piece. 3 is the third piece

(2) If the second piece falls into Area A, it is considered to be normal. A third piece dose not need to be taken and measured. If the second piece falls into Area D or the first two pieces falls into Area C, they are regarded as abnormal. If the second piece falls into Area B, the third piece should be taken and measured.
(3) If the third piece falls into Area A, it is regarded as normal. Continue by following rule (1). Otherwise it is regarded as abnormal.

Note: As to small-scale production process, samples can be taken and measured continuously. As to mass production process, samples can be dose at intervals.

Statistics Principles

If the process quality meets the set quality standard, the distributions of the different cases under the control rules are shown in the following Table 24.2. As can be seen from the table, cases considered as abnormal according to the control rules are all small probability cases. Such cases indicate that there are system factors in the process or the process has not the set quality standard, and therefore adjustment or improvement is necessary.

Table 24.3 The identifying capacity of the direct Control-Chart when the average value changes

K	β_1	β_2	β_3	β_4	ρ	ρ'
0	0.683	0.272	0.043	0.964	0.036	0.003
0.5	0.625	0.302	0.067	0.938	0.062	0.006
1	0.577	0.263	0.137	0.890	0.110	0.023
1.5	0.302	0.389	0.241	0.595	0.405	0.067
2	0.157	0.325	0.341	0.320	0.680	0.159
2.5	0.067	0.242	0.383	0.177	0.842	0.309
3	0.027	0136	0.341	0.432	0.957	0.500
3.5	0.006	0.061	0.242	0.838	0.992	0.692
4	0.001	0.021	0.136	0.160	0.998	0.841

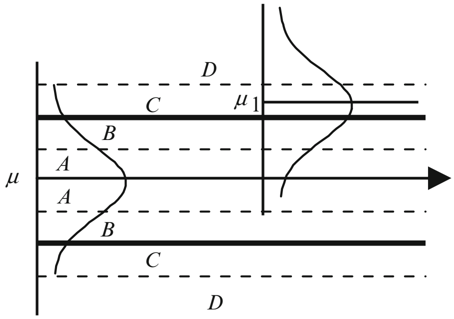


Fig. 24.2 The total N(μ, δ) changes into N(μ*, δ)

The Identifying Capacity

The identifying capacity of the direct control-chart shows the probability that the chart can properly find out the abnormal changes. The formula for calculating the identifying capacity is as following:

$$\rho = 1 - \beta$$

Where ρ is the identifying capacity, β is the probability of the second kind of error.

Let's make a study of the identifying capacity of the direct Control-Chart.

1. When there is no change in the total standard deviation but the total value changes. The identifying capacity is shown in the following Table 24.3. In Fig. 24.2, The total N(μ, δ) changes into N(μ*, δ). The deviation of the distribution center $\varepsilon = \mu_1 - \mu$. Suppose $K = \varepsilon/\delta$.

   Suppose the probability that N(μ*, δ) falls into Area A is β_1, the probability that into Area B is β_2, and into Area C is β_3, then:

$$\beta_1 = \Phi(\frac{\varepsilon + \delta}{\delta}) - \Phi(\frac{\varepsilon - \delta}{\delta}) = \Phi(k + 1) - \Phi(k - 1)$$

Table 24.4 The identifying capacity of the direct Control-Chart when the standard deviation changes

K	β_1	β_2	β_3	ρ	ρ'
1	0.6826	0.2719	0.0428	0.0362	0.0026
1.5	0.4972	0.3193	0.1380	0.1809	0.0456
2	0.3830	0.2996	0.1838	0.3553	0.1336
2.5	0.3108	0.1654	0.1936	0.4927	0.2302
3	0.2586	0.2386	0.1854	0.5942	0.3174
3.5	0.2282	0.2032	0.1766	0.6593	0.3900
4	0.1974	0.1833	0.1638	0.7156	0.4532
5	0.1586	0.1522	0.1406	0.7847	0.5489
6	0.1350	0.1236	0.1244	0.8253	0.6170

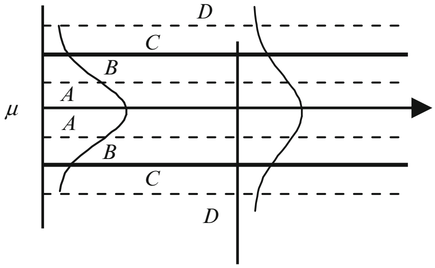


Fig. 24.3 The total N(μ, δ) changes into N(μ, δ*)

$$\beta_2 = \Phi(\frac{\varepsilon + 2\delta}{\delta}) - \Phi(\frac{\varepsilon - 2\delta}{\delta}) - \beta_1 = \Phi(k+2) - \Phi(k-2) - \beta_1$$

$$\beta_3 = \Phi(\frac{\varepsilon + 3\delta}{\delta}) - \Phi(\frac{\varepsilon - 3\delta}{\delta}) - \beta_1 - \beta_2 = \Phi(k+3) - \Phi(k-3) - \beta_1 - \beta_2$$

According to the theory of probability, probability of the second kind of error in the Direct Control-Chart is:

$$\beta = \beta_1 + \beta_1(\beta_2 + \beta_3) + \beta_1({\beta_2}^2 + 2\beta_2\beta_3)$$

Then the identifying capacity of the Direct Control-Chart is $\rho = 1 - \beta$
The following Table 24.3 shows the identifying capacity of the Direct Control-Chart when the average value changes (ρ' is the identifying capacity of X chart) The Direct Control-Chart capacity to identifying the total average value is far greater than that of X Control-Chart. It is equal to the $\bar{x}$ Control-Chart identifying capacity when n = 3.

2. If the total average value doses not change, but only the standard deviation changes, the identifying capacity is as following Table 24.4:

In Fig. 24.3, The total N(μ, δ) changes into N(μ, δ*). Suppose $K = \delta^*/\delta$, the probability that N(μ, δ*) falls into Area A is β_1, the probability that into Area B is β_2, and into Area C is β_3, then:

$$\beta_1 = 2\Phi(\frac{\delta}{\delta^*}) - 1 = 2\Phi(\frac{1}{k}) - 1$$

$$\beta_2 = 2\Phi(\frac{2\delta}{\delta^*}) - 1 - \beta_1 = 2\Phi(\frac{2}{k}) - 1 - \beta_1$$

$$\beta_3 = 2\Phi(\frac{3\delta}{\delta^*}) - 1 - \beta_1 - \beta_2 = \Phi(\frac{3}{k}) - 1 - \beta_1 - \beta_2$$

According to the theory of probability, probability of the second kind of error in the Direct Control-Chart is:

$$\beta = \beta_1 + \beta_1(\beta_2 + \beta_3) + \beta_1({\beta_2}^2 + 2\beta_2\beta_3)$$

Then the identifying capacity of the Control-Chart is:

$$\rho = 1 - \beta$$

The following Table 24.4 shows the identifying capacity of the Direct Control-Chart when the total standard deviation changes (ρ' is the X chart capacity to the identify the standard deviation)

The Direct Control-Chart capacity to identify the standard deviation is greater than that of X of chart. On the whole, the Direct Control-Chart is a chart with greater identifying capacity.

The Functions of the Direct Control-Chart

1. When the process capacity meets the set quality standard, the Direct Control-Chart is used to keep the process stable. The purpose of the process quality control at this point is to keep the process stable. The chart warning frequency now is 3.65%. The first piece of each of the six to seven groups of datum out of the ten groups taken for examination falls into Area A.
2. When the process capacity is below the set quality standard, the Direct Control-Chart is used to provide information for process improvement. The main purpose of the process quality control is to raise the process capacity. The chart warning frequency will increase at moment.
3. When the process capacity is above the set quality standard, the main purpose of the process quality control is economy. The warning frequency will decrease, allowing the process to fluctuate within a certain range.

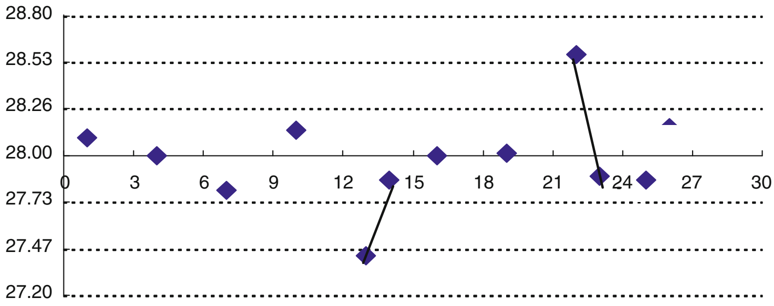


Fig. 24.4 The direct Control-Chart with δ = T/6 = 0.267

Steps of Applying the Direct Control-Chart

1. Set the process quality standard with the history and technical requirements of the process considered.
2. Draw the Direct Control-Chart
3. Check and measure according to control rules, and make dots on the chart. If the first of three pieces taken for examination falls into Area A, draw ♦ on the chart. If the second or the third piece falls into Area A, join them with a line. As to the abnormal cases, draw ×on the chart.
4. Analyze. If the first piece of each of the six to seven out of the ten groups of datum falls into Area A, the process has the set quality standard.

Application in the Workplace

In a machining workshop, a batch of spare parts is to be processed. The finish size is 2.8 ± 0.8. In the process quality control the direct Control-Chart tool. The steps are as follows:

1. Set the process quality standard. Suppose δ = T/6 = 0.267, that is, the process capacity index is 1.
2. Draw the Control-Chart.
3. Check and measure according to the control rules and make dots. The operation is shown in Fig. 24.4.
4. Analyze. As can be seen from the chart, seven out of nine groups of datum fall into Area A when the first piece is taken for examination. Therefore, the process capacity index is larger than 1.

Suppose we set the process quality standard as δ = T/8, that is, the process capacity index is 1.33, then let's observe the operation (see Fig. 24.5).

From Fig. 24.5 we can see that the process capacity is a little below the set standard δ = T/8, i.e. the process capacity index is below 1.33.

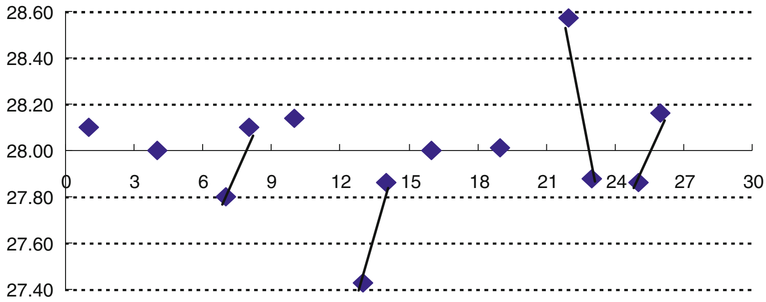


Fig. 24.5 The direct Control-Chart with δ = T/8 = 0.2

Table 24.5 The measure values of the 27 datum in the nine groups

NO.	Sample value	DEVI	*NO.*	Sample value	DEVI
1	28.10		15	27.80	0.06
2	27.90	0.20	16	28.00	0.20
3	27.70	0.20	17	28.00	0
4	28.00	0.30	18	27.90	0.10
5	28.20	0.20	19	28.01	0.11
6	28.10	0.10	20	27.82	0.19
7	27.80	0.30	21	28.16	0.34
8	28.10	0.30	22	28.57	0.41
9	27.95	0.15	23	27.88	0.69
10	28.14	0.19	24	28.12	0.24
11	28.20	0.06	25	27.86	0.26
12	28.30	0.10	26	28.16	0.30
13	27.43	0.87	27	27.96	0.20
14	27.86	0.43		$\bar{X} = 28.00$	$\bar{R}s = 0.25$

Actually examine and measure the 27 datum in the nine groups, we get the values in the following Table 24.5:

Draw X-Rs Control-Chart (see Fig. 24.6).

Calculate Process Capacity Index is Cp = 1.25.

The process capacity estimated by using the direct Control-Chart agrees with process capacity actually calculated. From the analysis we can see that the purpose of using the direct Control-Chart to control the process quality is not to keep the process stable but to control the occurrence of the sub-standard products. The process adjustment and improvement are made not before the process starts to work but before the sub-standard products occur. This is more economic and more suitable for small scale production process quality control.

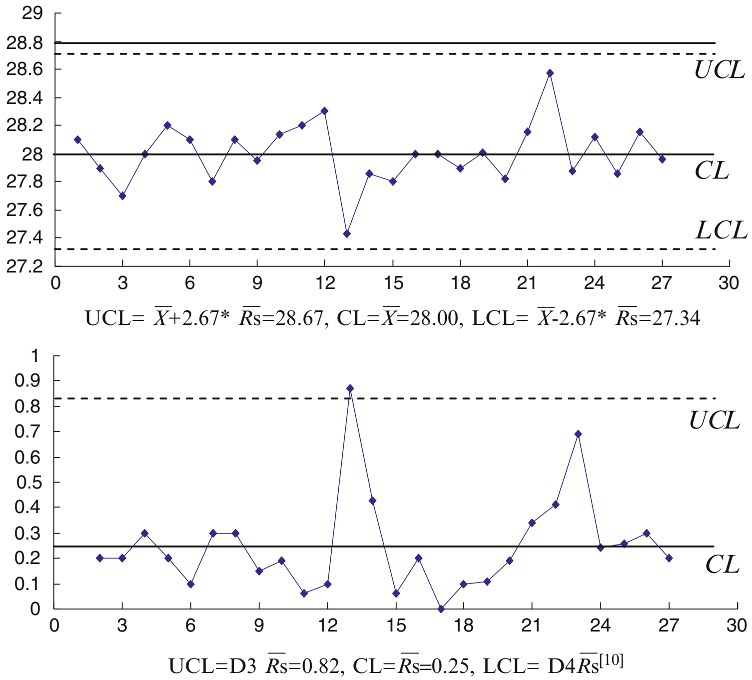


Fig. 24.6 X-Rs Control-Chart (Zhang Gongxu and Sun Jing 2002)

Conclusion

1. The Direct Control-Chart dose not need sample datum as basis. It can begin its control from the first piece. It not only applies to mass production process but also small-scale production process.
2. The Direct Control-Chart functions with the changes of the process. It realizes dynamic control over the process and provides a very good control method for unstable small-scale production process.
3. The Direct Control-Chart has greater identifying capacity.

References

Castillo ED, Montgomery DC (1994) Short-run statistical process control: Q-Chart enhancements and alternative methods [J]. Qual Reliab Eng Int 10(2):87–97

Duncan AJ (1986) Quality control and industrial statistics [M], 5th edn. Irwin, Homewood

Grant EL (1992) Statistical quality control [M], 3rd edn. McGraw-Hill, New York

Hillier FS (1969) X and R chart control limits based on a small number of subgroups [J]. J Qual Technol 1(1):17–26

Miao Rui, Sun X iao-Ming, Li Shu-gang, Yang Dong (2005) Research on statistical process quality control based on low volume manufacturing [J]. Comput Integr Manuf Syst 11 (11):1633–1635

Page ES (1954) Control charts for the mean of a normal population [J]. J R Stat Soc 16(1):131–135
Quesenberry CP (1991) SPC Q-charts for start-up processes sad short or long runs [J]. J Qual Technol 23(3):213–224
Roberts SW (1959) Control chart tests based on geometric moving averages [J]. Technimetrics 1(3):239–250
Wang Li-ying, Sun Li, Wang Xiu-lun (2006) Multi-type & small batch procedure quality control method based on virtual procedure [J]. Comput Integr Manuf Syst 12(8):1263–1266, 1283. (in Chinese)
Zhang Gongxu, Sun Jing (2002) Quality engineer handbook [M]. Enterprise Management Publishing Company, Beijing (in Chinese)

Chapter 25
Integration and Application of Lean Principles and Six Sigma in Residential Construction

Ying-hua Shan and Zhong-fu Li

Abstract China's large population size and rapid urbanization process have made the implementation model of residential construction under huge pressure. It is vital for residential developers to adopt the best practices of production planning and control system to ensure the quality requirements of residences. This paper aims at providing a residential production and construction process management tool for homebuilding industry to achieve the quality goal of zero-defect in construction process with exploring the possibilities of integrating Lean Principles and Six Sigma. The necessity and feasibility of integrating both Lean Principles and Six Sigma were conducted. The integration content and process of Lean Six Sigma construction mode were given. Finally, a Lean Six Sigma Construction Model was established to explain the implementation process of this integrated approach in residential construction.

Keywords Integration • Lean Principles • Residential construction • Six Sigma

Introduction

Prefabricated construction pattern is one of main development directions for residential buildings' industrialization with higher efficiency, higher quality assurance, less environmental pollution and consumption of resources, etc. Prefabricated

Supported by the Fundamental Research Funds for the Central Universities (DUT11RC(3)13)

Y.-h. Shan (✉)
Department of Construction and Real Estate, Harbin Institute of Technology, Harbin, China
e-mail: yinghua1@126.com

Z.-f. Li
Department of Construction and Real Estate, Harbin Institute of Technology, Harbin, China

Faculty of Infrastructure Engineering, Dalian University of Technology, Dalian, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_25,

residential construction has been considered one of main approaches to deal with the contradiction between the huge domestic demands for residential housing and relatively backward residential construction mode in China since the 1950s.

China's large population size and rapid urbanization process have propelled it into the ranks of the largest homebuilding nation, with energy consumption proportion from homebuilding continuing at a pace commensurate with its huge amount of housing completed. According to the statistics from "China Statistical Yearbook 2011", the floor spaces of buildings under construction and completed respectively reached 4,927,636,000 and 1,831,723,000 m^2. Besides, China's urbanization rate is about 45% with 630 million of urban population.

To facilitate the estimation, it is assumed that 60% of the population needs to solve the housing problem and the per capita housing area is 25 m^2. Then 2.55 billion m^2 of housing needs to be built in China. Additionally, the residential area of 20.7 m^2 needs increased to improve housing conditions. About 1 billion m^2 of new housing area will be increased due to the demolition of old houses. So the total housing area is more than 5 billion m^2.

However, the current residential construction industry in China still belongs to labor-intensive industry with the characteristics of widespread use of traditional construction mode. The efficiency of China's housing construction is still relatively low. Chinese average annual labor productivity of construction workers is about 30 m^2, which is only one-fifth of the United States or one-sixth of Japan. At the same time the level of residential construction technology content is relatively low. The contribution rate of science and technology in housing industry is less than 30%, which is below the internationally accepted 50% standard of intensive industry.

In this context, advanced and scientific construction management methods become one of most important approaches to improve housing quality and to alleviate the current housing pressure. Lean Principles and Six Sigma are two kinds of management methods, which have been proved to be effective in various industries around the world (Chen and Lyu 2009). Lean Principles aim at reducing/eliminating waste when reducing defects through variability (Hu et al. 2008); while Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability (Bendell 2006). The concepts on combining of Lean Principles and Six Sigma have been addressed in manufacturing industry for both productivity improvement and quality improvement at the same time (Mandahawi et al. 2012; Thomas et al. 2009). This paper attempts to integrate Lean Principles and Six Sigma to propose a model for Lean Six Sigma, which will allow using the tools of Six Sigma and Lean Principles to reduce/eliminate waste by working in unison rather than independently in prefabricated residential construction.

Table 25.1 Similarities and differences between Lean Principles and Six Sigma

Compared items	Similarities	Differences
Culture	Pursuit of perfection	Lean Principles are from the Eastern culture, while Six Sigma is from Western culture
Operation management mode	All are process-based management, similar to PDCA	Lean Principles focus on system optimization, Six Sigma is based on project management
Improvement Style	All adopt continuous improvement approach	Lean Principles use a gradual continuous improvement policy, Six Sigma emphasizes large financial breakthrough
Problem analysis and solving method	All adopt manufacturing methods and techniques	Lean Principles emphasize expert knowledge, use direct solution approach, Six Sigma emphasizes on statistical analysis approach
Key targets	Customer value	Lean Principles focus on the issue from the perspective of waste, Six Sigma focuses on variation

The Necessity and Feasibility of Lean Principles and Six Sigma Integration

Comparative Analysis of Lean Principles and Six Sigma

In order to conduct more in-depth study for the integration of Lean Principles and Six Sigma, it is necessary to compare both the similarities and differences between them. The results of comparative analysis are showed in Table 25.1.

As is shown in Table 25.1, although Lean Principles and Six Sigma are from different cultures, their pursuit goal of the perfect is the same. First, Lean Principles are originated from Japanese cultural environment, while Six Sigma is from American culture atmosphere (Ward 2006). The perfection of quality is their common goal. Second, their implementation is similar with the PDCA mode (Timans et al. 2012). Lean Principles are based on the value added processes to research the entire principles chain management (Shah et al. 2008). Six Sigma completes the project objectives based on the implementation of the DMAIC process. Third, these two models emphasize continuous improvement processes. But the ways to conduct improvement are different. Lean Principles use a gradual continuous improvement policy (Kaizen) (Chun 2005). Six Sigma emphasizes breakthrough change and requires that each item can give organizations tremendous financial benefits. Fourth, visual management and quantitative analysis are respectively adopted by Lean Principles and Six Sigma (Dahlgaard and Dahlgaard-Park 2006). Fifth, both of them are concerned on customer value, but the central concern of Lean Principles is to eliminate waste, while Six Sigma is concerned on variation.

The Necessity of Lean Principles and Six Sigma Integration

The above comparative results provide a basis for integrating Lean Principles and Six Sigma. The necessity of integration is discussed from the point of functional complementation.

The necessity is put forward in following five aspects. First, the target of Six Sigma optimization is often partial, but not for the whole system optimization. This shortage can be counterweighed by Lean Principles, which focus on system processes management and can provide effective framework to Six Sigma by enhancing the process or activity value of project management. Second, due to the dependence on expert knowledge and talents to solve problems, Lean Principles can not guarantee the successful resolution for complex problems without normative knowledge under statistical controlling status. Six Sigma has standardized DMAIC problem-solving processes and provides strong operational approaches and tools for complex problems. So it can help to solve complex problems by using quantitative analysis approach. Third, Six Sigma can complement the deficiencies of Lean Principles in dealing with problems of variation to ensure the construction process have sufficient capacity. Fourth, Lean Principles have many tools which are used to analyze customer value. Six Sigma provides a Quality Function Deployment (QFD), KANO model and other tools (Chakravorty and Shah 2012). These models and tools can improve the implementation of customer value analysis. Fifth, the integration is able to take full advantage of the enthusiasm of all the staff in order to ensure that the optimization process is under control (Lee and Wei 2010).

The Feasibility of Lean Principles and Six Sigma Integration

First, both Lean Principles and Six Sigma are continuous improvement, and pursuit of perfect idea. This is the essence of the homogeneity between the two, and also is the basis of integrating both. Second, they are closely linked to Total Quality Management (TQM), and are based on process management. Also, their implementation process is similar to the PDCA model (Andersson et al. 2006). This is the basis of integration for two kinds of similar system. Third, although there are many differences between them, they are not antagonistic in many aspects from the operational level. For instance, the essence of Lean Principles is to eliminate waste. The nature of Six Sigma is to control variation. Variation leads to waste reason, so the concerned target of both models is not contradictory, but complementary.

Their differences are complementary and don't mutually eliminate each other. From the points of technology, objective, philosophy and other aspects, their integration feasibility can be analyzed. In cultural one, even though both come from different cultural backgrounds, with the development of world economic integration, cultural differences are gradually narrowing. So, the created two

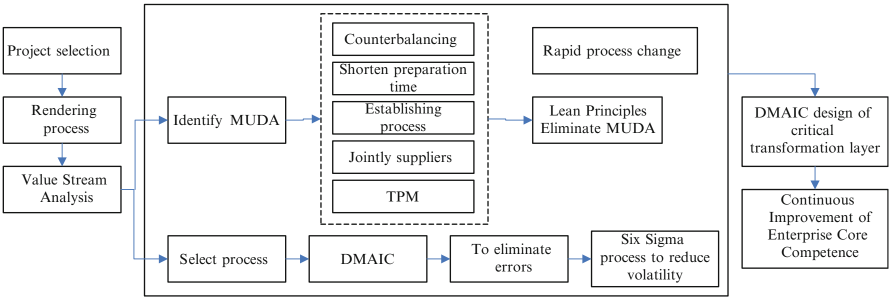


Fig. 25.1 The integration process of Lean Principles and Six Sigma

management methods by this kind of culture in different operational level will differently affects the implementation of Lean Six Sigma. Therefore, Integrating Lean Principles and Six Sigma to form Lean Six Sigma is feasible.

Integration Content of Lean Six Sigma Construction

On the basis of above discussion, the integrated mode of Lean Principles and Six Sigma is named Lean Six Sigma in this paper. It combines the main tools and process management methods from Lean Principles and Six Sigma. The integration process of Lean Six Sigma is showed in Fig. 25.1.

The objective of Lean Six Sigma is to absorb the advantages of these two management modes, to achieve better management results through the integration of Lean Principles and Six Sigma. It is based on continuous improvement management model process. It takes corporate strategy as guide, value stream analysis as cornerstone, perfection as objective. It solves problems through "Define-Measure-Analyze-Improve-Control". The integrated Lean Six Sigma should infiltrate organizational culture, organizational strategy in their daily work and project implementation.

Lean Six Sigma will analyze value stream, optimize processes from a system point of view. In the other hand, continuous efforts should start from the microscopic level, through design of experiment to optimize process parameters, and through the process control to improve process capability.

Lean Six Sigma Construction Model

Integrating these two methodologies, Lean Principles and Six Sigma, proposes a set of systematic methods and tools to analyze and assess the performance of the organization, production efficiency, and customer's satisfaction indicators of an organization (Delgado et al. 2010). The implementation of the proposed

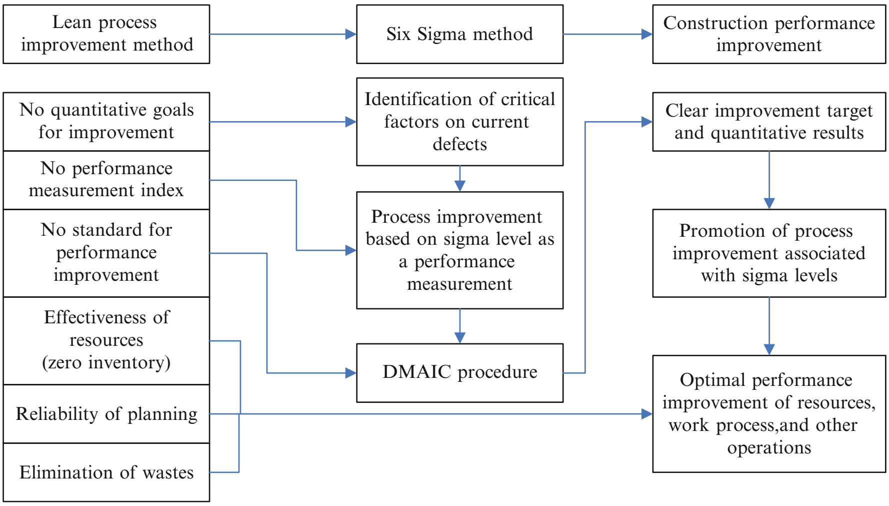


Fig. 25.2 Lean Six Sigma construction model

methodology starts with an assembled Lean Construction, and is structured on three integrated points, which are represented in Fig. 25.2.

Lean Six Sigma implementation flow combines Lean Principles thinking and Six Sigma DMAIC model ideas together. The principles of Lean Principles system are applied to diagnose the improvement opportunities. After that, Six Sigma methods are used to complete the project (Arnheiter and Maleyeff 2005). By initiating with lean techniques, some quick effects can be obtained by identifying the critical defects factors and reducing waste in maximum extent. When the causes of process waste are identified, other lean techniques are used in conjunction with Six Sigma techniques to maximize the benefits. From Figs. 25.1 and 25.2, it is obvious that the DMAIC process is used as the main functional system for the implementation of Lean Six Sigma approach.

For residence constructed in traditional concrete cast method, Lean Six Sigma construction can be used in the process of design and on-site construction. The role of Six Sigma can not play its inherent quantitative advantages at this early stage. The Lean construction method is used to eliminate MUDAs and saves costs through the whole process of project construction. In this case, the integration effect of Lean Principles and Six Sigma is not obvious.

For prefabricated residential construction, the roles of Lean Principles and Six Sigma show the characteristics of phases. The prefabricated residential construction process could be divided into three sub-stages, that are, design stage, factory-built stage, and on-site assembly stage. Lean construction can be applied in design and on-site assembly stage in which the function of Six Sigma is not evident. The works done in factory-built stage are similar to the manufacturing process in factories of manufacturing industry. This means that it provides a common platform for the joint role of Lean Principles and Six Sigma. This could be completed by the Lean Six Sigma Construction Model proposed in this paper.

As is showed in Fig. 25.2, it is clear that the processes dealt with Lean Principles could be divided into six categories. The three categories difficult to carry out the quantitative treatment (lacking quantitative goals, performance measurement index, or standards) could be further processed in accordance with the processing steps of Six Sigma. The other three categories (effectiveness of resources, reliability of planning, and elimination of wastes) can be processed by Lean Principles without the intervention of Six Sigma.

Conclusion

The paper analyzed, compared Lean Principles and Six Sigma, and proposed necessity and feasibility of Lean Principles and Six Sigma management integration. Then, the integration process between them was given. A Lean Six Sigma Construction Model was established to performance the application process of Lean Six Sigma construction method. Further research can be carried out in the aspects of organizational structure design, process implementation management tools selection, etc.

References

Andersson R, Eriksson H, Torstensson H (2006) Similarities and differences between TQM, six sigma and lean [J]. TQM Mag 18(3):282–296

Arnheiter ED, Maleyeff J (2005) The integration of lean management and Six Sigma [J]. TQM Mag 17(1):5–18

Bendell T (2006) A review and comparison of six sigma and the lean organizations [J]. TQM Mag 18(3):255–262

Chakravorty SS, Shah AD (2012) Lean Six Sigma (LSS): an implementation experience [J]. Eur J Ind Eng 6(1):118–137

Chen M, Lyu J (2009) A lean Six-sigma approach to touch panel quality improvement [J]. Prod Plan Control 20(5):445–454

Chun LG (2005) Lean manufacturing with six sigma implementation [J]. SMT Surf Mt Technol Mag 19(7):22–26

Dahlgaard JJ, Dahlgaard-Park SM (2006) Lean production, six sigma quality, TQM and company culture [J]. TQM Mag 18(3):263–281

Delgado C, Ferreira M, Branco MC (2010) The implementation of lean Six Sigma in financial services organizations [J]. J Manuf Technol Manag 21(4):512–523

Hu G, Wang L, Fetch S, Bidanda B (2008) A multi-objective model for project portfolio selection to implement lean and Six Sigma concepts [J]. Int J Prod Res 46(23):6611–6625

Lee K, Wei C (2010) Reducing mold changing time by implementing Lean Six Sigma [J]. Qual Reliab Eng Int 26(4):387–395

Mandahawi N, Fouad RH, Obeidat S (2012) An application of customized lean six sigma to enhance productivity at a paper manufacturing company [J]. Jordan J Mech Ind Eng 6(1):103–109

Shah R, Chandrasekaran A, Linderman K (2008) In pursuit of implementation patterns: the context of Lean and Six Sigma [J]. Int J Prod Res 46(23):6679–6699

Thomas A, Barton R, Chuke-Okafor C (2009) Applying lean six sigma in a small engineering company – a model for change [J]. J Manuf Technol Manag 20(1):113–129

Timans W, Antony J, Ahaus K, Van Solingen R (2012) Implementation of Lean Six Sigma in small- and medium-sized manufacturing enterprises in the Netherlands [J]. J Oper Res Soc 63 (3):339–353

Ward S (2006) How six sigma helps a lean project [J]. Quality 45(4):24–27

Chapter 26
A FMEA-Aided Equipment Life-Cycle-Cost Measurement System

Chee-cheng Chen and Hong Zhang

Abstract This research tries to establish an optimum life cycle cost (LCC) based strategy model of equipments' purchasing and maintenance. The study integrates the technique of failure modes and effect analysis (FMEA) and analysis of equipment maintenance cost to optimize LCC of equipments' decision in order to sustain and promote the firms' competitive capability. A revised FMEA table will be utilized to collect data and demonstrate the relevance among estimated failure cost, severity of effect and cost of actions-taken that constructs the main frame of the method. Finally, this study uses an equipment group in assembly house of semiconductor, S company as a case study to prove the model's applicability and suitability.

Keywords Equipment • Failure mode and effect analysis • Life cycle cost • Procurement strategy

Introduction

Massive centralized manufacturing has led to large equipment, increasing the proportion of enterprise fixed assets. If an enterprise plan to significantly reduce its' total cost, it is necessary to carefully consider the cost of equipment procurement.

Traditionally, price was the primary factor when choosing suppliers (Zachariassen and Arlbjørn 2011). However, the cost of equipment (or the like) based not only on the initial expenditure, but also on its cost from failure, maintenance and operating costs over its entire lifetime. The cost of unexpected downtime and lost production is a significant item in the total LCC (Goralczyk and Kulczycka 2005). Life cycle costs

C.-c. Chen (✉) • H. Zhang
School of Management, Shanghai University, Shanghai, China
e-mail: carlchen@shu.edu.cn; z11720484@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_26,

of a product or equipment can be many times the initial purchase or investment costs (Woodward 1997). To optimize total performance, the LCC should therefore be taken into consideration in the equipment management.

Literature Review

LCC

Life cycle cost (LCC) is the total cost of a device or system during its full life cycle including the cost of development, acquisition, operation, conservation and maintenance, and final disposal (Goralczyk and Kulczycka 2005). The LCC technique should be implemented to encompass both environmental and economic aspects (Goralczyk and Kulczycka 2005).

The LCC concept was developed by the Department of Defense, US during the 1960s and incorporated as policy by Directive 5000.1, Acquisition of Major Defense Systems, in 1971 (Goralczyk and Kulczycka 2005). The LCC concept has been moved from defense systems to industrial and consumer product areas (Utne 2009). Lutz et al. (2006) think of it as a standard engineering economic approach to be used for choosing among alternative products or designs that provide approximately the same service to the customer (Lutz et al. 2006). At present, LCC analysis is used widely in construction at home, industries and abroad (Wu et al. 2011; Olubodun et al. 2010; Korpi and Ala-Risku 2008).

FMEA

Failure mode and effect analysis (FMEA) is a technique that identifies the potential failure modes of a product or process, the effects of the failures and assesses the criticality of these effects on the product functionality (Teng and Ho 1996). FMEA is a widely used quality improvement and risk assessment tool in manufacturing (Teoh and Case 2004). FMEA is applied to project risk assessment (Murphy et al. 2011) and other fields.

Bowles pointed out that the FMEA scales for severity and detection are only qualitative (Chang and Sun 2009). The three indices used for RPN (risk priority number) calculation are ordinal scale variables. The cost due to failure cannot be defined using these ordinal numbers (Dong 2007). Several studies on overcoming the traditional FMEA weakness have been conducted. Use of fuzzy reasoning and grey relation with FMEA has been presented in failures risk evaluation for marine industry (Pillay and Wang 2003). Integration of the use of fuzzy logic and expert database with FMEA has been applied to prioritize failures for taking corrective or remedial actions (Sharma et al. 2005). Risk priority number and fuzzy weighted geometric mean of the risk factors are used to improve the performance of the risk evaluation (Ilangkumaran and Thamizhselvan 2010). The disadvantage is the costs are difficult to estimate without data.

Methodology

Life cycle costs of equipment are the sum of total costs during the entire lifetime from purchasing to the eventual disposal including acquisition, running costs, maintenance fees, the costs of recovery measures and final disposal fees. The formula is as follows:

$$LCC = C_I + C_O + C_F + C_R + C_M + C_D - C_S \tag{26.1}$$

Where C_I is the initial equipment acquisition cost including purchase price, installation, test and training costs; C_O is the operation cost main including energy cost, labor cost, and other related expenses; C_F is additional failure loses, such as downtime losses and customer complaints; C_R is the failure recovery, trouble-shooting cost; C_M is equipment preventive maintenance (PM) cost, including regular checking cost and check and repair costs due to failure; C_D is the equipment disposal costs, such as environmental cost and transportation fees; The salvage value (C_S) should be subtracted from the total.

FMEA-Aided LCC Analysis

The measurements for C_I, C_O, C_D and C_S are fixed, relatively static, or a ratio of the production volume, while C_F, C_R and C_M are more dynamic and fluctuate. A revised FMEA table (Table 26.1), RPN-based suggested PM interval (Table 26.2) and cost-based severity ranking (Table 26.3) are developed and co-worked with S company in this research to measure the latter three costs. The additional regular FMEA recording steps are as follows,

1. To measure the cost impact of failure (C_F), match the number of costs with the cost-based severity ranking table to determine the ranking number. Record the number of cost impacts and severity in columns {3} and {4} of the revised table accordingly in one case of machine failure.
2. To measure the cost of recovery, trouble-shooting actions (C_R) for fixing this failure will be recorded in columns {13} and {14} of this revised table.
3. To reset the preventive maintenance interval through the matching RPN ($\text{RPN} = (\text{S}) \times (\text{O}) \times (\text{D})$) and suggested PM interval as shown in Table 26.2 and measure the cost (C_M) that will be recorded in columns {11} and {12} of the revised table. A RPN versus (transformed to) suggested PM interval mechanism

Table 26.1 Revised FMEA table (K US$)

FMEA process									Action taken				
Item/ Date	Failure mode	Failure cost (C_F)	S	Failure cause/ part	O	Currently check method	D	RPN	Suggested measures	Suggested PM	Maintenance cost (C_M)	Recovery action	Recovery cost (C_R)
{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}

Table 26.2 RPN-based suggested PM interval

RPN	Severity < 8 PM	Severity ≥ 8 PM
450 < RPN	1 week	3 days
350 < RPN ≦ 450	2 weeks	1 week
250 < RPN ≦ 350	1 month	2 weeks
150 < RPN ≦ 250	2 months	1 month
50 < RPN ≦ 150	3 months	1.5 months
0 < RPN ≦ 50	6 months	3 months

Table 26.3 Cost-based severity ranking (K US$)

Effect	Cost of failure (C_F)	Ranking (S)	Effect	Cost of failure (C_F)	Ranking (S)
Hazardous without warning	1,600 < C_F	10	Low	70.0 < C_F ≦ 120.0	5
Hazardous with warning	900.0 < C_F ≦ 1600.0	9	Very low	40.0 < C_F ≦ 70.0	4
Very high	400.0 < C_F ≦ 900.0	8	Minor	20.0 < C_F ≦ 40.0	3
High	200.0 < C_F ≦ 400.0	7	Very minor	5.0 < C_F ≦ 20.0	2
Moderate	120.0 < C_F ≦ 200.0	6	None	0 < C_F ≦ 5.0	1

Table 26.4 Recording table of C_F, C_R, AND C_M

Item	Date	Action taken	Description	Portion	C_M	C_F	C_R	Remark
1	3/15	PM	3 months/interval	A	C_{M1}	–	–	
2	4/25	Failure happened and fixed	Crack and replace the parts	B	–	C_{F1}	C_{R1}	
...	...	...	...	...	...	...	...	...
n					C_{Mn}	C_{Fn}	C_{Rn}	
Total					TC_M	TC_F	TC_R	

can be developed by the multi-discipline FMEA team. Analysis of the past records, considerations of effectiveness and cost are necessary. The RPN mechanism versus PM interval can be very different for plants with different product-lines. The FMEA team members may be charged with reviewing performance data periodically to assess how much improving the cost of quality has become since implementing the system. The mechanism of S company is established as Table 26.2.

LCC Data Collection and Calculating

After the system's implemented for a certain period, a recording table of C_F, C_R, and C_M (Table 26.4) for recording and total LCC calculation and a Pareto diagram

Table 26.5 Part of the revised FMEA table of RTDC machine (K US$)

FMEA process									Action taken				
Item/date	Failure mode	Failure cost (C_F)	S	Failure cause/part	O	Detection methods	D	RPN	Suggested measures	PM interval	Maintenance cost (C_M)	Recovery action	Recovery cost (C_R)
To attach tape on L/F precisely/9-23-11	Tape releasing no good	150.0	6	Tapping turn table axle too loose (A)	6	Adjustment by condition	3	108	Changing Tapping turn table axle	2 months	46.0	Check the tape turn table	54.0
to attach tape on L/F precisely/12-27-11	Tape releasing no good	150.0	6	Table adjustment no good (D)	6	Adjustment by condition	6	216	Confirm the tape turn table status	3 months	60.0	Check transparent table	67.0

for prioritizing the cost-consumption for machine parts, subsystem or failure mode that can be very beneficial for developing improvement actions.

Case Study

We selected a case study involving an RTDC taping machine from S company to illustrate the proposed method. The main function of this machine is attaching tape onto a lead-frame (L/F) precisely. Table 26.5 is part of the revised FMEA table for RTDC machine. One possible failure and two causes for this failure are picked up to measure their C_F, C_R and C_M and calculate their RPN, 108 and 216 respectively as shown in Table 26.5. Referring to Table 26.2, the suggested PM frequencies, including the interval of PM for the two failure causes with RPN, 108 and 216 respectively determined as shown in Table 26.5. After the system is implemented for a certain period or at the end of the lifecycle, the recording results for C_F, C_R and C_M can be transferred step by step to make a summary table of total C_F (TC_F), C_R (TC_R) and C_M (TC_M) of all key parts (subsystems) (Table 26.6) for total LCC calculation and a Pareto diagram (Fig. 26.1) for prioritizing the cost-consumption sequence for machine parts, sub-system or failure mode that can be beneficial for developing a purchasing strategy.

LCC Analysis

Based on the results from Table 26.6 and Fig. 26.1, the LCC for the RTDC taping machine will be calculated using formula (26.1). Some interesting results were found that (1) the LCC is higher than another RTDC taping machine with a different brand whose purchasing price is higher, (2) the cost impact of failure (C_F) is significantly higher than the other cost items but it was always ignored in the past. The S company purchasing department also presented detailed records in the revised FMEA table and the analysis results for LCC to the equipment manufacturer in order to get significant improvement in LCC at the next purchasing decision. The manufacturer redesigned the condenser (G) and the main hydraulic cylinder (E) to lower the LCC.

Conclusion

This article presented that purchasing equipment should not consider just the price but take into account the LCC. This case study produced a structure for the LCC database with FMEA application to provide accurate technical and cost information.

Table 26.6 Summary table of TC_F, TC_R, AND TC_M (K US$)

Item or Part/date	TC_M	TC_F	TC_R	Total
Condenser (G)	720.0	724.0	250.0	1694.0
Hydraulic Cylinder (E)	280.0	457.0	140.0	877.0
Vacuum (C)	160.0	320.0	90.0	570.0
Press (B)	140.0	283.0	70.0	493.0
...	...	...	...	...
Total	1700.0	3785.0	1560.0	7045.0

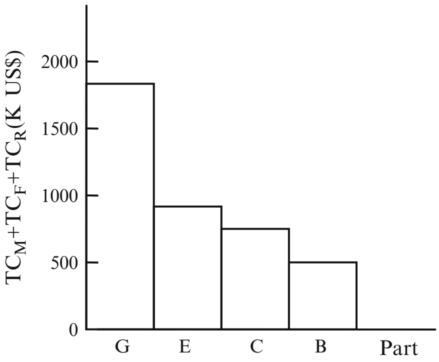


Fig. 26.1 Pareto diagram of $TC_F + TC_R + TC_M$ by part

The proposed LCC measurement model with more dynamic costs measurement, cost impact of failure (C_F), cost of recovery, trouble-shooting actions (C_R) and preventive maintenance (PM) cost (C_M) that could be applied by firms in different industries to address equipment concerns in manufacturing and purchasing management. The proposed model can assist firms in selecting and rewarding the best equipment supplier and integrating their capabilities to develop an appropriate profit improvement program for meeting and exceeding specific organization or customer requirements. This would be extended by purchasing management to the design and manufacturing stage to improve the competition of the entire supply chain. The estimated total cost and potential failure mode of new equipment within the life cycle of equipment can be applied to assess suppliers.

Acknowledgement This research has been supported by S company in Kunshan city, Jiangsu province, China. The authors would like to thank the management for providing the opportunity for this research, and especially staffs of the stamping department who provided us with useful technical information.

References

Chang DS, Sun KL (2009) Applying DEA to enhance assessment capability of FMEA. Int J Qual Reliab Manag 26(6):629–643

Dong C (2007) Failure mode and effects analysis based on fuzzy utility cost estimation. Int J Qual Reliab Manag 24(9):958–971

Goralczyk M, Kulczycka J (2005) LCC application in the polish mining industry. Manag Environ Qual Int J 16(2):119–129

Ilangkumaran M, Thamizhselvan P (2010) Integrated hazard and operability study using fuzzy linguistics approach in petrochemical industry. Int J Qual Reliab Manag 27(5):541–557

Korpi E, Ala-Risku T (2008) Life cycle costing: a review of published case studies. Manag Audit J 23(3):240–261

Lutz J, Lekov A, Chan P, Whitehead CD, Meyers S, McMahon J (2006) Life-cycle cost analysis of energy efficiency design options for residential furnaces and boilers. Energy 31(2):311–329

Murphy M, Heaney G, Perera S (2011) A methodology for evaluating construction innovation constraints through project stakeholder competencies and FMEA. Constr Innov 11(4):416–440

Olubodun F, Kangwa J, Oladapo A, Thompson J (2010) An appraisal of the level of application of life cycle costing within the construction industry in the UK. Struct Surv 28(4):254–265

Pillay A, Wang J (2003) Modified failure mode and effects analysis using approximate reasoning. Reliab Eng Syst Saf 1(79):69–85

Sharma RK, Kumar D, Kumar P (2005) Systematic failure mode effect analysis (FMEA) using fuzzy linguistic modeling. Int J Qual Reliab Manag 22(9):986–1004

Teng SH, Ho SY (1996) Failure mode and effects analysis: an integrated approach for product design and process control. Int J Qual Reliab Manag 13(5):8–26

Teoh P, Case K (2004) Failure modes and effects analysis through knowledge modeling. J Mater Process Technol 153:253–260

Utne IB (2009) Life cycle cost (LCC) as a tool for improving sustainability in the Norwegian fishing fleet. J Clean Prod 17(3):335–344

Woodward D (1997) Life cycle costing – theory, information acquisition and application. Int J Proj Manag 15(6):335–441

Wu CM, Sun CL (2011) Economy about the energy-saving of buildings' envelope with LCC theory. Build Energy Eff 121(2):63–64

Zachariassen F, Arlbjørn JS (2011) Exploring a differentiated approach to total cost of ownership. Ind Manag Data Syst 111(3):448–449

Chapter 27
Key Process Variable Identification for Quality Classification Based on PLSR Model and Wrapper Feature Selection

Wen-meng Tian, Zhen He, and Wei Yan

Abstract In modern manufacturing, hundreds of process variables are collected, and it is usually difficult to identify the most informative ones. Partial Least Square Regression provides an efficient way to evaluate each variable, but it cannot evaluate any variable subset as a whole. In the paper, a new framework of key process variable identification is proposed. It combines PLSR model and wrapper feature selection to firstly assess every variable individually and then the top variables in groups. Five datasets are tested, and the average classification accuracy is higher and the key process variables identified are less than the available approaches.

Keywords Classification • PLS • Variable Selection • Wrapper

Introduction

In modern manufacturing process, high dimensional process data play crucial parts in quality monitoring and diagnosis. Usually, the process variables are noisy and redundant, making it almost impossible to predict the quality effectively. Thus, identifying best "predictors" for quality classification is critical for process modeling, monitoring, and control (Su et al. 2006).

Partial Least Squares Regression (PLSR) is a well established statistical model, and it has lots of advantages as follows (Kettaneha et al. 2005). (1) It can deal with high multicollinearity between variables; (2) It requires smaller sample size than regular Multiple Linear Regression (MLR); (3) its parameters can be used to analyze variable importance. Also, PLSR methodology is helpful to identify best

Supported by National Natural Science Foundation of China (No.70931004, 70802043).

W.-m. Tian (✉) • Z. He • W. Yan
College of Management & Economics, Tianjin University, Tianjin, China
e-mail: megtiantju@gmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_27,

variables when combined with some other methods, such as data mining and feature selection (Anzanello et al. 2009, 2012). However, the available methods suffer from some serious problems. One is that correlations between variables are not taken into consideration. That makes their methods simple and flexible, while not effective for classification so as to evaluate each possible subset of variables.

On the other hand, Wrapper feature selection is widely used as a preprocessing technique to high dimensional datasets to find a best variable subset which has a good capability of classification (Kohavi and John 1997; Inza et al. 2004). Lots of wrapper algorithms have been developed to solve variable selection problems in microarray analysis, text classification, and industrial processes.

In the paper, a new variable selection methodology is proposed based on PLSR and wrapper feature selection techniques, making it easy to evaluate the variable subsets as a whole, instead of just calculating an importance index one by one.

The rest of the paper is organized as follows. A detailed introduction of the proposed methodology is presented in section "Methodology". Next, section "Proposed Framework" provides a framework of the proposed method. Then, section "Results" compares the experimental results with some other newly published methods. Last, the method is summarized and some future research topics are proposed in section "Conclusion".

Methodology

PLSR: Model Structure and Parameters

Partial Least Squares Regression (PLSR) model is not only widely used to model linear relationships between variables and responses, but also effective to deal with multicollinearity between the multiple variables or responses. Furthermore, it is highly tolerant to small sample sizes.

The most popular algorithms to implement PLSR are SIMPLS (Jong 1993) and NIPALS (Gerladi and Kowalski 1986). Both can be easily performed with the PLS functions in Statistical Toolbox of Matlab2011a.

The PLSR model can be developed from a training dataset of two matrices, $\boldsymbol{X}$ and $\boldsymbol{Y}$, which demonstrate N observations in K process variables and M final quality responses, respectively. In the model, a small number of components, $\boldsymbol{T}$ and $\boldsymbol{U}$, are extracted from original $\boldsymbol{X}$ and $\boldsymbol{Y}$. In fact, $\boldsymbol{T}$ and $\boldsymbol{U}$ are linear combinations of $\boldsymbol{X}$ and $\boldsymbol{Y}$, and they are often called "X-scores" and "Y-scores". Formulas are shown below, where $\boldsymbol{W}$ and $\boldsymbol{Q}$ are original matrices' weights on extracted components.

$$T = XW \tag{27.1}$$

$$U = YQ \tag{27.2}$$

Therefore, $\boldsymbol{T}$ and $\boldsymbol{U}$ could be good predictors of $\boldsymbol{X}$ and $\boldsymbol{Y}$, and the residual matrices $\boldsymbol{E}$ and $\boldsymbol{G}$ should be very small. In Eqs. (27.3) and (27.4), $\boldsymbol{P}$ and $\boldsymbol{C}$ are loading matrices of $\boldsymbol{X}$ and $\boldsymbol{Y}$.

$$X = TP' + E \tag{27.3}$$

$$Y = UC' + G \tag{27.4}$$

Then, $\boldsymbol{T}$ can be good predictors of $\boldsymbol{U}$. See Eq. (27.5), $\boldsymbol{H}$ is the residual matrix, which should be "small enough" to ensure prediction accuracy.

$$U = TD + H \tag{27.5}$$

Giving the Eqs. (27.1) and (27.2), Eq. (27.5) can be rewritten as a multiple regression model, and $\boldsymbol{F}$ is the residual matrix.

$$Y = XB + F \tag{27.6}$$

The data structures in the model can be clearly shown in Fig. 27.1, which employed the structure in Hoskuldsson (1988) with slight modifications to make it more understandable. More mathematical details in PLSR model can be found in literature (Wold et al. 2001).

Variable Importance on Projection Based on PLSR model

Variable Importance on Projection (VIP) is firstly defined in Gerladi and Kowalski (1986). It is a weighted summary of the variable's importance for the response matrix $\boldsymbol{Y}$, and it can be easily obtained by the formula below.

$$VIP_k = \sqrt{\frac{K \sum_a {w_{ka}^*}^2 \times SSY_a}{SSY_T}} \tag{27.7}$$

Where

$$SSY_a = \frac{1}{M} \sum_{m=1}^{M} \frac{Cov(y_m, t_a)^2}{Var(y_m) Var(t_a)} \tag{27.8}$$

$$SSY_T = \sum_{a=1}^{A} SSY_a \tag{27.9}$$

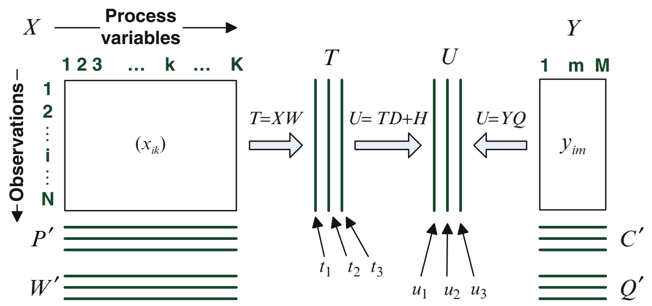


Fig. 27.1 The structure of partial least square regression

$$W^* = W(P'W)^{-1} \tag{27.10}$$

Here w^*_{ka} is the transformed x_k's weights of component a

Though there is another version of VIP in Anzanello et al. (2009), Eq. (27.7) is the most popular one. Both versions illustrate the same relationship between $\boldsymbol{Y}$ and $\boldsymbol{T}$.

Wrapper Feature Selection

Feature selection (FS) is a commonly used data preprocessing technique to identify most informative features (also called variables) for a better classification model (Guyon and Elisseeff 2003). There are two mainstream methods of feature selection, filter and wrapper.

Filter is to calculate a certain evaluation index, such as Information Gain (Hall and Holmes 2003) and Symmetrical Uncertainty (Yu and Liu 2003), for each variable, and then eliminate the variables with a "low value". Wrapper, on the other hand, is to search the feature space to find a variable subset with optimized classification accuracy based on a certain classifier. Compared with filters, wrappers can find a more satisfactory subset for a certain classifier (Hua et al. 2009). As our objective of variable selection is to build a more reliable, yet less complicated classification model to predict the quality of products, wrapper method can achieve better results due to its inherent advantage.

There are three key elements in a wrapper method, a search engine to generate variable subsets, a learning algorithm, and an evaluation criterion. The implementation framework is shown in Fig. 27.2. More detailed information about wrapper feature selection can be found in the literature (Kohavi and John 1997).

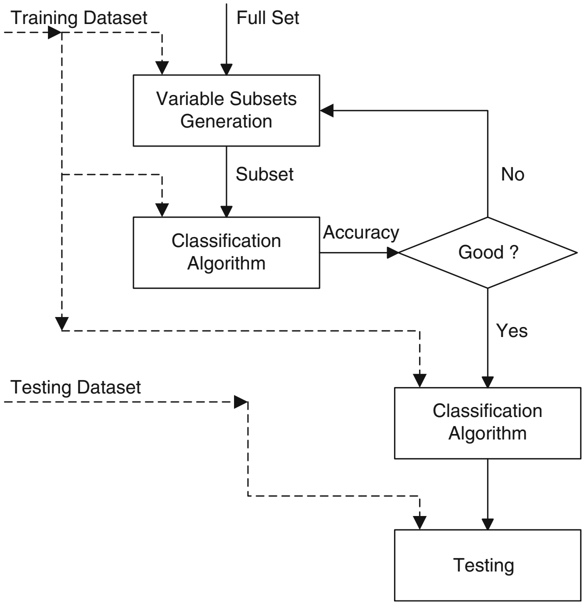


Fig. 27.2 The structure of wrapper feature selection

Proposed Framework

The framework of key process variable identification includes the following 4 steps. Step 1 is data preparation; Step 2 is to construct a PLSR model, and obtain the VIP values of the process variables; Step 3 implements a wrapper feature selection with the SFFS search engine and KNN classifier to evaluate the performance of each feature subset. At last, a testing step will be performed in Step 4, using the reduced testing dataset to predict the goodness of the variable selection.

Step 1: Split the original dataset into two exclusive subsets
The original dataset is separated into training and testing datasets by an appropriate proportion, say, 3:2 or 4:1. Also, as the process responses are continuous, some cut-off value of the responses should be obtained to meet the needs of classification. In this case, the proportion of different response classes should be almost the same in the training and testing datasets.

Step 2: Construct a PLSR model with the training dataset, and calculate VIP for each process variable
The process data should firstly be normalized or the data analysis would be affected by different scales of different variables. NIPALS algorithm can be implemented in the Statistical Toolbox of Matlab2011a. In the meantime, the parameter matrices can be calculated, and the VIP index of each variable should be obtained from Eq. (27.7). Also, the variable index should be reordered according to the descending order of VIP.

Step 3: Apply Wrapper feature selection to the training dataset to search for the optimal subset
Wrapper feature selection is to implement a heuristic search in the state space of the variables to find an optimal (or suboptimal) subset with the best performance of a certain learning algorithm. In this paper, Sequential Floating Forward Selection (SFFS) (Pudil et al. 1994) is our choice of the search engine, and K-Nearest Neighbor classification (Aha et al. 1991) is used to evaluate the subsets in each iteration step. The detailed algorithm of SFFS could be found in 16, and it is chosen for this good capability in jumping out of local optimum.
The KNN classification should be our first choice of learning algorithm for it is easy to understand, efficient for computation, and has only one parameter k to set in building the model (Anzanello et al. 2012). Furthermore, the appropriate value of k can be obtained from cross validation. The distance is defined as Euclidean distance for it is widely used in instance-based classification rules. By majority voting of the k nearest training samples, the class label of the testing sample can be predicted efficiently (Aha et al. 1991).

Step 4: Classify the testing dataset with the optimal subset of variables obtained in Step 3
Based on the optimal variable subset obtained from Step 3, the testing dataset can be examined to compute the classification accuracy. In this case, the parameter k and Euclidean distance are applied so that the model for testing is identical with the result of wrapper feature selection.

Results

To justify the effectiveness of the proposed framework, five datasets from real industry are used. Also, the proposed PLSR-Wrapper framework is compared with the method in literature (Anzanello et al. 2009) and the PLSR model in literature (Gauchi and Chagnon 2001). Both of the two methods above have been applied to these five datasets, and the testing result can be easily employed for a fair comparison.

All the datasets, namely ADPN, LATEX, OXY, SPIRA, and PAPER, are from chemistry industry. They are real process data from production of nylon, latex, titanium dioxide, antibiotics, and paper recycling, respectively. The samples of each datasets are categorized into two classes with a proper cut-off value of the final response for each dataset. The values come from (Anzanello et al. 2012; Gauchi and Chagnon 2001).

The PLSR model is applied to the five datasets just as it is in Anzanello et al. (2009), and the VIP index for each variable is calculated. The variable index is reordered in the descending order of VIP so that it can be used in the wrapper feature selection method.

Table 27.1 Comparison of available and proposed approaches

	All variables used		After variable selection CCR		Percent of variables retained	
Datasets	KNN CCR	PLS CCR	Method in [3]	PLSR-Wrapper	Method in [3]	PLSR-Wrapper
ADPN	0.78	0.86	0.87	0.86	8.0%	11.0%
LATEX	0.78	0.83	0.87	0.77	7.7%	7.7%
PAPER	0.81	0.59	0.83	0.90	18.5%	3.7%
OXY	0.73	0.73	0.73	0.90	6.3%	2.1%
SPIRA	0.86	0.83	0.9	0.93	4.2%	6.3%
Average	0.792	0.77	0.84	0.872	8.9%	6.15%

Then, the wrapper feature selection algorithm with a VIP-defined order is performed. The summary of the performance of the proposed framework and some previous methods are shown in Table 27.1. In the table, two variable subset performances, classification accuracy and percent of retained variables of different methods are compared.

In Table 27.1, the first column is the name of the datasets; the second and third column record the Classification Correct Rate (CCR) with all variables to construct the KNN and PLS model; the next two demonstrate the CCR of variable selection method in Anzanello et al. (2009) and in this paper, respectively; the last two show percent of retained variables of both methods. It is indicated in the table that both variable selection approaches can retain a small percent of variables while obtaining a higher CCR. Comparing with the approach in Anzanello et al. (2009), the proposed method is more effective in dimension reduction and it can obtain more accurate classification models as well.

Conclusion

A new framework combining PLSR model and wrapper feature selection is proposed to identify the key process variables in high dimensional process data for quality classification. VIP is applied to determine the relative importance of variables, and to generate a reordered variable sequence. A wrapper feature selection method is employed, with SFFS to heuristically search the space and KNN to evaluate the variable subsets in each iteration step.

The framework has been applied to five widely tested datasets in chemistry industry, and the experimental results indicate that the proposed method can construct a classification model with better average performance with a smaller percent of retained variables.

Future research includes how to determine which classification algorithm or variable selection method should be applied for different datasets, for the result also indicates that the proposed framework is not equally effective to all the five datasets.

Acknowledgment We would like to express our gratitude to Prof. Jean-Pierre Gauchi for providing the datasets of ADPN, LATEX, OXY, and SPIRA; and to Prof. Svante Wold for providing the PAPER dataset and some helpful advice about PLSR model. We also thank Dr. Michel J. Anzanello and Prof. Susan L. Albin for their supportive advice and encouragement during the algorithm testing.

References

Aha DW, Kibler D, Albert MK (1991) Instance-based learning algorithms. Mach Learn 6:37–66

Anzanello MJ, Albin SL, Chaovalitwongse WA (2009) Selecting the best variables for classifying production batches into two quality levels. Chemom Intell Lab Syst 97:111–117

Anzanello MJ, Albin SL, Chaovalitwongse WA (2012) Multicriteria variable selection for classification of production batches. Eur J Oper Res 218:97–105

Gauchi J, Chagnon P (2001) Comparison of selection methods of explanatory variables in PLS regression with application to manufacturing process data. Chemom Intell Lab Syst 58:171–193

Gerladi P, Kowalski BR (1986) Partial least squares regression: a tutorial. Anal Chim Acta 185:1–17

Guyon I, Elisseeff A (2003) An introduction to variable and feature selection. J Mach Learn Res 3:1157–1182

Hall MA, Holmes G (2003) Benchmarking attribute selection techniques for discrete class data mining. IEEE Trans Knowl Data Eng 15(3):1437–1447

Hoskuldsson A (1988) PLS regression methods. J Chemom 2:211–228

Hua J, Tembe WD, Dougherty ER (2009) Performance of feature-selection methods in the classification of high-dimension data. Pattern Recognit 42:409–424

Inza I, Larranaga P, Blanco R, Cerrolaza AJ (2004) Filter versus wrapper gene selection approaches in DNA microarray domains. Artif Intell Med 31:91–103

Jong S (1993) SIMPLS: an alternative approach to partial least squares regression. Chemom Intell Lab Syst 18:251–263

Kettaneha N, Berglundb A, Wold S (2005) PCA and PLS with very large data sets. Comput Stat Data Anal 48:69–85

Kohavi R, John GH (1997) Wrappers for feature selection. Artif Intell 97:273–324

Pudil P, Novovicova J, Kittler J (1994) Floating search methods in feature selection. Pattern Recognit Lett 15:1119–1125

Su C, Chen L, Chiang T (2006) A neural network based information granulation approach to shorten the cellular phone test process. Comput Ind 57:412–423

Wold S, Sjostrom M, Eriksson L (2001) PLS-regression: a basic tool of chemometrics. Chemom Intell Lab Syst 58:109–130

Yu L, Liu H (2003) Feature selection for high-dimensional data: a fast correlation-based filter solution. In: Proceedings of the twentieth international conference on machine learning (ICML-2003), Washington, DC

Chapter 28
Research on Setup Adjustment Problem Considering Adjustment Error Based on AR Model

Zhi-jie Zhang, Zhan-wen Niu, Zhen He, and Xu-tao Zhang

Abstract Aiming at the short-run discrete manufacturing process with setup error, the optimal adjustment scheme to minimize the total process quality loss for the situation of adjustment with quadratic cost and considering adjustment error based on autoregressive (AR) model is developed. Based on the state-space process control model, the optimal adjustment scheme is derived by using Kalman filter on line estimation and linear quadratic Gaussian (LQG) theory. A simulation case is presented to illustrate the implement method of the optimal adjustment policy. Furthermore, the optimal adjustment scheme is compared with other quality control policy by simulations, and the results show that the adjustment solution presented by this paper is more effective than other to reduce the total quality loss of the process.

Keywords Optimal adjustment • Kalman filter • Statistical process adjustment • State-space model

Introduction

In the Deming's funnel experiment (Deming 1986), there are two important aspects to notice: first, the process starts on target and remains there unless an adjustment is made. Secondly the observations form an i.i.d sequence. If assumed the second condition above but assumed that, at the start up of the process, there is a setup

This research is supported by the key project of the National Science Foundation of China (Grant No.70931004,71071107)

Z.-j. Zhang (✉) • Z.-w. Niu • Z. He
Department of Industry Engineering, Tianjin University, Tianjin, China
e-mail: zhangzhijierise@163.com

X.-t. Zhang
Department of Equipment Support, Academy of Military Transportation, Tianjin, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_28,

error. If the cost is considered when running the process off target, then it is evident that adjustment is necessary. How to do this in such way that minimized the cost of output is called the Setup Adjustment Problem.

Solutions to the setup adjustment problem are important for the control of discrete part manufacturing processes. In this type of processes, the operation of setting up a machine for production of a new lot may induce offsets or shifts in the values of the quality characteristics of the part relative to their targets. Grubbs (1983) solved the problem first (Grubbs 1983). When the initial setup error is an unknown constant, the solution is given by the Harmonic rule. If several lots are produced, the setup error can be considered random variable form normal distribution over lots. Then Grubbs proposed to model the offset and obtained the solution that is called extended rule.

Del Castillo et al. (2003) showed that the unifying view of the process adjustment using a simple Kalman filter to estimate the state variable and adjust the process.

The formulation allows to apply linear quadratic Gaussian theory to extend the basic setup adjustment problem and connect other statistical techniques such as stochastic approximation and recursive least squares (Del Castillo et al. 2003). And Del Castillo et al. (2003) further studied setup adjustment problem from a view of small sample (Castilio et al. 2003).

When considering the cost of adjustment and off target, Sullo and Vandevan (1999) developed optimal adjustment strategies for a process with run to run variation and 0–1 quality loss function for a short run manufacturing process. They considered a setup error induced at the beginning of each run and remaining fixed through the run. The solution depends on the actual process parameters such as adjustment error, run size, and adjustment and sampling cost (Sullo and Vandevan 1999). Trietsch (1998, 2000) introduced a generalized procedure that allows skipping some adjustment without losing information when constant adjustment cost and quadratic off target cost are considered. And further analyzed effects of the adjustment error (Trietsch 1998, 2000). Pan and Del Castillo (2004) defined a schedule of adjustments by minimized the sum of total cost of running the process off target and of adjusting, and compared the robustness of these adjustment methods (Pan and Del Castillo 2003). For the case of an asymmetric off target cost in discrete part manufacturing, Colosimo et al. (2005) introduced a bias term in the control rule permits the process quality characteristic to converge to the target from the lower cost side, thus reducing the process quality losses incurred during the adjustment (Colosimo et al. 2005).

When the process parameters are unknown in the setup adjustment problem, Colosimo et al. (2004) studied such type setup adjustment problem using Bayesian and Markov Chain Monte Carlo (MCMC) techniques. The approach presented is based on repeatedly estimating the initial offset in each lot through MCMC method (Colosimo et al. 2004). Lian (2006) further presented the sensitivity analysis and performance of MCMC controller and compared with other controller when process parameters are unknown (Lian et al. 2006a). Lian (2006) developed multiple lots setup adjustment problem using Sequential Monte Carlo (SMC) method when process parameters are unknown. Compared with MCMC method, the SMC method has performance equivalent but at a small computational cost (Lian et al. 2006b). Lian (2006) further studied setup adjustment problem when considering constant adjustment cost and unknown parameters, using a dynamic programming formulation based on the Bayesian estimation of all unknown process parameters, the results showed that optimal process adjustment policy is of a deadband form (Lian and Castillo 2006).

Liu and Ma (2010) studied setup adjustment problem for multivariate process using Bayesian inference and dynamic programming when adjustment cost is constant. Based on the state space process model, the time varying deadband form of adjustment scheme is derived (Liu et al. 2010). And further discussed setup adjustment problem consider random adjustment error (Liu et al. 2011). But he only considered that adjustment random error is white noise.

In order to more close to the actual production process, this paper studies setup adjustment problem considering adjustment error based on AR model and adjustment cost is quadratic function. Based on the state-space process control model, the optimal process adjustment scheme is derived by using Kalman filter on line estimation and linear quadratic Gaussian (LQG) theory.

Process Model and Cost Criterion

Process Model

Suppose N parts are to be processed sequentially in time and we are interested in controlling a single quality characteristic. Suppose the machine setup results in an unknown initial offset θ_0 in the quality characteristic, which, if unadjusted, will affect all N parts. Without loss of generality, the target value of process equal to zero. Let us denote by y_i the deviation from target of the quality characteristic of interest for the ith part. The mean variable deviation from process target is θ_i, $i \in [0, N]$. We assume a controllable factor $U(i)$ exists to adjust the process in a linear manner, The adjustment $U(i)$ is then computed based on observations obtained up to and including part i. Considering adjustment is biased, the adjustment error sequence W has AR model. Then the state equations and observed equations of process can be expressed as follows:

$$\begin{aligned} \theta(i+1) &= \theta(i) + U(i) + W(i) \\ y(i+1) &= \theta(i+1) + V(i+1) \\ W(i+1) &= AW(i) + \xi(i) \end{aligned} \tag{28.1}$$

Where v_i and ξ_i are white noise with mean zero, given by

$$v_i \sim N(0, {\sigma_v}^2), \ \ \xi_i \sim N(0, {\sigma_\xi}^2),$$

A is the coefficient of autoregressive model, the unknown initial offset is given by $\theta_0 \sim N(\theta_d, P)$, and, ξ_i, v_i and θ_0 are independent of each other.

Cost Criterion of Process

We assume that there exists a quadratic and symmetric off-target cost, and when adjustment variable $U(i)$ is nonzero, adjustment cost is also a quadratic. Then, under these assumptions, the process expected loss function is:

$$J = \min E\left[\theta(N)'Q(N)\theta(N) + \sum_{i=0}^{N-1}(\theta(i)'Q(i)\theta(i) + U'(i)R(i)U(i)\right] \tag{28.2}$$

Where, $Q(i)$ is the coefficient of off target cost, $R(i)$ is the coefficient of adjustment cost. The objective is to find the optimal adjustments sequence $U(i)$ based on the observed deviations from target in order to minimize the cost criterion in (28.2).

Optimal Adjustment Policy of Setup Adjustment Problem

Kalman Filter Estimation

From above process model, we will estimate the state variable using Kalman filter. Notice that there is a AR sequence noise W in the formula, so we transfer the color noise to the white noise with extend state variable method. The sequence W will also be as state variable, and then we define as follows:

$$\theta^*(\mathrm{i}) \triangleq \begin{bmatrix} \theta(i) \\ w(i) \end{bmatrix} \quad \Phi^* \triangleq \begin{bmatrix} 1 & 1 \\ 0 & A \end{bmatrix}$$

$$H^* \triangleq \begin{bmatrix} 1 \\ 0 \end{bmatrix}' \quad \Gamma^* \triangleq \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad \Psi^* \triangleq \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{28.3}$$

The primary process model can be rewritten as

$$\begin{aligned} \theta^*(i+1) &= \Phi^*\theta^*(i) + \Psi^*\nabla U(i) + \Gamma^*\xi(i) \\ y(i+1) &= H^*\theta^*(i+1) + V(i+1) \end{aligned} \tag{28.4}$$

Where $\xi(i)$ and $V(i)$ are white noise with mean zero, and the transformed process model meet the requirements of the Kalman filter equation. According to Kalman filter algorithm, the optimal estimation of the process state variable is given by

$$\begin{aligned} \hat{\theta}^*(i+1) &= \hat{\theta}^*(i+1|i) + K^*(i+1)(y(i+1) - H^*\hat{\theta}^*(i+1|i)) \\ \hat{\theta}^*(i+1|i) &= \Phi^*\hat{\theta}^*(i) + \Psi^*\nabla U(i) \\ K^*(i+1) &= P^*(i+1|i)(H^{*\prime})[H^*P^*(i+1|i)(H^*)' + \sigma_\xi(i+1)]^{-1} \\ P^*(i+1|i) &= \Phi^*P^*(i)\Phi^{*\prime} + \Gamma^*\sigma_v(i)\Gamma^{*\prime} \\ P^*(i+1) &= (I - K^*(i+1)H^*)P^*(i+1|i) \end{aligned} \tag{28.5}$$

Where, the original values of equations are given by

$$\begin{aligned} \hat{\theta}^*(0) &= \begin{pmatrix} \bar{\theta}(0) \\ 0 \end{pmatrix} = \begin{pmatrix} E\theta(0) \\ EW(0) \end{pmatrix} \\ P^*(0) &= \begin{pmatrix} P(0) & 0 \\ 0 & Q(0) \end{pmatrix} = \begin{pmatrix} \mathrm{var}\theta(0) & 0 \\ 0 & \mathrm{var}W(0) \end{pmatrix} \end{aligned} \tag{28.6}$$

Optimal Adjustment Policy

From the extended state variable process model, there is equivalent to the original process model for optimal adjustment policy. Then, cost criterion of process is rewritten as:

$$J = \min E\left[\theta^*(N)'Q^*(N)\theta^*(N) + \sum_{i=0}^{N-1}(\theta^*(i)'Q^*(i)\theta(i) + U'(i)R(i)U(i)\right] \tag{28.7}$$

Where, $Q^*(i) \triangleq \begin{bmatrix} \mathbf{Q(i)} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}$, Therefore, by linear quadratic random optimal control theory, it is known that making this problem to minimize cost criterion of optimal adjustment policy can be divided as the determinate optimal control and optimal state estimation. So for the optimal adjustment policy $U(i)$, we have

$$U(i) = -M(i)\hat{\theta}^*(i) \tag{28.8}$$

Where, $M(i)$ is optimal feedback adjustment coefficient, it is derived from determinate optimal control theory, it is given by:

$$M(i) = [R(i) + (\Psi^{*\prime} S(i+1)\Psi^{*})]^{-1} \Psi^{*\prime} S(i+1)\Phi^{*})$$

$$S(i) = Q^{*}(i) + \Phi^{*\prime} S(i+1)\Phi^{*} - \Phi^{*\prime} S(i+1)\Psi^{*} \cdot M(i)$$

$$S(N) \triangleq Q^{*}(N) = \begin{pmatrix} Q(N) & 0 \\ 0 & 0 \end{pmatrix} \tag{28.9}$$

Optimal Adjustment Policy Online Implementation

For a practical production process, after we obtain the prior information of production process, first we will calculate the feedback adjustment coefficient M of every stage in the process of production, then input the results to the online control system of production, according to real-time online state estimation of the production process. Thus, we get optimal adjustments policy of process to online real-time quality adjustment.

A Illustrative Example and Simulation

Using the proposed adjustment policy applied to the actual production process, suppose that the production process is divided into 20 stages. That is n = 20, process parameters are as follows: variance of observation is $\sigma_v = 0.15$, variance of adjustment error with AR model is $\sigma_\xi = 0.2$, Autocorrelation coefficient of adjustment error with AR model is $A = 0.5$. According to prior information of process, the mean of Unknown initial setup error is $\theta_0 = 4$, variance of initial setup error is $P = 1$, if unadjusted, will affect all parts of the production process. The coefficient of off target cost is $Q = 1$, the coefficient of adjustment cost is $R = 1$. According to proposed adjustment policy in formulation (28.8) by this paper, the optimal adjustment values of the process are shown in the Table 28.1.

According to optimal adjustment value in the Table 28.1, we have adjusted to the production process. Figure 28.1 is the optimal estimate value by Kalman filter algorithm and observations value of process quality characteristics.

From the Fig. 28.1, it is can be seen that the estimate value of the quality characteristic of process through Kalman filter algorithm have closed to output target of process. Then, according to optimal adjustment policy in formulation (28.8), the production process is online adjusted . Therefore, the proposed adjustment policy by this paper is more effective to adjust the process.

Table 28.1 Optimal adjustment value of each stage of process

Stage	U	Stage	U
1	−5.31	11	2.79
2	−6.04	12	−5.30
3	−4.80	13	−7.35
4	−3.31	14	1.67
5	−5.10	15	2.86
6	−6.00	16	−8.86
7	1.52	17	−5.07
8	2.71	18	6.99
9	−4.96	19	5.46
10	1.67	20	−3.68

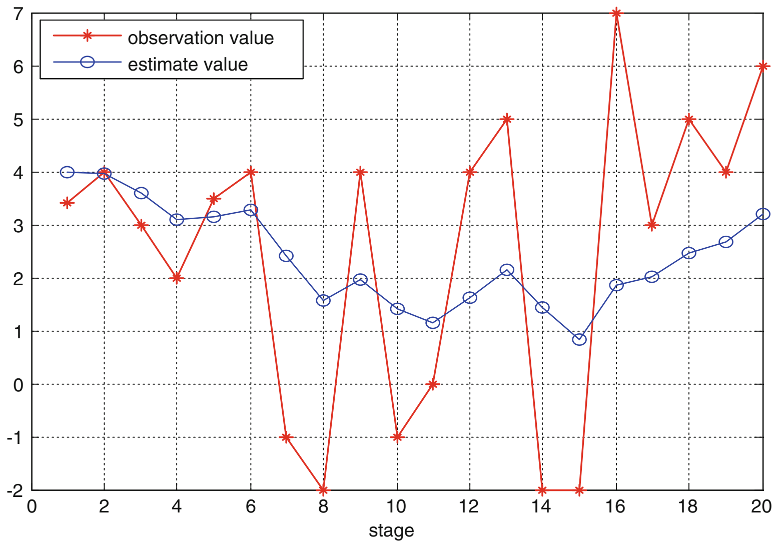


Fig. 28.1 Plot of estimate value and observations value of process quality characteristics

Comparison of Adjustment Effects

It is presented to illustrate the implement method of the proposed optimal adjustment policy through a simulation case. Then, considering changes of process unknown initial error and adjustment cost, the adjustment effects to the total quality loss of process are compared to proposed adjustment policy and the policy that considering adjustment error as white noise. The variable R is the coefficient of adjustment cost. θ_0 is the initial setup error of the process, J_1 is the quality loss of process considering adjustment error as white noise, J_2 is the quality loss of process considering adjustment error as AR model. The Save is given by $Sav = (1 - J_2/J_1) \times 100\,\%$.

Table 28.2 Total quality loss saving compared considering different adjustment error

Adjustment cost coefficient R	Initial setup error θ_0	Total quality loss adjustment error as white noise J_1	Total quality loss adjustment error as AR model J_2	Save %
1	4	36.57	27.06	26.01
	8	159.49	104.72	34.35
	12	374.73	234.16	37.51
2	4	63.58	46.05	27.57
	8	276.54	177.19	35.93
	12	583.47	365.75	37.31
3	4	96.76	64.16	33.69
	8	389.11	246.14	36.74
	12	896.26	549.44	38.70

The average of total quality loss of process is obtained after the simulation for 1,000 times for each group of parameters and the results are shown in the Table 28.2.

From the Table 28.2, It is can be seen that when process has initial setup error, compared to adjustment policy for adjustment error as white noise, the proposed adjustment policy for adjustment error as AR model can significantly reduce the total quality loss of the process. When initial setup error of process is equal, adjustment cost is higher; process quality loss saving for the proposed adjustment policy is more significant. And when there is the same in the adjustment cost, the setup error of process is greater; the proposed adjustment policy is more effective in reducing the loss of process. In other words, when initial setup error and adjustment cost are both greater, saving to quality loss of process for the proposed adjustment policy is more significant. Because of considering process adjustment error as AR model, it is more close to actual production process than considering adjustment error as white noise, the proposed adjustment policy by this paper is more effective than other to reduce the total quality loss of the process and improve the quality of products.

Conclusion

This paper studied the optimal adjustment scheme to minimize the total process quality loss for the situation of adjustment with quadratic cost and considering adjustment error based on AR model for the short-run discrete manufacturing process with setup error. Based on the state-space process control model, the optimal adjustment scheme is derived by using Kalman filter on line estimation and linear quadratic Gaussian (LQG) theory. A simulation case is presented to illustrate the implement method of the optimal adjustment policy. Furthermore, the optimal adjustment scheme is compared with other quality control policy by simulations, the results show that the adjustment solution presented by this paper is more effective than other to reduce the total quality loss of the process and improve the quality of products.

References

Castilio D, Pan R, Colosimo BM (2003) Small sample comparison of some setup adjustment methods. Commun Stat Simul Comput 32(3):923–942

Colosimo BM, Pan R, Castillo ED (2004) A sequential Markov Chain Monte Carlo approach to setup process adjustment over a set of lots. J Appl Stat 31(5):499–520

Colosimo BM, Pan R, Castillo ED (2005) Setup adjustment for discrete-part manufacturing processes with asymmetric cost functions. Int J Prod Res 43(18):3837–3854

Del Castillo E, Pan R, Colosimo BM (2003) A unifying view of some process adjustment methods. J Qual Technol 35(3):286–293

Deming W (1986) Out of crisis. MIT Center for advanced Engineering Study, Cambridge, MA, pp 309–320, ch. 11

Grubbs FE (1983) An optimum procedure for setting machines or adjusting processes. J Qual Technol 15(4):186–189

Lian Z, Castillo ED (2006) Setup adjustment under unknown process parameters and fixed adjustment cost. Stat Plan Inference 136:1039–1060

Lian Z, Colosimo BM, Castillo D (2006a) Setup error adjustment: sensitivity analysis and a new MCMC control rule. Qual Reliab Eng Int 22(4):403–418

Lian Z, Colosimo BM, Castillo ED (2006b) Setup adjustment of multiple lots using a sequential Monte Carlo method. Technometrics 48(3):373–385

Liu LP, Ma YZ (2010) Deadband adjustment scheme for multivariate process. Sys Eng Theory Pract 30(3):538–542 16 (Chinese)

Liu LP, Ma YZ (2011) Research on setup adjustment problem considering random adjustment error. Appl Stat Manag 30(5):896–903 (Chinese)

Pan R, Del Castillo E (2003) Scheduling methods for the setup adjustment problem. Int J Prod Res 41(7):1467–1481. Correction, 2004, 42(1):211–212

Sullo P, Vandevan M (1999) Optimal adjustment strategies for a process with run to run variation and 0–1 quality loss. IIE Trans 31:1135–1145

Trietsch D (1998) The harmonic rule for process setup adjustment with quadratic loss. J Qual Technol 30(1):75–84

Trietsch D (2000) Process setup adjustment with quadratic loss. IIE Trans 32(4):299–307

Chapter 29
Research on Engineering Variations Management of Urban Rail Transit Project in BT Mode – A Case of Shenzhen Metro Line 5

Xiao-chun Lu and Yi-lin Yin

Abstract The financing way of projects in BT mode provides a feasible way for solving the contradiction problem of the municipal infrastructure construction funds. As the key risk factor of influencing BT project investment control, engineering variations controlling rights becomes the focus point between two parties of BT project. The paper explains the definition and category also demonstrates processing program of engineering variations, and further analyzes the reasons of variations, then takes Shenzhen metro line 5 as an example, which provides the theoretical basis and empirical analysis for engineering variations management in domestic urban rail transit project under BT mode.

Keywords Urban rail transit project • BT mode • Engineering variations • Shenzhen Metro Line 5

Introduction

BT(Build—Transfer) is a financing way that the owner determined the undertaker through open tender, which is responsible for project financing and construction, then transfer the completed project and accept the repurchase price from owner (Tong lin 2007). The application of BT mode effectively realized the diversification of investment and improved the phenomenon of simplex investors in the filed of urban infrastructure construction (Wang xianjin 2005). Therefore, BT mode put widely use in urban rail transit project such as Nanjing metro line 2, Chongqing light rail line 3, Shenzhen metro line 5, Beijing subway of Olympic extension project and so on (Wang hao 2005). Although urban rail transit project in BT mode adopt lump price generally, the influence of BT project by engineering variations, faultiness in design stage, unpredictable

X.-c. Lu (✉) • Y.-l. Yin
School of Management, Tianjin University, Tianjin, P. R. China
e-mail: tjuzhangyatao@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_29,

Table 29.1 Demarcation of variations in different contract

Contract documents	Demarcation of variations
FIDIC Conditions of Contract for Construction	(1) Changes of quantities in working contents; (2) Changes of quality or other characteristics in work; (3) Changes of elevation, position and (or) size in engineering; (4) Cuts of works, except the works dealing to others; (5) Any additional work, permanent equipment, material or service in permanent works, including joint completion check, drilling and other inspection and investigation. (6) Changes of order or time arrangement in woks.
The standard construction bidding documents	(1) Cancel any of the works in contract, except the works turned to others; (2) Changes of quality or other characteristics in work; (3) Changes of elevation, position and (or) size in engineering; (4) Changes of time, construction technology or process in works; (5) External works to complete.

environment change in construction stage is inevitable. Thus, it's the focus of both sides to limit the conditions and procedures of variations strictly while the key point of investment control in BT project.

Definition of Engineering Variation in BT Mode

Definition of Engineering Variation

The project of one-time and irreversible determined the deviation in the process of construction, which caused engineering variations (Gao hua 2009). Of course, engineering variations refer not only design variations but also other variations in construction, so there isn't an exactly definition in variation at present. Different contracts such as *FIDIC Conditions of Contract for Construction* and *The standard construction bidding documents* make clear define of engineering variations, which is shown in Table 29.1.

According to the definition of engineering variations in different contracts, the paper defined engineering variations that the changes for the contract in the implementation also the modification and addition based on the original contract documents, besides the corresponding measures of adjustment for contract value and time.

Definition of Engineering Variation in Urban Rail Transit BT Project

Concerned for urban rail transit projects, BT project sponsor selected the BT undertaker by the preliminary design budgetary estimate after the preliminary design in general. BT undertaker didn't involved in BT preliminary design, but participated in construction design for the design constructability. Engineering variations in urban rail transit BT project usually referred to the relative to the changes for the preliminary design. As BT undertaker completed the project construction drawing design work, changes in construction design filed should be included in the scope of the engineering variations in the process of BT project. Therefore, engineering variations of urban rail transit project in BT model mainly referred to the modification and addition in the approved documents by preliminary and construction design.

Classification of Engineering Variation in BT Mode

Classification of Engineering Variation

Classification of engineering variations by different principle will get different results (Liu qingming 2009). For example: classification can be divided into the owner variation, contractor variation and the designer variation according to the different subject, also can be divided into mandatory variation, constructive variation and core variation. But no matter what the classification of engineering variation, they are inseparable from changes in the content of the work. Based on this, the paper mainly determined the classification of engineering variation by the *FIDIC Conditions of Contract for Construction* as well as *The standard construction bidding documents*, in which engineering variations is concentrated in four areas, such as design variations, construction variations, plan variations and additional engineering variations. The classification of engineering variations is shown in Fig. 29.1.

Classification of Engineering Variation in Urban Rail Transit BT Project

In the theoretical and practice study, engineering variations can be classified according to the degree of influence in the engineering variations control. From the attribution of responsibility, they can be divided into variations which caused by the project sponsors and undertakers. Therefore, the variations in BT projects can be classified into two categories: variations caused by BT project sponsor and undertaker. Actually the variations for the undertaker didn't make the adjustment for the contract price while the variations for the sponsor should be adjusted by the specific circumstances.

1. Variations caused by BT project sponsor: These variations are mainly caused by sponsors, which including variations due to preliminary design of the unit, such as approval reason, the scale and scope of works, survey and design, improvement

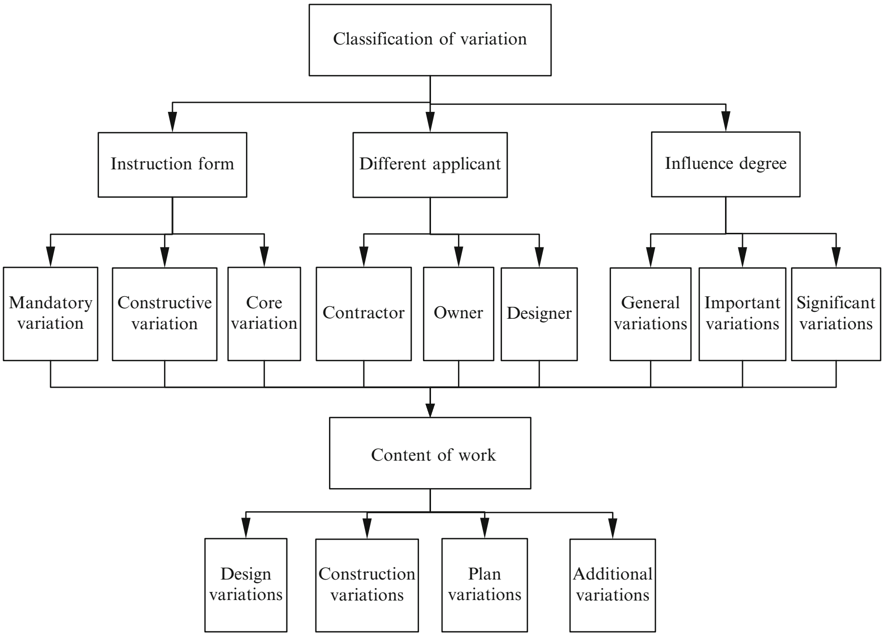


Fig. 29.1 Classification of engineering variations

of the technical standards and so on. Based on this, classification of engineering variations should be divided in accordance with the degree of the impact again.

2. Variations caused by BT project undertaker: These variations are mainly caused by undertakers, such as construction methods, time and quality. Based on this, classification of engineering variations should be divided in accordance with the degree of the impact again.

Factor Decomposition of Engineering Variations in BT Mode

BT construction projects possessed the complexity in the technology, processes, management, which led to the risk factors (Lin Jianyi 2007). According to the contract and literature, the major risk factors of variations can be divided into the behavior of subjects factors, personal behavioral factors, policies and regulations of factors, economic factors, environmental factors, contract factors, technical factors, cost factors and quality factors (Fang jun 2004), as shown in Fig. 29.2. To classify the risk factors is mainly to manage engineering variations in different types of risk factors for BT sponsor.

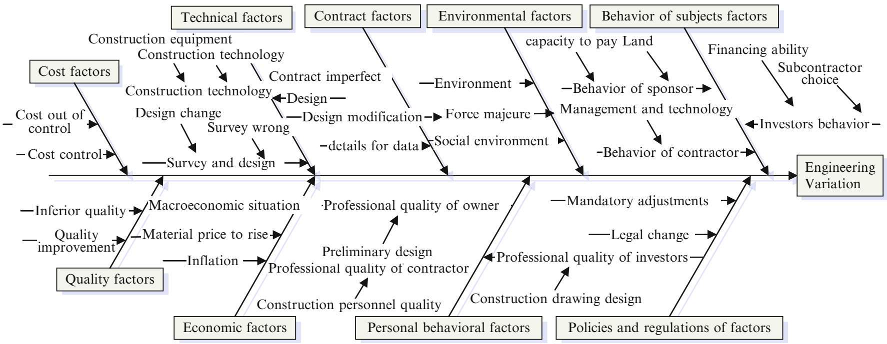


Fig. 29.2 Influencing factors of engineering variations

Process of Engineering Variations in BT Mode

The process of engineering variations in BT mode is similar to the general. According to the relevant provisions in the contract, the process of the engineering variations can be divided into two parts, one is determination of scheme, that's whether need for variations, the other one is the work of variation valuation, that's how much it cost to complete variations.

According to influence degree (the importance of content, the technical standard and complexity, the cost, the scale of development, etc.) engineering variations can be divided into significant variations, important variations and general variations, the process of examination and approval is also different (ZhangLi 2006). The significant variations is pointed to the changes of design scheme, construction measures scheme, technical standard, scale of development and construction standards. The important variations mean that the changes not belong to significant variations in the certain limitation. General variations mean design error, replacement of materials, local modify to construction site and so on below the certain limitation (Liu wen and Zhu yihai 2012). The process of significant variations is shown in Fig. 29.3.

At the same time, the limitation of significant variations, important variations and general variations is in accordance with the scale of investment, contract control objectives and the comprehensive set of practice and other factors. The processing procedures of the three different types are shown in Table 29.2:

Engineering Variations Management of Shenzhen Metro Line 5

The Reason and Classification of Engineering Variations

In accordance with the terms of engineering variations in BT contract of Shenzhen Metro Line 5 (A Contract in September of 2008), the main reasons of engineering variations of BT projects concentrated in approval reason, survey reason, design reason, technical standards or functional reason, construction reason, force majeure and other factors (Lin maode 2009), as shown in Table 29.3.

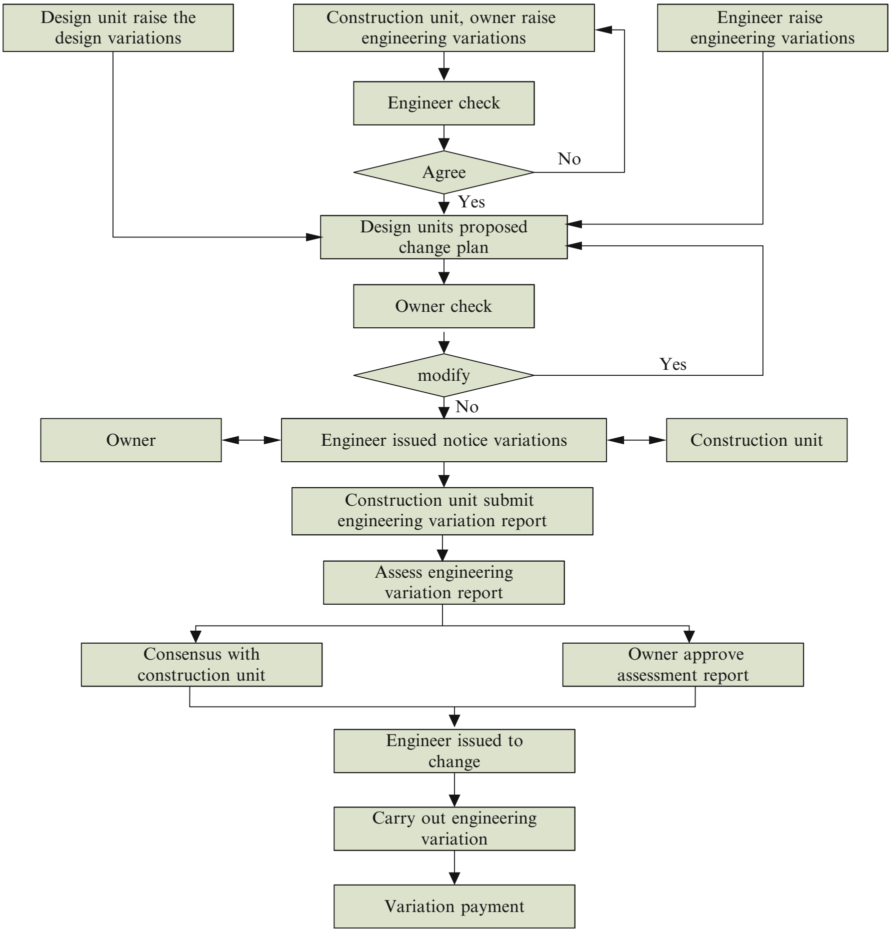


Fig. 29.3 The process of significant variations

Table 29.2 Comparison of the process of three variations

Comparison	General variations	Important variations	Significant variations
Approval of variations intention	General engineer	Owner	Owner
Approval of variations report	General engineer	General engineer	Owner
Composition of variations report	Professional engineer	General engineer	Assessment team

According to the practice in project, variations of Shenzhen Metro Line 5 BT project conclude A kind change of subway company and B kind change of south China railway. A divided into AI, AII, AIII, AIV. B divided into BI, BII.

The kind of AI and AII variations adjust the contract value, AIII variation adjust the beyond part over the certain amount, AIV variation didn't adjust the contract value, The kind of B didn't cause the adjustment of contract value.

Table 29.3 Reason of BT mode variations

No.	Reason of variations	Contents
1	Approval reason	Urban management and other government departments need to modify the design requirements variations not meet the needs of engineering variations.
2	Survey reason	The engineering variations happened in the construction process of the terrain, geophysics data, engineering geology and hydrogeology, underground pipelines, ground underground structure (build) things which not accord with the actual data.
3	Design reason	The engineering variations in the addition and optimization for design documents defects, errors, omissions and collision.
4	Technical standards or functional reason	The engineering variations in the changes of countries or industry technology standards, norms change, function change or requirement of subway company.
5	Construction reason	The engineering variations caused by construction technology, construction equipment, time limit and construction conditions change
6	Force majeure	The engineering variations caused by force majeure and other factors.
7	Other reasons	The engineering variations except the above reason.

Responsibilities of the Departments in BT Project

According to the provisions of the variance management, the responsibilities of the departments in the BT project are as follows:

Variances of category AI are reviewed and approved by Subway Corporation, and reported to relevant government departments in Number 5 Office which would review them again. The governmental professional sectors in charge of planning, construction, fire, air defense will participate in reviewing the significant variances involved in the planning, construction, fire, air defense; development and Reform Commission and the audit governmental professional sectors will participate in reviewing variances involved in the proposed budget adjustments. Review comments are reported he Urban Rail Transit Construction Headquarters or its Office and would be implemented after approved.

Variance AII would be implemented after approved by the Subway Corporation.

Variance AIII would be implemented after approved by the leader of the Subway Corporation; Variance AIV would be implemented after formally approved by branch of Construction Company of line 5. The significant variances should be reported to No. 5 Office and be recorded.

Variances of A which need the amount of 100 million (inclusive) and above are required to approve by Chief Financial Officer of Subway Corporation.

Variance BI would be implemented by undertaker of BT project and recorded by No. 5 Office, after reviewed by the Subway Corporation.

Variance BII would be implemented by undertaker of BT project and recorded by the Subway Corporation.

Approval Procedure of Engineering Variations

According to the engineering practice, the approval procedure of Shenzhen metro line 5 BT project engineering variations is as shown in Fig. 29.4:

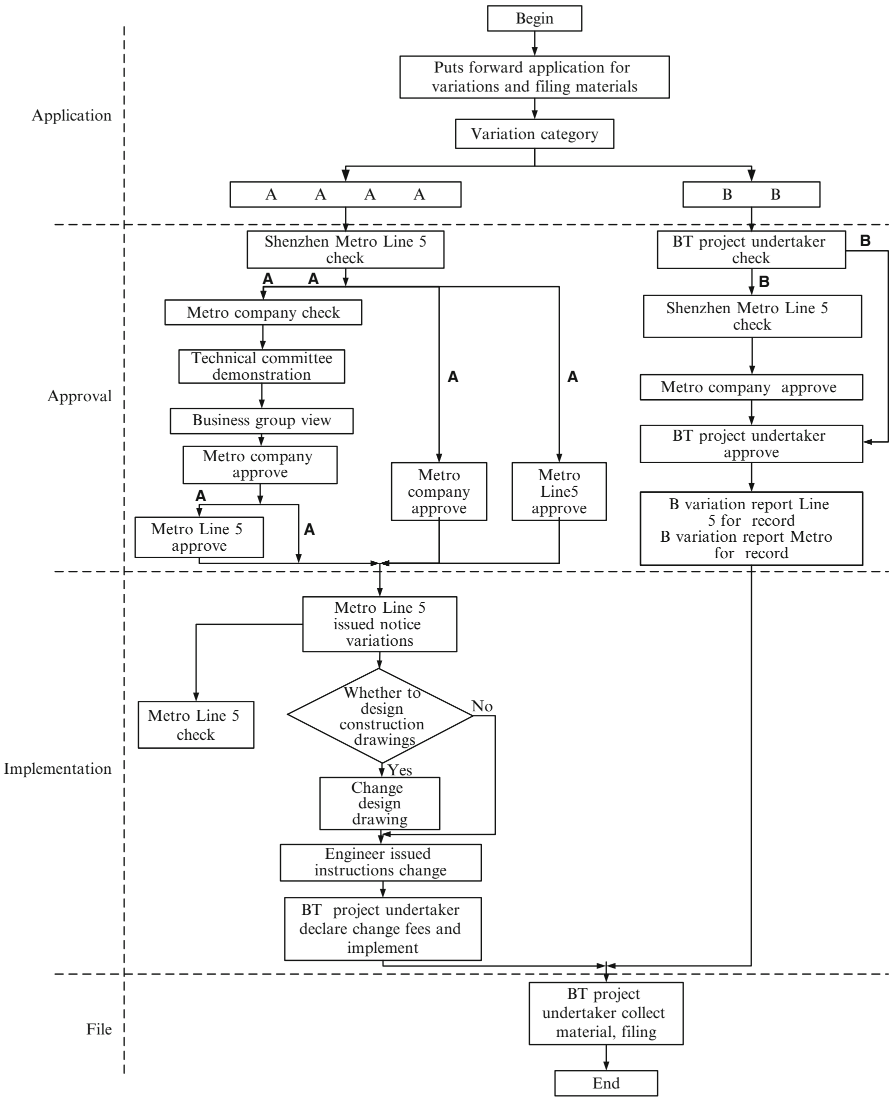


Fig. 29.4 Procedure of engineering variations

Conclusion

The paper defined and classified engineering variations in BT mode, then divided engineering variations into BT sponsors and undertakers. Based on this, further decomposed the factors which affected the engineering variations in BT project and clearly demonstrated the procedure of variations, finally took Shenzhen Metro Line 5 for an example to discuss the reasons of variations and the responsibilities of the various departments as well as the procedure in BT project, which provided reference for engineering variations management of urban rail transit project.

References

Fang jun (2004) Construction project engineering variations management and control. Constr Econ (10):54–57

Gao hua (2009) Research on the investment and construction contract of BT mode in China. Tianjin University, Tianjin

Lin Jianyi (2007) Management of project changes in construction engineering. Beijing Jiaotong University, Beijing

Lin maode (2009) Shenzhen subway BT model innovation of application. Urban Rapid Rail Transit (6):56–59

Liu qingming (2009) Brief talk on change management of construction project. Shanxi Archit (13):188

Liu wen, Zhu yihai (2012) Engineering design and variations in Shenzhen metro line 5 BT project. Railw Eng (1):73–76

Tong lin (2007) Study on BT model of public infrastructure projects. Tong-Ji University, Shanghai

Wang hao (2005) The application of infrastructure projects in BT mode. Macroeconomics (10):49–53

Wang xianjin (2005) Questions discussion on BT model of municipal infrastructure projects. J Chongqing Traffic Inst (4):24–27

ZhangLi (2006) Research on investment control in BT project. Southeast University, Nanjing

Chapter 30
Studying Two-Stage Vehicle Scheduling at Distribution Center Based on Cross-Docking Model

Jing Gao and Ju-hong Gao

Abstract The reasonable arrangement of the time of inbound trucks' arrival at the distribute center was very important to ensure the smooth circulation of goods and cost reduction. The course of unloading and sorting were regarded as two stage flow shop in the Cross-docking (CD) environment including only one door and one conveyor, applying the Johnson algorithm to solve the problem of minimizing working hour of goods (work piece). Finally, according to a distribution center' order data, the minimum time required for sorting all the batch of goods was calculated, and the optimum sequence of inbound trucks was obtained, which can provide guidance for CD practice.

Keywords Cross-docking • Johnson Algorithm • Sorting • Two-stage Flow Shop • Vehicle Scheduling

Introduction

Putting effective control on information and physical flow on the supply chain has been two key tasks of supply chain management (Wen Shi and Xue Ding 2009). In many areas, Cross-docking model has gained successful applying, such as JIT manufacturing industry (McEvoy 1997), EDI (Ross 1997), mail system (Forger 1995; Yonghui et al. 2006). Retailing industry realizes the goals of improving the efficiency of two flows' management, reducing related costs and enhancing the customers' satisfaction level successfully by means of Cross-docking model. Wal-Mart is a typical case (Stalk et al. 1992). It requires a synchronization and coordination of inbound and outbound trucks to make sure that transport time and temporary inventory at the distribution center (DC) are kept as low as possible.

J. Gao (✉) • J.-h. Gao
Department of Management and Economic, University of Tianjin, Tianjin, P. R. China
e-mail: gaoj_tju@163.com; gaojuhong2003@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_30,

With successful application of Cross-docking model in management practice, many scholars have spent much time in studying Cross-docking vehicle scheduling problem (Nils Boysen 2010; Wooyeon Yu and Egbelu 2008). Among them, someone regarded it as a two-stage problem to analysis. For example, Dong-yan MA and Feng CHEN abstracted the inbound/outbound trucks and goods needed to sort as two machines and work pieces respectively, established constrains on “work pieces” according to orders, and then solved this scheduling problem with Dynamic Programming Method (Dong-yan Ma and Feng Chen 2007). Dong-yan MA calculated it further with simulated annealing algorithm afterwards (Dong-yan Ma 2008). Jie CHEN and Feng CHEN discussed a kind of two-stage problem in the case of uncertain processing time (Jie Chen and Feng Chen 2010).

Kai-lei SONG has raised two-stage Cross-docking trucks scheduling problem based on direct transport and milk project in condition of different supplier/customer’s goods supply/demand (Kai-lei 2008). By testing with numerical example and practical proof, two-stage research method is a good method for solving Cross-docking scheduling problem. The papers using Johnson algorithm to solve this kind of problem are less at present. Gang WANG made a tentative research in his M.A. theses, putting forward the idea of utilizing the improved Johnson algorithm to Two-Stage Flexible Flow Shop Scheduling Problem in order to optimize arrangement of tasks in distribution center (Gang Wang 2008).

This paper’s research springboard is to see this problem as a Two-Stage Flow Shop Problem, which is solved by Modulo-Matrix multiplications based on Johnson algorithm (Yu-ai Qin 2009). On the basis of constructing Cross-docking implementing basic environment, making Cross-docking vehicle scheduling analysis factor-products relevant to elements of Johnson algorithm-work pieces, setting up the objective function of minimizing trucks’ staying time in DC is to get the optimal arrival consequence of inbound trucks and offer a proposal in Cross-docking practice.

Problem Descriptions

DC Layout

Cross-docking environment described in detail is shown in Fig. 30.1:

Only one unloading location, the inbound truck must wait until the former unloads all of goods;

Just one convey belt, whose rate is known and fixed;

Platforms on both sides of convey belt; when all of goods on one platform according to order is collected, the relevant outbound truck will load the goods and leave;

No temporary storage area, all of goods can be distributed to platforms.

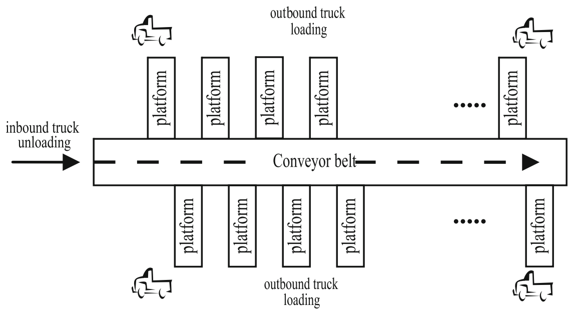


Fig. 30.1 Distribution center layout diagram

Basic Ideas

In this paper, the course of goods going through the DC is regarded as a kind of flow shop problem concerning manufacturing "work pieces" on order on two machines. The object is to minimize the total time spent on the two machines by all the work pieces, obtain the best sequence of inbound trucks accordingly.

Set two machines M_1 and M_2: M_1 expresses the course of unloading goods on the convey belt from inbound truck; M_2 expresses the process between falling on the convey belt and arriving at each platform;

There is a one-to-one correspondence between every inbound truck and one supplier;

Only one kind and different goods is loaded on a truck, unloaded at once, being counted as a "work piece" of J_1, J_2... J_n;

Each work piece passes the machine M_1 and M_2 in order; the length of stay on them is marked as $T_{1,1}$, $T_{1,2}$,... $T_{1,i}$,...$T_{1,n}$ and $T_{2,1}$,$T_{2,2}$,...$T_{2,i}$,...$T_{2,n}$ separately and is known.

Two-Machine Flow Shop

Work Schedule

Table 30.1 is a two-machine work schedule, $T_{1,i}$ and $T_{2,i}$ means respectively the time of "work piece i" staying on machine M_1 and M_2 ($i = 1,\ldots,n$). The assumptions are as follows: for each time point, one machine can only process a work piece uninterruptedly; after processed on machine M_1, the work piece can enter the machine M_2 if M_2 is available; work pieces are processed one by one with no stop between them.

Table 30.1 Two machines work schedule

Workpiece Machine	J_1	J_2	J_3	...	J_i	...	J_n
M_1	$T_{1,1}$	$T_{1,2}$	$T_{1,3}$	...	$T_{1,i}$	...	$T_{1,n}$
M_2	$T_{2,1}$	$T_{2,2}$	$T_{2,3}$	...	$T_{2,i}$	...	$T_{2,n}$

Time Data's Implication and Abstracting

In cross-docking scheduling management practice, the time in the work schedule is given a specific meaning.

$$T_{1,1}\ T_{1,2}\ T_{1,3} \ldots T_{1,i} \ldots T_{1,n}$$

$T_{1,i}$: time of unloading all goods from one inbound truck to convey belt.

$$T_{2,1}\ T_{2,2}\ T_{2,3} \ldots T_{2,i} \ldots T_{2,n}$$

This paper supposes that each platform corresponds to one delivery route carried out by one outbound truck. Unless there is a large fluctuation in the number of orders (including store and goods), DC will fix every delivery route, assigning fixed driver to finish the task by experience. When stores distributed to each platform is determined, all the goods information of each platform can be obtained according to customer order information table (Table 30.2). Then if the location of each platform and the running speed of convey belt are known, the time $T_{2,i}$ spent on the convey belt is known accordingly.

Johnson Algorithm for Optimal Solution

1. *Formulation describing*: Work piece set $G_1 = \{J_1, J_2, \ldots J_n\}$ performs flow shop on two machines, supposing G_1 has a feasible solution ω_1. $T_{1,i}$ and $T_{2,i}$ are processing time of J_i on machine M_1 and M_2. The work piece J_j is behind J_i. when the sequence of work pieces in front of J_i is denoted as S, and the one behind J_i is denoted as S', so: $\omega_1 = SJ_iJ_j\,S'$.

   A(S): the Modulo-Matrix' multiplication formula of S;
   $A(S')$: the Modulo-Matrix' multiplication formula of S';

   So, the time span of ω_1:
   $$A(\omega_1) = A(S) \otimes A(J_i) \otimes A(J_j) \otimes A(S');$$

   Exchange the position of J_i and J_j, the new feasible solution ω_2 and its time span:
   $$A(\omega_2) = A(S) \otimes A(J_j) \otimes A(J_i) \otimes A(S').$$
   $$\text{Where: } A\,(J_i) \otimes A(J_j) = \begin{bmatrix} T1,i \otimes T1,j & H(i,j) \\ & T2,i \otimes T2,j \end{bmatrix};$$

Table 30.2 Customer order information table

Goods	Goods 1		...	Goods n		Each store' goods total
Stores	Num	Vol	...	Num	Vol	Vol
Store1	$N_{1,1}$	$N_{1,1} * V_1$	...	$N_{1,n}$	$N_{1,n} * V_n$	$\sum_{y=1}^{n}(N_{1,y} * V_y)$
Store2	$N_{2,1}$	$N_{2,1} * V_1$	...	$N_{2,n}$	$N_{2,n} * V_n$	$\sum_{y=1}^{n}(N_{2,y} * V_y)$
...	...	...	...	...	...	...
Store m	$N_{m,1}$	$N_{m,1} * V_1$	...	$N_{m,n}$	$N_{m,n} * V_n$	$\sum_{y=1}^{n}(N_{m,y} * V_y)$
Goods' total num / vol	$SQ_1 = \sum_{x=1}^{m} N_{x,1}$	$SQ_1 * V_1$	...	$SQ_n = \sum_{x=1}^{m} N_{x,n}$	$SQ_n * V_n$	$\sum_{x=1}^{m}(\sum_{y=1}^{n} N_{x,y} * V_y)$
Total num / vol by each supplier	SQ_1	$SQ_1 * V_1$	...	SQ_n	$SQ_n * V_n$	

Notes: ① store no:1,2,. . .,m; ② type code of goods: 1,2,. . .,n; ③ the number of goods y needed by store x: Nx,y (x = 1,. . .,m; y = 1,. . .,n); ④ Vy: unit volume of goods y; ⑤Total number of goods y: SQy (y = 1,2,. . .,n);⑥ *Num* number, *Vol* volume.

$$A(J_j) \otimes A(J_i) = \begin{bmatrix} T1,j \otimes T1,i & H(j,i) \\ & T2,j \otimes T2,i \end{bmatrix};$$

$$H(i,j) = T_{1,i} \otimes T_{1,j} \otimes T_{2,j} \oplus T_{1,i} \otimes T_{2,i} \otimes T_{2,j}$$
$$H(j,i) = T_{1,j} \otimes T_{1,i} \otimes T_{2,i} \oplus T_{1,j} \otimes T_{2,j} \otimes T_{2,i}$$

Suppose real number $H(i,j) \leq H(j,i)$;

$$\text{So, } T_{1,i} \otimes T_{1,j} \otimes T_{2,j} \oplus T_{1,i} \otimes T_{2,i} \otimes T_{2,j} \leq T_{1,j} \otimes T_{1,i} \otimes T_{2,i} \otimes T_{1,j} \otimes T_{2,j} \otimes T_{2,i} \tag{30.1}$$

Change (30.1) into inequality:

$$\max\{T_{1,i} + T_{1,j} + T_{2,j}, T_{1,i} + T_{2,i} + T_{2,j}\}$$
$$\leq \max\{T_{1,j} + T_{1,i} + T_{2,i}, T_{1,j} + T_{2,j} + T_{2,i}\}$$
$$\min\{T_{1,i}, T_{2,j}\} \leq \min\{T_{1,j}, T_{2,i}\} \tag{30.2}$$

When inequality (30.2) holds, $A(\omega_1) \leq A(\omega_2)$
Inequality (30.2) is Johnson formula.

2. *Algorithm application*: For work scheduling T, Johnson algorithm coming from Johnson formula can get optimal solution (Liu-tao Yang 2010); the specific methods are as follows:

Step1: take minimum value in T, then if it is at the first row, put the related "work piece" in the first place, otherwise if it is at the second row, put the related "work piece" in the last place;
Step2: eliminate this "work piece" stated in Step1, go back to Step1 until all piece work are sorted.

Case Analysis

A third party logistics company adopts cross-docking management model to provide distribution service for community supermarkets. There are seven suppliers, supplying 15 stores with 7 different goods such as rolls and steamed bread and so on (Table 30.3). The object is making trucks scheduling plan to minimum the time span of all goods going through unloading and sorting course.

According experience, four routine lines corresponding to four platforms are utilized. The stores concluded on each line are as follows: L_1:1-5-7-9; L_2:2-3-4-13; L_3: 6-8-10-15; L_4: 11-12-14. By means of calculation, all goods concluded on one line can be loaded on to an outbound truck. After fixing the platform location, the time of seven kinds of goods staying on the convey belt can be known. Every good is regarded as a work piece, and the course of unloading and transmitting to appointed platform is regarded as two stages according to the thought of two-stage flow shop. Considering the unloading time next, two machines work schedule of this case is obtained (Table 30.4).

Two-machine flow shop's "mifang diagram" (Fig. 30.2):

Change into Modulo-Matrix form:

$$A(0) = [0 \quad 0]; \qquad A(1) = \begin{bmatrix} 3 & 8 \\ z & 5 \end{bmatrix}; \qquad A(2) = \begin{bmatrix} 6 & 14 \\ z & 8 \end{bmatrix}$$

$$A(3) = \begin{bmatrix} 9 & 16 \\ z & 7 \end{bmatrix}; \; A(4) = \begin{bmatrix} 4 & 11 \\ z & 7 \end{bmatrix}; \qquad A(5) = \begin{bmatrix} 12 & 30 \\ z & 18 \end{bmatrix}$$

$$A(6) = \begin{bmatrix} 15 & 35 \\ z & 20 \end{bmatrix}; A(7) = \begin{bmatrix} 10 & 17 \\ z & 7 \end{bmatrix}; \quad A(8) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

According to Johnson algorithm, optimal schedule has two results as follows:

1. J_1-J_4-J_2-J_5-J_6-J_3-J_7
2. J_1-J_4-J_2-J_5-J_6-J_7-J_3

By calculating the Modulo-Matrix' multiplication formula On the basis of maximal Quasi-Fields (R, max, +) combining with the two schedule results, time span T is as follow:

$$T = A(0) \otimes A(1) \otimes A(2) \otimes A(3) \otimes A(4) \otimes A(5) \otimes A(6) \otimes A(7) \otimes A(8)$$

Table 30.3 Customer order information table

Stores supplier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
J_1	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	450
J_2	40	50	40	60	60	50	35	30	45	50	40	50	50	60	40	700
J_3	50	50	50	100	50	50	50	50	50	50	50	50	50	50	50	800
J_4	40	30	40	30	40	40	40	30	40	40	40	40	30	40	40	560
J_5	80	80	80	70	80	80	80	80	80	80	80	80	80	80	80	1,190
J_6	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1,500
J_7	40	50	60	75	45	50	60	140	50	60	70	40	130	50	50	970
Total	380	390	400	465	405	400	395	460	395	410	410	390	470	410	390	6,170

Table 30.4 Two machines work schedule (unit: minutes)

Work piece Machine	J_1	J_2	J_3	J_4	J_5	J_6	J_7
M_1	3	6	9	4	12	15	10
M_2	5	8	7	7	18	20	7

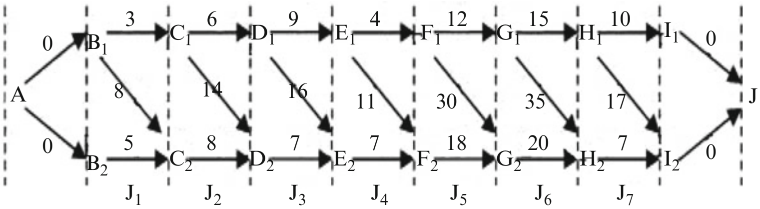


Fig. 30.2 Two machines flow shop "mifang" diagram

The minimal time span is 77 min. That means the minimal time of all goods spent on the two courses is 77 min, and the best sequence of inbound truck arriving at DC is known too.

Conclusion

This paper analyses the whole course from unloading to sorting in DC. Regarding goods in each inbound truck as a "work piece", the minimal time span, as a index of calculating the total time spent in above process, can be known by means of two-stage flow shop theory. That means the inbound trucks' arriving sequence can be determined in meeting the minimal time span. This study belongs to a part of vehicle scheduling. Abstracting useful information by excel is highly workable policy, and the Johnson algorithm can solve this kind of problem easily and effectively. This paper's disadvantages are: first, lack of vehicle scheduling programming for outbound trucks; second, the data of stores included in each route line and the platforms' exact location has effect on the final result. In theory, for above two elements changing, all the possible situations need to be calculated and compared to obtain the best result.

This case study shows calculating the optimal result by hand applies only to small-scale problem. For large-scale problem, creating new program is an effective method to extend the application scope of Johnson algorithm theory in cross-docking. As a starting point combining the study of cross-docking vehicle scheduling and practice, searching the new algorithm, the improvement of Johnson algorithm, and the breaking point of this area will be focus in future research.

Acknowledgment The authors wish to thank the reviewer for his or her helpful comments, which have led the authors to consider the subject of two-stage vehicle scheduling at distribution center based on Cross-docking model problem more deeply. The authors also would like to thank the Scientific and Technical Personnel Servicing Business Project, which offers subsidization to this project.

References

Dong-yan Ma (2008) Simulated annealing algorithm for two-machine Cross-docking scheduling problem. Logist Technol 27(2):67–69, 95 (Chinese)

Dong-yan Ma, Feng Chen (2007) Dynamic programming algorithm on two machines cross docking scheduling with total weighted completion time. J Shanghai Jiao Tong Univ 41(5):852–856 (Chinese)

Forger G (1995) UPS starts world's premier cross-docking operation. Mod Mater Handl 50(13):36

Gang Wang (2008) Queue and sort based algorithm of scheduling for job of two-stage Cross-docking. Master Degree, University of Beijing Jiao Tong, Beijing, China (Chinese)

Jie Chen, Feng Chen (2010) Algorithm on cross docking scheduling in asymmetrically uncertain environment. J Shanghai Jiao Tong Univ 44(9):1302–1306 (Chinese)

Kai-lei Song (2008) Two-stage hybrid scheduling models and optimization algorithm on cross docking logistics. Master Degree, University of Shanghai Jiao Tong, Shanghai, China (Chinese)

Liu-tao Yang (2010) How to make the sequencing of parts in workshop work plan more effective. Manager J 26(1):354 (Chinese)

McEvoy K (1997) DSD or cross-docking or both? Progress Groc 76(3):23

Nils Boysen (2010) Truck scheduling at zero-inventory cross docking terminals. Comput Oper Res 37(1):32–41

Ross JR (1997) Office depot scores major cross-docking gains. Store Mag 79(12):39

Stalk G, Evans P, Shulman LE (1992) Competing on capabilities: the new role of corporate strategy. Harv Bus Rev 70(2):57–69

Wen Shi, Xue Ding (2009) To study on the present situation in Cross-docking. Value Eng 28(3):85–87 (Chinese)

Wooyeon Yu, Egbelu PJ (2008) Scheduling of inbound and outbound trucks in cross docking systems with temporary storage. Eur J Oper Res 184(1):377–396

Yonghui Oh, Hark Hwang, Chun Nam Cha, Suk Lee (2006) A dock-door assignment problem for the Korean mail distribution center. Comput Ind Eng 51(2):288–296

Yu-ai Qin (2009) The optimal path problem (book style). The Science & Technology Press, Shanghai, pp 45–62, Chinese

Chapter 31
Factors for Improving the Supply Chain Management Performance: A Survey of Chinese Toy Makers

Hong-bo Shi, Wei-na Zou, and Sanchoy Das

Abstract This paper contributes to the ongoing discussion about the supply chain management (SCM) of Chinese toy makers by conducting a survey among 148 respondents from the industry. The questionnaire includes 24 questions that belong to six sections, which are design and buying, materials procurement, production operations, product distribution, quality control, list of tools (technology). Through analyzing the feedback data from 36 respondents, this study reveals the update circumstances of Chinese toy industry regarding SCM. Notably, on the one hand, most toy makers (about 90%) suggest that they value quality control, which is essential for global competition. On the other hand, less toy makers prefer to adopt advanced SCM tools; this may hinder their competitiveness in the long run. To conclude, both constructive and practical suggestions are given to the toy makers for improving their SCM performance.

Keywords Procurement • Quality control • Supply chain management • Survey • Toy makers

Introduction

With the development of supply chain management (SCM) theory and global competition, Chinese toy makers continue to make steady progress across the areas of supply chain competency (Wong et al. 2005). Although most companies

H.-b. Shi (✉) • W.-n. Zou
School of Economics and Management, Harbin Institute of Technology at Weihai, Weihai, China
e-mail: hongbo.shi@hotmail.com; zouweina910717@163.com

S. Das
Department of Mechanical and Industrial Engineering, New Jersey Institute of Technology, Newark, NJ, USA
e-mail: sanchoy.k.das@njit.edu

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_31,

are at about the same stage of evolution, there is still a significant gap between the performance of the leaders and the rest – and that is a gap the followers need to start closing now. These are among the key findings of the SCM Survey of Chinese Toy Makers.

In the International Spotlight

In August 2007, the head of a Chinese company that made Sesame Street and other toys that were recalled in the United States due to safety fears had committed suicide. Zhang Shuhong, the boss of Lee Der Industrial Co, was found dead in a factory warehouse in southern Guangdong province. Fisher-Price, a subsidiary of Mattel, recalled nearly one million toys, including popular Sesame Street and Dora the Explorer-branded models sold in US stores, because of fears they contained toxic lead paint (Agencies 2007c).

Many of the toys were produced by Lee Der. The government ordered Lee Der and another toy manufacturer at the center of a similar high-profile recall in the United States to suspend their exports.

The newspaper quoted Lee Der staff as saying Zhang was distraught over feeling he had been "hurt" by the supplier of the suspect paint, whom he had counted as a good friend. China's national product-quality watchdog has blamed Lee Der's paint supplier for providing "fake lead-free paint powder" used on the toys. The other toy manufacturer, Hansheng Woodware, made 1.5 million wooden "Thomas the Train" figures for US importer RC2 Corp. Those products were recalled by the US company in June for similar fears over lead paint.

Lessons from this case:

(a) Overlooking Quality Control.
(b) Ignoring International Standards.
(c) Poor Supply Chain Management.

On Nov. 1, 2007, Chinese regulators said that they had suspended the export licenses of more than 750 toy companies because of quality control problems. And an additional 690 toy factories in southern China, the world's largest toy manufacturing region, had been ordered to renovate or improve their facilities. The regulatory moves could hurt toy makers gradually and possibly upset their extensive supply chain (Agencies 2007b).

The Posing of This Topic

What happened to the Chinese toy makers? Was their quality control proved to be unreliable? Responsibly, we may start a research of Chinese toy makers by looking into their supply chain management performance.

There is no law stating that all toys have to be made in China. People get goods made in China because they are cheaper, and then the company sells the toys for 4X the price and makes a significant profit. All companies do this. Is it smart? Only, if you have quality control and you are truly testing the batches to test for safety and quality.

On the other hand, we have found that the Chinese top 50 toy makers only have 18% share of the total market, which is quite different than that of other industries. This also indicates that the small- and medium-sized companies have been playing an important role (Agencies 2007a).

So, to probe into this interesting industry, we would like to launch a survey concerning the supply chain management performance of Chinese toy makers.

Survey Methodology

The questionnaire includes 24 questions that belong to six sections, which are design and buying, materials procurement, production operations, product distribution, quality control, list of tools (technology). In each section, we seriously designed four questions, trying to induce as much information as possible. These questions may cover the fundamental domains that constitute true supply value (Poirier and Quinn 2003).

The Chinese Toy Makers Supply Chain Management Survey questionnaire was sent by e-mails to 148 supply chain professionals in Mainland China. The names and addresses were drawn randomly from the relative web sites.

Promisingly, a total of 36 respondents completed the well-prepared, five-page questionnaire. No wonder that the majority of the responses came from small- and medium-sized toy companies.

Literature Review of SCM in China

Role of Supply Chain Management

Seen from the above figure (Fig. 31.1), we can judge that SCM has been becoming an important domain in the field of management science and engineering (Rudzki 2008). And the key words of SCM include supply chain design, product design, product development, lead time, inventory management, demand uncertainty, etc. Most of them are reflected in the composition of the questionnaire.

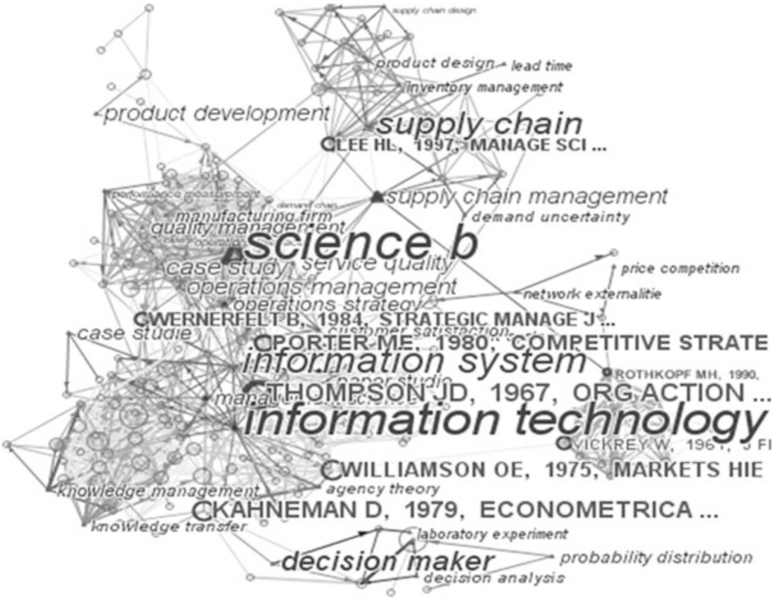


Fig. 31.1 Documents co-citation network of main theories in management (1992–2006)

Main Ideas Regarding SCM in China

Zhang Ruimin, the former CEO of Haier Group points out that the most important problem for Chinese local corporations lies in the incomplete environment of domestic logistics. For example, in USA, the corporations have UPS, FedEx or DHL to do most of their logistics; in Japan, they make good use of Just-in-Time. But it is hard to name out a competitive local logistics entity of China. We must rely on overseas corporations (Mu 2001).

Other supply chain professionals find that to improve the performance of Chinese supply chain, logistics, SCM and E-commerce must run corporately (Child and Yan 2003).

As global manufacturers expand operations in China, many face challenges in the basic building of supply chains. For instance, receiving updates on inventories or shipping cycles can take days because few Chinese companies have the technology to provide information electronically. As Mann of Accenture puts it, “China still has a Third World feeling (Kover 2005).”

Promisingly, Infor Global Solutions, which makes supply chain management and ERP software, found an experienced partner to facilitate its introduction to Chinese market (Poirier et al. 2007).

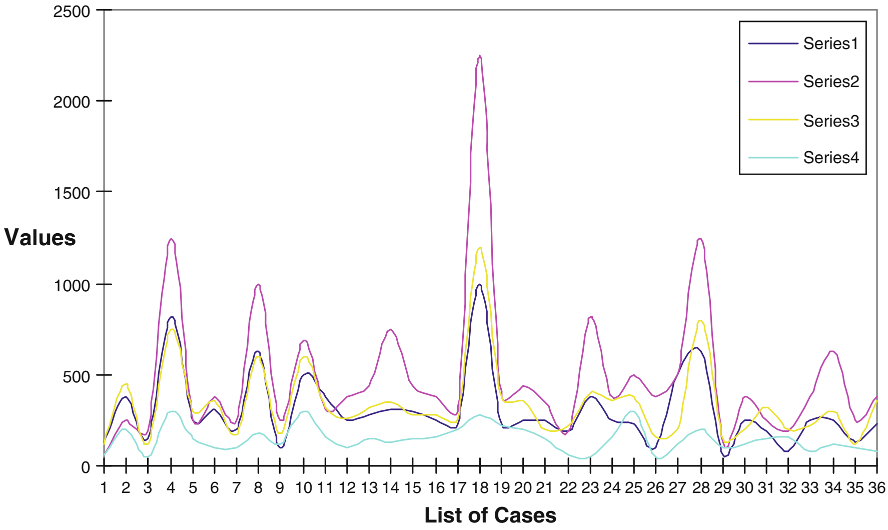


Fig. 31.2 Correlation of annual sales, profits, employees and designers

The Analysis of the Feedback

Distribution of the Respondent Toy Makers

Frankly, we are satisfied with the feedback we got from this survey. To provide a simple first glance of the information, the following figure was prepared to show the basic data of the 36 respondent toy makers. The initial monetary unit was exchanged from RMB to US dollars.

To simplify the data, we can illustrate it by an Excel graph (data units adjusted proportionally), which makes the comparison and contrast among the respondent toy makers more visually.

Seen from the above figure (Fig. 31.2), we can conclude that most indexes across the toy makers are positively related. On the one hand, this indicates that the data we got are relatively authentic. On the other hand, this provides us some clue to mine more valuable discoveries.

Analytical Methods

To articulate more clearly how supply chain efforts among the respondents related to the dimensions referred above, the survey questions were broadly categorized

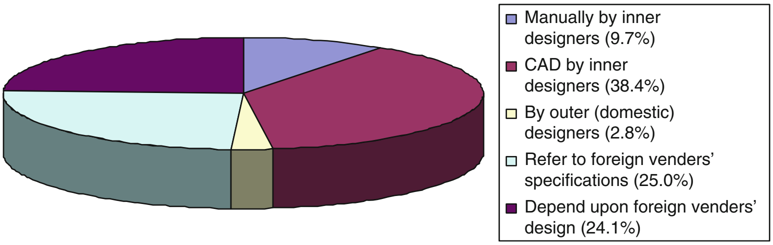


Fig. 31.3 Means of design

into these areas: Design and buying, Materials procurement, Production operations, Product distribution, Quality control, List of tools (Technology) (Foster 2005).

The result of the survey indicates the progress that Chinese toy makers have made to date in advancing their supply chain – and reflects the considerable work that still needs to be done. From a competitive standpoint, the good news is that with handful exceptions, most companies are at about the same stage of supply chain evolution.

The findings are inspiring but far from spectacular. In order to better illustrate the feedback data, we take advantage of the MS software Excel to turn the results into graphs.

Data Illustrations

Design and Buying

As shown in the questionnaire, the first question in this section was: how many qualified toy designers do you have? Then, to determine how the design modes varied across the industry, we asked by which means do you design your products? The answers are transferred into a graph like the following (Fig. 31.3):

In terms of the basic period from an order to final products, frankly, the answers seemed promising, like this (Fig. 31.4):

We can conclude that about four out of five toy makers can fulfill an order within 1 month.

Materials Procurement

In this section, we posed the first question: rate the following in their importance in selecting material suppliers.

(a) Location proximity
(b) Cooperative relationship

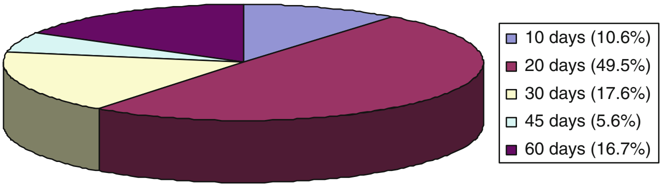


Fig. 31.4 Period from order to products

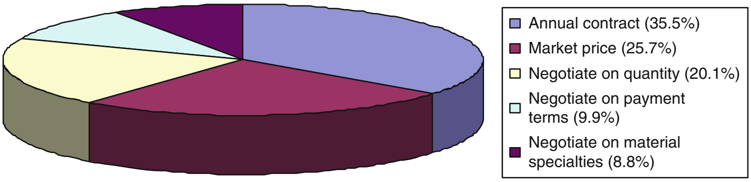


Fig. 31.5 Modes determine the supply price

(c) Material price
(d) Brand recognition
(e) Delivery reliability (Time lines)

About 52.8% respondents chose material price as their priority in selecting material suppliers. Not surprisingly, location proximity took a position of No.2 (22.2%). This indicates that three out of four or more respondents considered procurement to be a source of competitive advantage.

Since most respondents were apt to think material price as first things first, as we assumed initially, the next question which of the following modes determine the supply price for a current order were answered correspondingly (Fig. 31.5):

As a matter of fact, about two third respondents made multiple choices upon this question, indicating that for different material orders, the determining modes are varied.

When we continued to talk about the inventory level, responding to the question, the answers showed that more than 95% toy makers have a 1 week ~ 2 month raw material inventory (1 week ~ 1 month 63.4% and 1 month ~ 2 months 32.9% respectively). As far as what kind of inventory policy is used to reorder material, we got data as illustrated in the above figure (Fig. 31.6). According to the on-spot practice, this question is also multiple-choice applicable.

Production Operations

The first question here was supposed to evaluate the priority in their plant locating – rate the following in their importance as far as plant locating is concerned (Berman and Wang 2006):

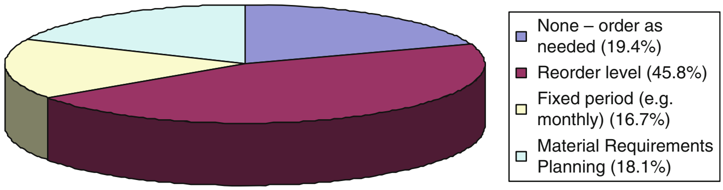


Fig. 31.6 Inventory policy to reorder material

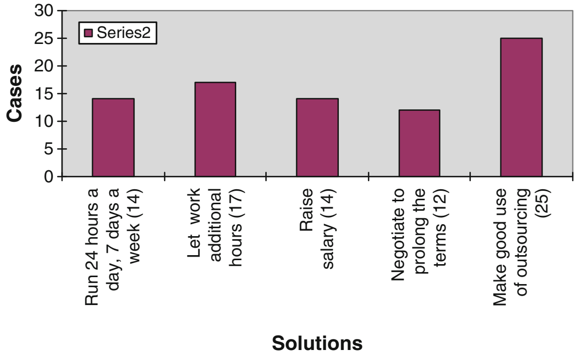


Fig. 31.7 Solutions to unexpected big order

(a) Labor cost
(b) Material sourcing
(c) Environment
(d) Transportation
(e) Enterprise-government relationship

Nowadays less and less companies need to pay too much attention to E-G relationships. Interestingly, material sourcing placed first in the overall rankings (44.4%), and secondly labor cost (41.7%). The answers regarding this issue made it quite clear as we expected.

Answers to the followed multiple-choice question, which your priority is as you receive an unexpected big order, what we got are as following (Fig. 31.7):

Though the answers seemed diverse, we can tell easily that a quarter of the respondents knew to make good use of outsourcing in face of unexpected big orders. To deeply explore this question, we continued the question as far as what types of working shift has your company acquired to advance the production operations. Seen from the results, it is clear that most Chinese toy makers prefer a combination of permanent workers (8-h) and temporary workers (unfixed hours), which is typical and popular. The truth is, most the companies in other businesses are doing the job likewise.

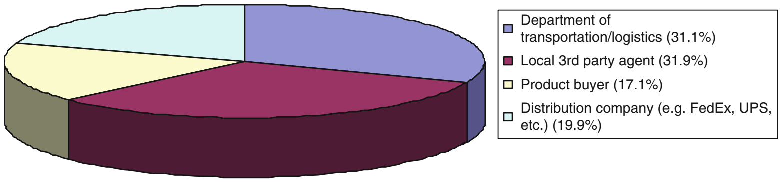


Fig. 31.8 Product distribution

Generally manual workshops take a considerable portion in toy industry, so we implemented the question do you use any of the following in most of the manual workshops to probe into this. Inspiringly, about 70% of the respondents use diverse lights, background music, coffee or tea time, and break exercise respectively.

Product Distribution

Who is responsible for your product distribution? The first question in this section was designed to probe the actuality of the logistics in the toy industry (Fig. 31.8).

For this is a multiple-choice question, choosing "D" does not mean a company depends on FedEx or UPS completely, they sometimes turn to it in emergency.

In response to a question, what frequency is product shipments made? 86.1% answered "once per order". Although in this case, the cost of supply chain may enhance, they have no other choice in the global competition arena.

Then, as far as the distribution lead-time, which is interval between factory exits to arrival at export location, was concerned, the more telling number was that almost two third indicated "1 ~ 2 weeks". While about 19.4% chose "within 1 week", 18.1% chose "2 ~ 3 weeks".

Quality Control

Quality control is a conventional but always hot topic. To set the context for this line of inquiry, we first asked respondents what methods were used to inspect / audit incoming material quality, and got interesting feedbacks (Fig. 31.9):

But it is obvious that about half of the respondents would prefer random sampling.

Followed up, we asked questions to reveal the percent of QC staff and percent of supervisors, and got ideal answers respectively. To simplify, we can say that about 90% respondents have 2 ~ 5% QC members and 78% respondents have 2 ~ 5% supervisors.

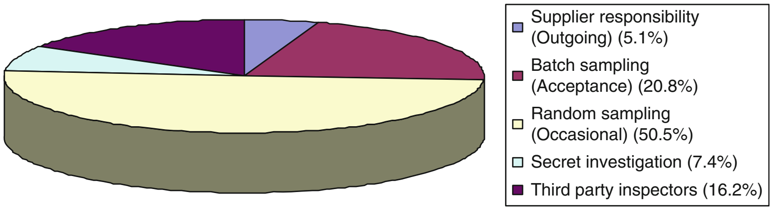


Fig. 31.9 Incoming material inspection

List of Tools (Technology)

In an effort to discover what toy makers are doing to advance their supply chain performance, we initiated four questions, inquiring about specific technology usage in the stages as: design & buying, materials procurement, production operations and quality control (Le and Koh 2002).

And 12 common tools were mentioned here. In all of these technological areas, roughly more than half of the respondents gave their encouraging answers. The results could be organized like above (Fig. 31.10):

The survey shows that respondents are relying on a wide range of technology to drive supply chain results, though some of the tools are no longer updated globally.

Conclusions

Supply chain management is important for Chinese toy makers, what should be done to improve their SCM performance? Based on extensive research and the survey feedback, we assume that this question could be answered from three perspectives.

Most toy makers are at the supply chain evolution stage between corporate excellence and partner collaboration (Houlihan 1985). They have made considerable process activities and may have taken initial steps to extend this integration to a few of their external partners.

The toy recall story exposed the problem of incoming material quality control. Seen from the feedback data of the survey, we are glad to see that about 90% respondents have 2 ~ 5% quality control members (2 ~ 3% 58.3%, 4 ~ 5% 30.6% respectively). But cases study and hands-on working experience indicate that this does not necessarily mean perfect quality control effectiveness. Thus, quality control must be infiltrated into the whole process of supply chain management.

Through a variety of tools and techniques, the toy companies make profits by reducing cycle period, achieving faster time to market, and utilizing assets more effectively. Customers are a major driver for some companies and for some initiatives, but they are not the dominate driver. The survey findings reveal that

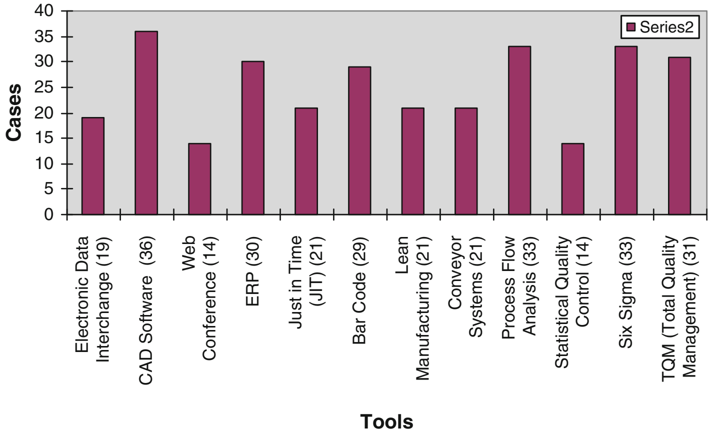


Fig. 31.10 List of tools

other factors, such as cost reduction, play a greater role in driving supply chain initiatives. On this aspect, technology has an extremely important function. Toy makers still should adopt updated technologies before it's too late (Semchi-levi et al. 2008).

Acknowledgment This paper was supported by the funding from China Scholarship Council (CSC), Shandong Provincial Project (J11WG53) and Harbin Institute of Technology at Weihai.

References

Agencies (2007a) Chinese top 50 toy manufacturers, 2007. http://www.data.icxo.com/. 18 Sept 2007

Agencies (2007b) China bars exports by 750 toy makers. http://www.nytimes.com/. 2 Nov 2007

Agencies (2007c) China toy firm boss kills self after recall. http://www.economictimes.indiatimes.com/. 14 Aug 2007

Berman O, Wang Q (2006) Inbound logistic planning: minimizing transportation and inventory cost. Transp Sci 40:287–299

Child J, Yan Y (2003) Predicting the performance of international joint ventures: an investigation in China. J Manag Stud 40:283–320

Foster TA (2005) Correct your supply chain vision to see what you need to see. http://www.supplychainbrain.com. 1 Nov 2005

Houlihan JB (1985) International supply chain management. Int J Phys Distrib Mater Manag 15:51–56

Kover A (2005) China under construction. In Industry Week, 254(4):52–57, April 2005

Le TT, Koh AC (2002) A managerial perspective on electronic commerce development in Malaysia. Electron Commer Res 2:7–29

Mu JJ (2001) Keep innovative: the case of Haier logistics. Logist Mater H 1:2–6

Poirier CC, Quinn FJ (2003) A survey of supply chain progress. Supply Ch Manag Rev 7(5):40–47

Poirier CC, Swink ML, Quinn FJ (2007) Global survey of supply chain progress. Supply Ch Manag Rev 11:20–27

Rudzki R (2008) Supply management transformation: a leader's guide. Supply Ch Manag Rev 12:12–21

Semchi-levi D, Kaminsky P, Semchi-levi E (2008) Designing and managing supply chain: concepts, strategies and case studies. McGraw-Hill, New York, pp 27–76

Wong A, Tjosvold D, Zhang P (2005) Supply chain relationships for customer satisfaction in China: interdependence and cooperative goals. Asia Pac J Manag 22:179–199

Chapter 32
Based on the Method of Baumol – Wolfe Empirical Research on Blending Center Site Selection Problem

Li-jun Liu

Abstract The paper analyses the necessity of developing power coal blending, and discusses the effect of it in the rational utilization of coal mining resources, reducing logistics cost, improving the economic benefit of coal enterprises, promoting energy conservation and emission reduction, and protecting the mining area environment. Based on this, the paper researches the site selecton problem of coal blending center in the coal mining, and determines the location and number of logistics nodes by establishing Baumol – Wolfe model.

Keywords Power coal blending • Site selection • Baumol-Wolfe model • Blending center

Introduction

China as a coal producer and consumer of main energy in coal, it is very important practical significance to achieve the effective and reasonable utilization of energy to realize "saving energy and emission reduction" targets. However, in the coal resources utilization, there is the problem on low combustion efficiency, the serious waste and environmental pollution, and etc. Therefore, it is effective measures that adopt actively power coal blending technology, raise the proportion of power coal blending , at the meantime, strive to develop coal selected by washing, improve the quality of coal, is to improve the efficiency of burning coal mining, reduce the waste and pollution, and protect the environment. Power coal blending technology is to variety in different categories and coal quality is processed after a certain proportion. The coal physical, chemical properties and burning characteristic are

L.-j. Liu (✉)
College of Management Science and Engineering, Shandong Institute of Business and Technology, Yantai, China
e-mail: llj2002-1@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_32,

changed, so as to come up to the complementation of coal quality, optimize the structure of products, meet the user requirements with combustion equipment of coal, in order to improve efficiency and reduce combustion pollutants.

The importance of power coal blending in the following (Da-guang Xiang 1988; Feng-jun Jia 2006; Pei-ao He and Yan-ping Dong 1988):

(1) Contribute to adjust the industrial structure, saving energy and reducing consumption, to formate of coal resources centralized processing, storage, distribution, management pattern in origin so that play to the advantages of coal origin, realize the integration of coal production and marketing of coal industry, and improve the overall economic benefits.
(2) Contribute to reduce logistics cost, meet the different needs of customers. Coal is matched in network node according to user requirements of quantity and quality reasonable blending, formed new coal products, and transported to users with the most economical and convenient through the highway and railway. This can effectively reduce the coal purchasing and transportation cost, and drives the development of downstream of logistics industry, promote the economic development, boost the economy development.
(3) Contribute to promote coal quality, create brand of coal. At moment blending technology research and application is more mature at home and aboard, therefore advanced blending technology can be utilized to improve "the coal brand" degree of satisfaction in the consumers mind, and promote the core competitiveness.
(4) Contribute to the effective utilization of coal resources and protecting the environment. Advanced power coal blending technology can effectively reduce the coal consumption per unit, thereby reduce the consumption of coal resources, slow down coal mining speed, and reduce the damage for environment and land resources. At the same time, the dynamic blending coal can reduce coal consumption, increase the combustion efficiency, and reduce harmful emissions.

From the above, we can choose proper nodes existing in logistics network of mining area, and engaged in coal washing and blending operations. This can be integrated coal resources, improve the quality of coal, and increase coal variety so as to meet different varieties of users demand. At the same time, it is useful to achieve the goal of "energy conservation and emission reduction" for and the local ecological environment protection.

Establishing Location Mode

We establish Baumol – Wolfe model and determine the position and number of blending node based on the principle of minimum total cost integrating with mining area and user distribution (Fang Zhang and Bing-wu Liu 2007; Jing Hou and Yi-kun Zhao 2006; Li-juan Ma 2008; Xia Li 2008; Xiang-you Gui and Yun-dong Ma 2005).

Problem Description

As shown in Fig. 32.1, coal mining logistics flow: raw coal is transported to coal blending nodes via the highway, then processed circulation (blending operations). It is divided into different kinds of products according to customer's demand and transported coal to the user.

Therefore, the location problem (Fang Zhang and Bing-wu Liu 2007; Pei-ao He and Yan-ping Dong 1988) can be described as: for m coal mining, selecting a certain amount of nodes in n location choice, for q user product in coal, and getting the selected node distribution the total cost of the minimum requirements in the premise during the planning period. Among them, in the planning period, coal mine transport to node n_1 times, node to user n_2 times.

Comprehensive considering and solve problems as follow in modeling process: what locations become alternative nodes, how to arrange delivery plan, namely traffic of the coal to each node and each node to each user can realize the planning of the minimum total cost targets to meet with the user requirement.

Hypothesis of Model

The location problem that this paper studies in mining area is to choose a certain number of nodes from the alternative nodes which establishes coal center and carries on coal processing (blending operations) and distribution. Expenses indicator in model including: fixed investment costs on building node, the product transportation costs from coal mine to node, the product distribution costs from node to customers and the product processing costs in the node due to blending coal. The first term is fixed costs, after three for variable expenses. The expression of expenses can be obtained on the analysis of the main factors that affect the cost and make total cost the minimum or close to the minimum (Cai-sheng Dai 2000; Fang-li Zhao and Ya-li Niu 2007; Fang-min Zhang 2001; Ge-fei Ma 2000; Hua-ting Fan 2006; Ji-chun Zheng 2006; Jing-kun Liang 2004).

In order to facilitate solving the model, and making the model unapt too complicated and practical value, the assumption:

(1) Only consider the car distribution of coal products and coal product quantity of distribution according to the number of transportation to calculate.
(2) Only in optional nodes range to choose.
(3) A node can supply by multiple coal mine, a user needs by multiple nodes can provide, don't consider nodes between the supply.
(4) The coal transportation in network includes from coal mine to nodes and from nodes to users.
(5) Transportation cost is proportional to the traffic.
(6) The transportation costs among coal mines, nodes and users is known constants.

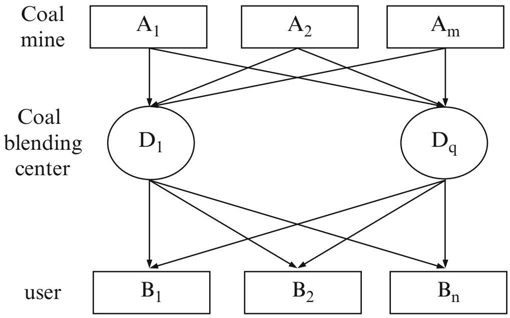


Fig. 32.1 Coal flow diagram

(7) Each user demand for coal products is known constants.
(8) The fixed investment cost of establishing and managing nodes is known.
(9) The treatment costs of nodes is concave function of flow, and the unit treatment cost of nodes are known.
(10) The number and capacity of nodes is restricted.

The Target Function and Constraints

To construct the model of the location, the related parameters and the relevant decision-making variables are defined as follows:

(1) *The parameters for the mode*:

m—The number of coal mine.
n—The number of optional nodes.
q—Number of users.
n_1—The number of coal mine supply coal to the node during the planning period.
n_2—The number of the node supply coal to user during the planning period.
a_{ki}—The unit cost of transportation from k coal mine to i node.
c_{ij}—The unit distribution costs from i node to j user.
A_k—The total supply capacity from k coal mine to nodes.
D_j—The quantity demand for j user.
M_i—The maximum capacity of i optional node.
f_i—The fixed cost of i node.
v_i—The product processing cost coefficient of i node.
θ—The economic performance indicators considering scale,$0 \leq \theta \leq 1$.
P—The maximum number of nodes are selected.

(2) *Model variable*:

x_{ki}—The carryings from k coal mine to i node at every turn.
y_{ij}—The distribution volume from i node to k user at every turn.

z_i—0–1 Integer variables, When $z_i = 1$, how i node get the nod; When $z_i = 0$, show i node not get the nod.

(3) *Objective function*:
During the planning period, the total costs made up by four parts: the total transportation cost of coal from supplying place to nodes, the total distribution costs of coal from node to users, expenses for handling the product in nodes and the total fixed expenses of nodes. The total expenses are for the four sums of minterms, according to the principles of economics, need the total cost E minimum, namely:

$$MinE = \min\begin{pmatrix} \sum_{k=1}^{m}\sum_{i=1}^{n} n_1 a_{ki} x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{q} n_2 c_{ij} y_{ij} + \\ \sum_{i=1}^{n} z_i v_i W_i{}^{\theta} + \sum_{i=1}^{n} z_i f_i \end{pmatrix} \tag{32.1}$$

(4) *Constraints*:
Supply constraint: the amount of coal from the supplying place to each node every time must not exceed its total supply capacity:

$$\sum_{i-1}^{n} x_{ki} \le A_k, k = 1, 2, \cdots, m \tag{32.2}$$

Demand constraint: Every time distribution, delivery of goods amounts from each node to a user can meet the user's total demand, namely:

$$\sum_{i-1}^{n} y_{ij} \ge D_j, j = 1, 2, \cdots, q \tag{32.3}$$

Balance constraint: Flow balance during the planning period, namely the stock equal shipments of each node:

$$n_1 \sum_{k=1}^{m} x_{ki} = n_2 \sum_{j=1}^{q} y_{ij} = W_i, i = 1, 2, \cdots, n \tag{32.4}$$

Capacity constrain: Each time, the sum of the goods of the supplying place which supply any node cannot exceed the biggest capacity of node:

$$\sum_{i-1}^{n} x_{ki} \le z_i M_i, i = 1, 2, \cdots, n \tag{32.5}$$

Number constraint: Number of the nodes to build less than a given P:

$$\sum_{i-1}^{n} z_i \leq P \tag{32.6}$$

Non-negative constraint: Variable in the model must be equal to or greater than zero, namely:

$$x_{ki} \geq 0, y_{ij} \geq 0,\ k = 1, 2, \cdots, m;\ \ i = 1, 2, \cdots, n;\ \ j = 1, 2, \cdots, q \tag{32.7}$$

Integer constraint:

$$z_i = \begin{cases} 1, & selected \quad node\ i \\ 0, & or \end{cases} \tag{32.8}$$

(5) *Model form*:
Comprehensive analysis, the location model of nodes is:

$$MinE = \min\left(\sum_{k=1}^{m}\sum_{i=1}^{n} n_1 a_{ki} x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{q} n_2 c_{ij} y_{ij} + \sum_{i=1}^{n} z_i v_i W_i^{\theta} + \sum_{i=1}^{n} z_i f_i\right) \tag{32.1}$$

s.t.

$$\sum_{i-1}^{n} y_{ij} \geq D_j, j = 1, 2, \cdots, q \tag{32.9}$$

$$n_1 \sum_{k=1}^{m} x_{ki} = n_2 \sum_{j=1}^{q} y_{ij} = W_i, i = 1, 2, \cdots, n \tag{32.10}$$

$$\sum_{i-1}^{n} x_{ki} \leq z_i M_i, i = 1, 2, \cdots, n \tag{32.11}$$

$$\sum_{i-1}^{n} z_i \leq P \tag{32.12}$$

$$x_{ki} \geq 0, y_{ij} \geq 0,\ k = 1, 2, \cdots, m; i = 1, 2, \cdots, n; j = 1, 2, \cdots, q \tag{32.13}$$

$$z_i = \begin{cases} 1, & selected \quad node\ i \\ 0, & or \end{cases} \tag{32.14}$$

Model Solving

Model Data Processing

This paper is based on the basic data of Ordos mining area logistics as an example for empirical research.

m values: The existing 276 coal mines will be merged into 13 big supply of coal area, namely $m = 13$.
n values: Ten optional node preliminarily will be selected, namely $n = 10$.
q values: The number of users on highway transportation in this model only take into account the power users, take $q = 24$.
n_1 values: Number of times for the supply of coal area to node in planning period (1 year), $n_1 = 13 \times 2{,}000$(vehicles) = 26,000 times/1 day = 9,490,000 times/1 year; $n_1 = 13 \times 2{,}000$ (vehicles) = 26,000 times /per day =9,490,000 times/year (1 year by 365 days).
n_2 values: The number of supply of material from nodes to users in planning period (1 year), $n_2 = 2{,}500$ times /per day =912,500 times /1 year.
a_{ki} values: The unit transportation cost from coal supplying area to each node is the basic same, take 0.40 yuans/t-km, the transportation distance from coal supplying area to each node take the average. Unit transportation cost see Table 32.1.
c_{ij} values: The unit cost of distribution from each node to users takes 0.45 yuan/t-km, the distribution distance from each node to users takes actual value. The unit cost of distribution from each node to the user in Table 32.2.
A_k values: The total capacity for supplying coal from the coal supplying area to nodes in Table 32.3.
D_j values: Each user's demand sees Table 32.4.
M_i values: The maximum capacity of optional node sees Table 32.5.
f_i values: The fixed fee of each node sees Table 32.6.
v_i values: The blending coal cost coefficient of each node is the same, $vi = 10$ yuan/t.
θ values: Consider economic performance indicators, all the raw coal entering nodes can deliver users after dressing by washing and blending, $\theta = 1$.
P values: The maximum number of nodes are selected, $P \leq 10$.

Model Solving

Except for fixed cost constant function in the selection of model established above, the others are linear functions, it belongs to the linear mixed 0–1 programming model. This model can be applied to solve LINGO software. Calculation results see Table 32.7.

Table 32.1 Unit transportation cost from supplying coal area to each node

Unit: yuan/t

	Nodes				
Area	M1	M2	M3	M4	M5
A1	16	18	20	15.2	24
A2	15.6	21.6	18.8	21.2	20.4
A3	16.8	15.6	17.6	20.4	18.4
A4	20.8	18	18.4	19.2	15.2
A5	18	18.4	20.4	14.8	19.2
A6	18.4	17.2	23.6	18.8	19.2
A7	15.2	18	15.6	19.2	22.8
A8	17.2	18.4	18.8	20.8	16.4
A9	14	21.2	18.4	18	17.6
A10	10.4	16.8	18.4	14.4	20.4
A11	20.8	11.2	14.8	18	21.2
A12	14	18.4	19.2	16.8	12.4
A13	16	17.2	15.2	18.4	16.8

Renewal table

	Nodes				
Area	M6	M7	M8	M9	M10
A1	22	17.6	13.2	18.4	25.6
A2	18.4	19.2	20	21.6	23.2
A3	20.8	18.8	19.2	21.2	15.2
A4	18.8	22.4	23.6	26.8	13.2
A5	22.4	14.8	20.4	15.6	16
A6	20.8	18.8	18.8	16.4	18
A7	18.8	21.2	18.8	16.8	17.2
A8	15.6	14.8	16.8	14.4	15.2
A9	22	26.4	14.8	16.8	22.4
A10	19.2	14	18.8	21.2	17.6
A11	14.4	18	13.2	21.2	16.8
A12	18.4	15.2	21.6	14.4	22
A13	13.2	18.4	20.4	14.4	19.6

Conclusion

In existing logistics network of mining area, choosing proper nodes and engaging in coal washing and blending operations can be integrated coal resources, improve the quality of coal, increase coal varieties and meet different users' demand. At the same time, it is in favor of achieving the goal of "energy conservation and emission reduction" and the local ecological environment protection. This paper analyses the necessity of developing power coal blending in mining area, and studies location problem of coal logistics network nodes. At last, the node location and number of area is made sure by establishing Baumol – Wolfe model.

Table 32.2 Unit distribution cost from each node to user

Unit: yuan/t

Users	Nodes				
	M1	M2	M3	M4	M5
D1	22.5	24.75	18	20.25	27
D2	20.25	22.5	24.75	27	22.5
D3	20.25	24.75	29.25	27	24.75
D4	22.5	29.25	24.75	20.25	15.75
D5	18	22.5	13.5	29.25	31.5
D6	27	20.25	29.25	15.75	18
D7	24.75	22.5	20.25	18	29.25
D8	29.25	18	24.75	22.5	27
D9	20.25	22.5	31.5	27	18
D10	13.5	24.75	20.25	29.25	33.75
D11	27	22.5	24.75	29.25	20.25
D12	18	22.5	27	31.5	33.75
D13	22.5	29.25	24.75	20.25	18
D14	15.75	20.25	33.75	29.25	24.75
D15	24.75	22.5	27	20.25	18
D16	20.25	24.75	29.25	27	22.5
D17	29.25	24.75	20.25	15.75	20.25
D18	15.75	24.75	20.25	29.25	24.75
D19	18	24.75	29.25	20.25	15.75
D20	22.5	29.25	20.25	24.75	20.25
D21	24.75	22.5	20.25	24.75	29.25
D22	20.25	24.75	22.5	18	15.75
D23	22.5	29.25	20.25	15.75	27
D24	24.75	22.5	20.25	15.75	18

Renewal table

Users	Nodes				
	M6	M7	M8	M9	M10
D1	22.5	20.25	27	24.75	27
D2	27	31.5	18	24.75	29.25
D3	18	20.25	24.75	29.25	15.75
D4	18	27	24.75	20.25	29.25
D5	31.5	24.75	20.25	27	20.25
D6	27	22.5	24.75	20.25	24.75
D7	24.75	15.75	31.5	33.75	15.75
D8	18	13.5	27	18	22.5
D9	22.5	31.5	24.75	20.25	15.75
D10	24.75	20.25	27	22.5	24.75
D11	15.75	27	24.75	33.75	36
D12	29.25	24.75	20.25	15.75	27
D13	27	27	22.5	18	29.25
D14	20.25	29.25	24.75	20.25	20.25
D15	15.75	20.25	24.75	29.25	22.5

(continued)

Table 32.2 (continued)

Renewal table					
	Nodes				
Users	M6	M7	M8	M9	M10
D16	22.5	24.75	20.25	24.75	20.25
D17	33.75	29.25	20.25	29.25	20.25
D18	24.75	29.25	33.75	27	22.5
D19	20.25	24.75	33.75	15.75	20.25
D20	20.25	29.25	24.75	22.5	18
D21	15.75	29.25	20.25	33.75	18
D22	27	29.25	20.25	24.75	24.75
D23	22.5	18	24.75	20.25	24.75
D24	29.25	24.75	20.25	27	18

Table 32.3 Supplying coal capability list unit: ten thousands ton

A_k	1	2	3	4	5	6	7
Ability	16,000	6,000	6,000	6,000	1,200	1,200	1,200
A_k	8	9	10	11	12	13	
Ability	1,200	1,200	1,200	1,000	1,000	1,000	

Table 32.4 User's demand table unit: ten thouysands ton

UserD_j	1	2	3	4	5	6	7	8
Demand	795	330	50	330	300	150	100	300
UserD_j	9	10	11	12	13	14	15	16
Demand	300	150	100	300	300	300	150	300
UserD_j	17	18	19	20	21	22	23	24
Demand	287.5	307.5	150	150	250	300	300	1,200

Table 32.5 Node's maximum capacity unit: ten thousands teon

NodeM_i	1	2	3	4	5
Capacity	15,000	5,500	5,500	5,000	1,000
NodeM_i	6	7	8	9	10
Capacity	1,000	1,000	1,000	1,000	1,000

Table 32.6 Node's fixed charge table unit: ten thousands yuan

Nodef_i	1	2	3	4	5
Capacity	95,000	65,000	65,000	55,000	35,000
Nodef_i	6	7	8	9	10
Capacity	35,000	35,000	35,000	35,000	35,000

Table 32.7 The computational results

	M1	M2	M3	D1	D2	D3
A1	16.00	18.00	15.60	–	–	–
A2	21.60	16.80	15.60	–	–	–
M1	–	–	–	22.50	20.25	20.25
M2	–	–	–	24.75	22.50	24.75
M3	–	–	–	18.00	24.75	29.25

References

Cai-sheng Dai (2000) Research on power blending of theory and practical application [D]. China University of Mining and Technology Ph.D. thesis, pp 52–66 (Chinese)

Da-guang Xiang (1988) The research status of United States coal combustion technology. Power Stat Syst Eng 4:1–21 (Chinese)

Fang Zhang, Bing-wu Liu (2007) The location of logistics distribution center based on mixed integer programming model. Logist Technol 26(11):81–83 (Chinese)

Fang-li Zhao, Ya-li Niu (2007) Using simplex method to implement the optimization model of the dynamic blending. Henan Norm Univ (Nat Sci Ed) J 35(2):179–180 (Chinese)

Fang-min Zhang (2001) Linear programming optimization blending. Gas Heat Power 21 (2):138–139 (Chinese)

Feng-jun Jia (2006) Power coal blending technology and its significance. Ind Technol 2 (18):127–128 (Chinese)

Ge-fei Ma (2000) To determine the optimal blending index and blending option of power coal blending [J]. Zhongzhou Coal 107(5):3 (Chinese)

Hua-ting Fan (2006) Calculation of coal blending technology principle and characteristics of coal quality parameters about the power plant [J]. Coal Technol 5(5) (Chinese)

Ji-chun Zheng (2006) Logistics node location model and empirical research [D]. Beijing Jiaotong University Ph.D. thesis, pp 1–44 (Chinese)

Jing Hou, Yi-kun Zhao (2006) Dynamic mathematical model and optimizationof coal blending. Taiyuan Univ Sci Technol J 37(4):486–488 (Chinese)

Jing-kun Liang (2004) Based on the analysis of coal quality engineering of the dynamic blending optimization research. North China Electric Power University, Hebei, pp 1–4 (Chinese)

Li-juan Ma (2008) Logistics center location mathematical method. Logist Technol 5:32–35 (Chinese)

Pei-ao He, Yan-ping Dong (1988) The research situation of Japan coal technology experiment. Power Stat Syst Eng 4:35–64 (Chinese)

Xia Li (2008) Based on the Baumol – Wolfe model and algorithm in distribution center site selection application. Xi'an University of Architecture and Technology, Xi'an (Chinese)

Xiang-you Gui, Yun-dong Ma (2005) The application of nonlinear optimization theory in the power of the coal blending. China Min Mag 14(6):49–51 (Chinese)

Chapter 33
Status and Trend of the Swine Biogas Supply Chain in Poyang Lake Ecological Economic Zone

Min Fan, Xiao-qin Gan, and Jian-hui Guo

Abstract Based on the status of swine biogas supply chain in Poyang Lake Ecological Economic Zone, two different supply chain mode were established which are household biogas and intensive swine biogas in the paper. Each node of two supply chain was offered. After processing the data from statistics, documentary investigation and visiting on-the-spot, the trend of it was analyzed by quantitative methods which the results showed that the transform from the household to joint household and livestock production biogas engineering is inevitable due to the change of pig culture structure. Then the paper described that the swine biogas supply chain in Poyang Lake Ecological Economic Zone would be promoted by the diversification of raw material, high-value-use of biogas and by products, construction of service systems, clean development mechanism and distributed energy.

Keywords Poyang Lake Ecological Economic Zon • Biogas • Supply chain • Status and trend • Structure of pig breeding

---

Supported by National Natural Science Foundation of China (No.70962002) and KR I of Humanities and Social Studies of Higher Education in Jiangxi Province (No. JD1065)

M. Fan (✉)
Department of Science, Nanchang University, Nanchang, China

Jiangxi Academy of Sciences, Nanchang, China
e-mail: rice70@163.com

X.-q. Gan
Department of Business, Jiujiang University, Jiujiang, China
e-mail: gxq2007@jjtu.edu.cn

J.-h. Guo
Jiangxi Academy of Sciences, Nanchang, China
e-mail: jianhuig@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_33,

Introduction

Swine industry is the traditional advantage of animal husbandry in Jiangxi province which promote the rural economic development, farmers employment and incomes (Zhang et al. 2006; Bowersox et al. 2002). In order to solve the resources and environment problem caused by the rapid development of swine industry, accelerating the rural biogas as an important measure to promote the construction of Poyang Lake Ecological Economic Zone and green ecological Jiangxi which result in the overall development of household biogas, small scale joint household biogas and livestock production biogas engineering in recent years. It owns 1,600 thousands household biogas and approximately 1980 livestock production biogas engineering which the annual biogas output reaches approximately 5 billion m^3 in 2011 (Statistical Bureau of Jiangxi province). It is have important realistic meanings for optimizing the rural energy structure, reducing greenhouse gas emission and constructing the new socialist countryside to study in swine biogas supply chain (Hu et al. 2008). The trend and suggestion was presented based on analyzing the status of swine biogas supply chain in Poyang Lake Ecological Economic Zone.

Swine Biogas Supply Chain Mode in Poyang Lake Ecological Economic Zone

Different swine biogas supply chain mode is corresponding to different breeding way which can be divided into household, specialized commercial pig farms, large-scale pig farms by the number of slaughtered fattened hogs in current year in Poyang Lake Ecological Economic Zone. According to agriculture standard named “standard in scale classification of rural biogas engineering (NY/T 667–2011)”, five types were illustrated in Table 33.1. For the convenience of comparison, this paper classified two different swine biogas supply chain mode which are household biogas (including joint household biogas) and intensive swine biogas by two different breeding modes.

Household Biogas Supply Chain

The development of rural household biogas mainly relies on the promotion by government which takes greatly risk on investment with subsidy and technology service (Lin 2010; Zhang 2004). The structure graph of household biogas supply chain was drawn which including the node as follow in Fig. 33.1 (Cachon and Lariviere 2001; Martin Jacob Zuidhof 2004).

Table 33.1 Classification of rural biogas engineering

Different type	Number of slaughtered fattened hogs in current year (head)	Production type	Different biogas use patterns	Daily output of biogas (m^3/d)
Household	0–50	Adult porcine	Self-consumption	1–2
Small scale	50–1,500	Adult porcine, piggy	Self-consumption or central gas supply	5–150
Middle scale	1,500–5,000	Adult porcine, breeding pig	Self-consumption or central gas supply	150–500
Large scale	>10,000	Adult porcine, breeding pig	Power generation or central gas supply	500–5,000
Oversize	>50,000	Adult porcine, breeding pig	Power generation	≥5,000

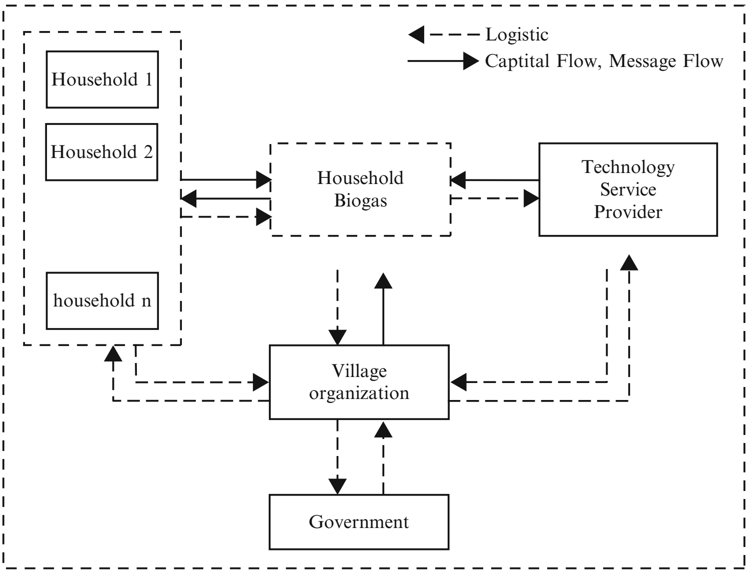


Fig. 33.1 Rural household biogas supply chain

- The Farmer: It is the key node in household biogas supply chain which is not only the direct implementer but also the beneficiary. The development of household biogas will be stagnation without positive participation of the farmer.
- The Technical Service Provider: It takes the role which guarantees the normally operation and improve the efficient of biogas project. The specific technique

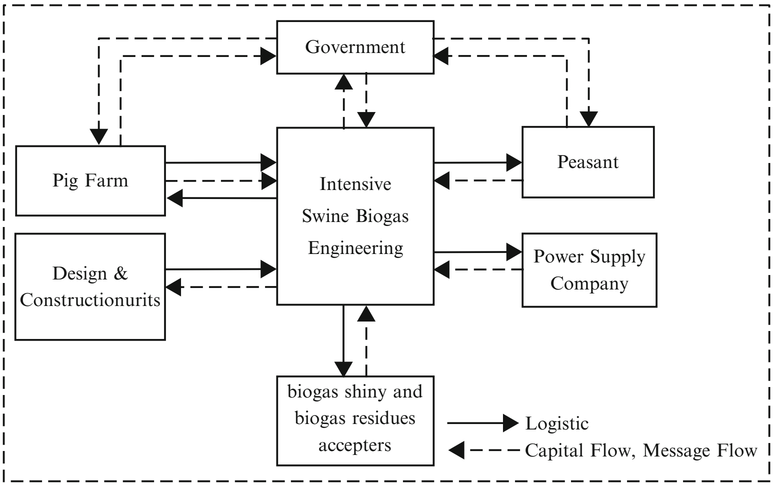


Fig. 33.2 Intensive swine biogas supply chain

demand for biogas has to be satisfied concerning pipe maintenance, safety check, gas cooker repairment, maintenance and supply in parts components of biogas digest, guide for properly and rationally use in biogas digest and how to make full use of biogas slurry and biogas residues.

- Government: It always acts as a positive promoter and a supporter in rural household biogas supply chain which the obstacle from capital and technology can not be overstep without the money and corresponding policies even if the peasant is volunteer to join in the biogas project.
- Village organization: As the supervision department of rural household biogas, village organization not only supervise its proper implement but also take the role of connection between provincial organization and peasant to whom money and message were conveyed.

Intensive Swine Biogas Supply Chain

The development of intensive swine biogas not only rely on the promotion by government but also depend on the function of biogas market in which each unit of supply chain may benefit. The structure graph of intensive swine biogas supply chain was drawn which including the node as follow in Fig. 33.2 (Gustavus aird murray 2000; Gold and Seuring 2011).

- Pig Farm: Pig farm is the investment and implement subject which constructing the biogas engineering, providing its raw material, consume the biogas as fuel or power generation, offering the by-product such as biogas slurry and biogas residues for planting industry and aquaculture.

- Design & Construction units: At present, there are 10 design units and 24 construction units who are qualified for technology service in biogas engineering in Jiangxi province, which meet the requirement of "Implementing Regulations of Rural Biogas Construction Project Management in Jiangxi" and "Announcement of Records Management for Design & Construction Units of Large and Middle biogas Engineering in Jiangxi".
- Biogas slurry and biogas residues accepters: Biogas slurry and biogas residues are good fertilizers which can be utilized as the important resources. The paths and ways of treatment is various and diversiform which can be used to produce organic complex fertilizer, cultivate mushroom, spray fruit tree and vegetable, feed fish and pig, etc. Biogas slurry and biogas residues accepters may be planting and aquaculture household, or professional collecting and processing enterprise. The high efficient utilization of biogas slurry and biogas residues remains to be further developed and promoted the popularization and application due to the disjunction of planting industry and livestock and poultry breeding in Poyang Lake Ecological Economic Zone (Haq and Easterly 2006).
- Government: Existing of the economic externality, it must give full play to government investment as the obvious guidance function. In order to reduce the environment pollution of pig farm and promote its sustainable development, "Notice on Project Proposals for Ecological Swine Biogas Engineering of Substituting Subsidies with Rewards in Jiangxi" was issued by local government. For its further standardized management, "Construction Scheme for Ecological Swine Biogas Engineering of Substituting Subsidies with Rewards in Jiangxi" was revised in which only those project meet the requirement can get award of fiscal which type of payment is "building first, substituting subsidies with rewards, settlement after completion acceptance and reward and subsidy is no more than 50%".
- Farmers and Power Supply Company: Biogas can be used as fuels substitute for other rural household energy in which the biogas engineering is close to the village. The farmers is at the downstream node of central biogas supply chain. As for some large or super large biogas engineering with power generation, the downstream node of supply chain is local power supply company (Owens 2007).

Status of Swine Biogas Supply Chain in Poyang Lake Ecological Economic Zone

The status of swine biogas supply chain in Poyang Lake Ecological Economic Zone is basically felt out by investigation for several pig farm in Pinxiang paishang town, Jiujiang shahe, Nanchang Jinxian, Shangrao Wannian, etc. The specific data of swine biogas in Poyang Lake Ecological Economic Zone from 2006 to 2010 which is in Table 33.2 was obtained from Jiangxi Agriculture Environmental Monitoring

Table 33.2 Data of swine biogas in Poyang Lake Ecological Economic Zone

	Household biogas				Intensive biogas					
Year	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Z
2006	43,416	11,734	42,482	119	287	0	30	0	3,800	140
2007	41,837	11,156	42,238	134	575	180	723	816	54,200	272
2008	73,019	19,028	44,089	146	2,462	1,500	743	1,927	53,200	490
2009	19,485	7,215	49,698	152	3,202	1,828	816	16,334	101,990	2,387
2010	15,888	6,252	49,474	160	5,107	2,288	2,452	39,729	136,790	3,152

Station (the former Jiangxi Rural Energy Management Station) and Jiangxi Statistical Yearbook from 2006 to 2010. In order to directly observe and analyze the trend of swine biogas, each group data of household biogas and intensive biogas are respectively defined, which household biogas: X_1, total investment (ten thousands yuan); X_2, government subsidy (ten thousands yuan); X_3, annul output of biogas (ten thousands cubic metre); X_4, household of gas supply (ten thousands household); intensive biogas: Y_1, total investment (ten thousands yuan); Y_2, government subsidy (ten thousands yuan); Y_3, annul output of biogas (ten thousands cubic metre); Y_4', household of gas supply (ten thousands household); Y_5, area of biogas digester (cubic metre); Z, technical service person (person).

The data in Table 33.2 was processed so as to reflect directly the development trend of rural biogas supply chain. Then two different supply chain trend figure were illustrate in which technical service person was put the figure of household biogas.

As it shown in Figs. 33.3 and 33.4, the resources allocation of biogas project is transforms from the household to joint household and livestock production biogas engineering due to the change of pig culture structure in Poyang Lake Ecological Economic Zone.

The Trend of Swine Biogas Supply Chain in Poyang Lake Ecological Economic Zone

Based on above data analysis and the investigation in stockholder of supply chain such as government and the farmer, and pig farm, we can find the tendency of swine biogas supply chain as follows.

The Development Household Biogas Became Slow with Rapid Growth of Large-Scale Farming Biogas

The pig culture mode in Poyang Lake Ecological Economic Zone has been changed continually in recent years especially during the eleventh 5-year which transformation from traditional scatter-feed to scale feed and factory farming is obvious (Chen et al. 2010). The data from authority shows that the number of pig farming

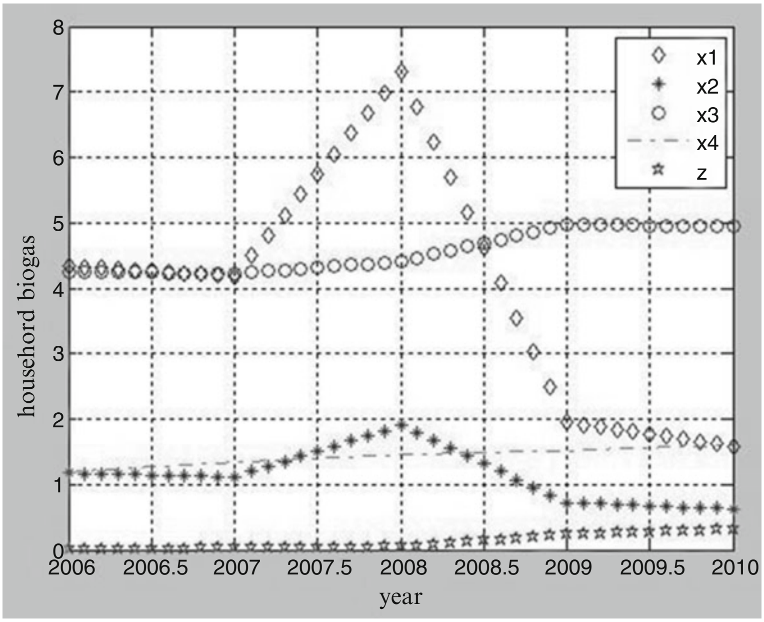


Fig. 33.3 Tendency chart of household biogas

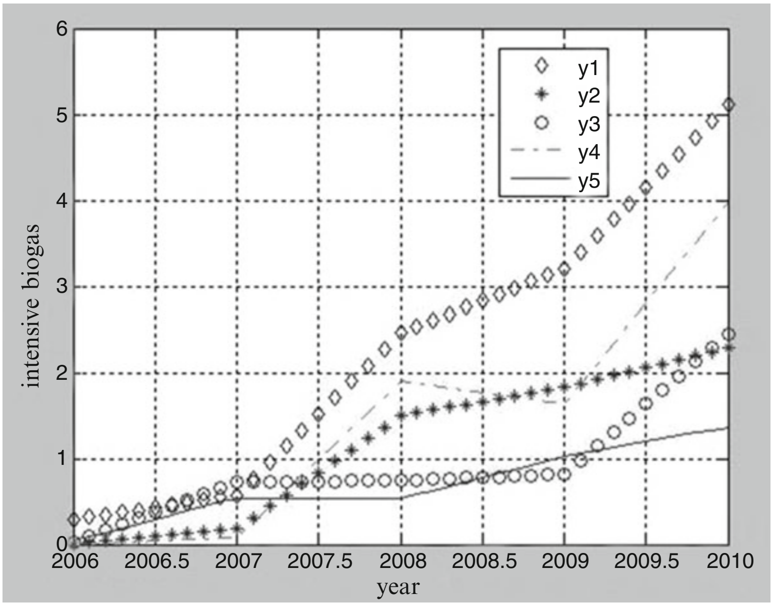


Fig. 33.4 Tendency chart of intensive biogas

is 1,373 thousands which account for 15.8% of the peasants in Poyang Lake Ecological Economic Zone, decreased by 27.9% compared to 2005. The pig farming which slaughtered fattened hogs in current year over 500 head reached ten thousands and the proportion of scale feeding increased to 80.6. As the withdrawal of the peasants, the development household biogas became slow which its investment decrease year by year after reach to peak in 2008.One reason is The popular rate of household biogas is high in adaptive region which on one hand economically developed region is not suitable again for household biogas, on the other hand the undeveloped region such as the remote mountain areas it is hard to build the biogas digest which the peasants can not afford. The other reason is function of the traditional theory of the diminishing marginal utility. As the fast development of scale feeding, joint household biogas and scale biogas developed fastly which the annual output of biogas is rising constantly and the gas supply household is increasing continuously due to the increasing input.

The Biogas Supply Chain Become Stable Because of Diversification of Raw Material and Widely Product Application

The core node of household biogas supply chain is peasants which quantity decrease result in seriously affecting the stable supply of raw material. Jiangxi Agriculture Bureau is developing the pilot program concerning replacing animal manure for straw (rice straw, cotton's stalk, straw of wheat) (Srivastava 2007). The core node of intensive biogas supply chain is pig farming which have the production of waste. In intensive biogas supply chain, fermenting materials is positively correlated with productivity of pigs which is depend on price of pork due to the relation between supply and demand, so that it is inevitable with the development of substituted material. For stable supply chain, different utilization of biogas and by-product conforming to circumstances are adapted to prolong supply chain such as biogas power generation, high-value-use of biogas slurry and biogas residues.

Construction of Biogas Service Systems Is Strengthening and Corresponding Equipment Develop Fastly

Construction of rural biogas service systems in Poyang Lake Ecological Economic Zone is energetically promoted by national assistance fund and local counterpart funds. Service network in country and village are encouraged to set up by supporting according to different function of service. Not only the professional person but also various relevant equipments such as transporter, electric pump, biogas tester and repair tools are necessary. The enterprise which product these equipments concerning biogas engineering were given opportunity to expand under the circumstance that the equipments are bidding by local government.

Clean Development Mechanism and Distributed Energy Bring New Opportunities

Biogas engineering is methane recovery and utilization project in clean development mechanism which can effectively reduce the greenhouse gas emission (Berglund and Borjesson 2006). Biogas power generation project of pig base in Jinxian country of Jiangxi province is such a project which is constructed by Jiangxi Huidenen Ecological Science and Technology Company. It was approved by National Development and Reform Commission which can reduce 63,633 t CO_2 emissions annually. With the constantly improvement of CDM methodology and more and more success application experience, CDM project concerning biogas will be increasing which can give more contribution for biogas industry in Poyang Lake Ecological Economic Zone. As the policy of distributed energy was issued, biogas will be industry pioneer due to its characteristic such as mature technology, easy to spread and wide range of applications with the improvement of relevant policies and smart grid construction under the circumstance of vigorously developing renewable energy in China.

Conclusion

With the adjustment of pig breeding structure in Poyang Lake Ecological Economic Zone, swine biogas supply chain is changing significantly. The transform from the household to joint household and livestock production biogas engineering is inevitable. Diversification of raw material biogas supply chain, different utilization of biogas and by-product, construction of biogas Service Systems, CDM and distributed energy will make the biogas industry enter into a new stage which gives more contribution to improving the energy structure, protecting from a Poyang lake of clean water and reducing GHG emission in Poyang Lake Ecological Economic Zone.

References

Berglund M, Borjesson P (2006) Assessment of energy performance in the life-cycle of biogas production. Biomass Bioenergy 30:254–266

Bowersox J, Closs J, Cooper M (2002) Supply chain logistics management. China Machine Press, Beijing, pp 18–26

Cachon GP, Lariviere MA (2001) Turning the supply chain into a revenue chain. Harv Bus Rev 20–21

Chen Y, Yang G, Sweeney S, Feng Y (2010) Household biogas use in rural China:a study of opportunities and constraints. Renew Energy 4:176–178 (Chinese)
Gold S, Seuring S (2011) Supply chain and logistics issues of bio-energy production. J Clean Prod 19:32–42
Gustavus aird murray (2000) Supply chain management in the Ontario chicken and pork industries. Master Dissertation, University of Guelph
Haq Z, Easterly JL (2006) Agricultural residue availability in the United States. Appl Biochem Biotechnol 129:3–21
Hu H, Zhang H, Yue DP (2008) An analysis of the determinants in option of biogas technology for swine farmers in Jiangsu province(Chinese). Ch Biogas 10:21–25
Lin B (2010) Development of biogas engineering theory and practice in the biomass energy. China agricultural science and technology Publishing House, Beijing (Chinese)
Martin Jacob Zuidhof (2004) A bio-economic model of the broiler chicken supply chain. Dissertation of Doctor of Philosophy, University of Alberta
Owens GM (2007) Analyzing impacts of bioenergy expansion in China using strategic environmental assessment. Manag Environ Qual 18(4):396–412
Srivastava SK (2007) Green supply-chain management: a state-of the-art literature review. Int J Manag Rev 9(1):53–80
Statistical Bureau of Jiangxi province. Statistical yearbook in Jiangxi Province. China statistical Publishing House, 2006–2011 (Chinese)
Zhang YL (2004) The current situation and development countermeasures of rural biogas in China. Renew Energy 4:38–42 (Chinese)
Zhang WD, Yin F, Liu N, Liu SQ (2006) Industrial development and marketable analysis on rural biogas. Trans Chin Soc Agric Eng 22:72–76 (Chinese)

Chapter 34
Market Orientation, Operational Synergistic Capability and Performance: 3PLs User Perspective

Xiao-yu Wang

Abstract This study concentrates on the relationships among market orientation, operational synergistic capability and performance from 3PL perspective. A sample of 201 companies in Guangdong province with experiences in 3PL services are identified for this study. The data analysis shows 5 of 7 hypotheses are supported. The results show that market orientation affects performance indirectly, operational synergistic capability is the key mediator that market orientation affects performance, which indicates the whole process of operational synergistic capability affects performance. Based on these findings, it is suggested that firms have to consider outsourcing non-core logistics functions to 3PLs for better logistics service performance and market performance. So, a conclusion is reached that the collaboration with 3PLs is one potential strategic action for firms in advancing the operations.

Keywords Market orientation • Operational synergistic capability • Performance • 3PL

Introduction

As a central tenet of the modern marketing sciences, market orientation (MO) has been heralded by academics and practitioners for decades (Qu 2009). China's average economic growth ranked among the highest in the world in the past two decades, and is deemed one of the world's economic powerhouses with increasing importance to the world economy (Sternquist et al. 2010). Its dramatic development in the market provides big opportunities for companies in China. In order to catch

X.-y. Wang (✉)
Department of Marketing, South China University of Technology, Guangzhou, People's Republic of China
e-mail: wangxy@scut.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_34,

these opportunities, the marketing literature suggests firms to be market oriented. A company's market orientation is verified to be the original predictor of its performance (Harris and Ogbonna 2001). However, research papers recently revealed that the relationship between market orientation and performance may not fully explain the company's practice (Sinkovics and Roath 2004; Singh 2009). Relationship theory is held that companies can get more by working closely with third parties (Nesheim 2001). This may explain the company's performance and mediate the market orientation and performance relationship. So, working with third parties could be one of the key determinants of company's performance. Based on this research propositions, this study empirically investigates the relationship among market orientation, operational synergistic capability and performance.

In the following parts, past research papers on market orientation, operational synergistic capability and performance are first reviewed, then a conceptual model and hypotheses are developed. Data analysis and results are then reported after research methods. Finally, conclusions are drawn based on the findings.

Literature Review

In this part, literatures on market orientation, operational synergistic capability and performance are reviewed separately.

Market Orientation

According to Narver and Slater (1990, p 21) market orientation is the organization culture that most effectively and efficiently creates the necessary behaviors for the creation of superior value for buyers and, thus, superior performance for the business. Based on in-depth interview, market orientation is composed of two dimensions: customer orientation and competitor orientation. Such market orientation is consisted with some of the research works and tested to strongly affect the company's performance (Sin et al. 2003; (Sinkovics and Roath 2004).

Customer orientation is the idea that the organization focus on providing superior service quality to customers (Sinkovics and Roath 2004). According to Zhou et al. (2007) customer orientation positively affect company's performance.

Competitor orientation is the notion that a company gathers information about its competitor and competitor reactions to the company's movement (Sinkovics and Roath 2004). It was tested that this orientation is significantly related to performance (Sin et al. 2003).

Operational Synergistic Capability

In order to focus on their competencies to face market competition, companies in the world are outsourcing their logistics activities increasingly (Mitra 2006). Based on this cooperative relationship, it is good for companies to reduce logistics cost due to the economies of scale and expertise of 3PLs, to improve service resulting from 3PLs' efficiency and focus (Maloni and Carter 2006), and to increase flexibility (Laarhoven et al. 2000), (Skjoett-Larsen 2000). Synergy means the outcome or effect of cooperative interactions that individual parts cannot achieve alone, and then some resource can be absorbed (Persaud 2005). This study concentrates on companies cooperate with 3PL. When they are working together, the companies need to coordinate internally and externally, and to operate flexibly, which is helpful to produce operational synergistic capability and to make better performance eventually. Operational synergistic capability is defined as a higher order operational capability due to logistics outsourcing, which is composed of three factors: external coordination, internal coordination, operational flexibility.

1. *External coordination*: In this study, external coordination means the ability that the company and third party logistics providers work closely to help the company to be better in the market. Some research works have concentrated on how companies make full use of their special resources through managing their relationships to enhance cooperation and collaboration among them (Anderson and Narcus 1990; Borys and Jemison 1989; Hamel 1991), which improve the companies' performance finally (Achrol 1997; Bello and Gilliland 1997; Hunt 1995). It is verified that the extent of external collaboration shows the intense of relative parties, resulting in a better performance (Byrne and Javed 1992). It is held that coordinating with third parties can lead to a better performance (Yeung et al. 2006).
2. *Internal coordination*: In this study, internal coordination means the ability that the different units, departments or individuals in a company keep communicating and sharing information in order to enhance the coordination between the company and the 3PLs. Companies that seek to gain advantages in competition by external collaborating must be much more concentrated on internally; therefore it should better react to customers' expectations and satisfy their needs (Germain and Iyer 2006). It is held that internal coordination positively affects performance (Atuahene-Gima 1996).
3. *Operational flexibility*: In this study, operational flexibility means the ability to flexibly accommodate to external environment and customers' changing needs based on making full use of one's own advantages during the process of coordinating with 3PLs. Previous research showed that companies with better operational flexibilities resulting in a better performance (Suarez et al. 1995).

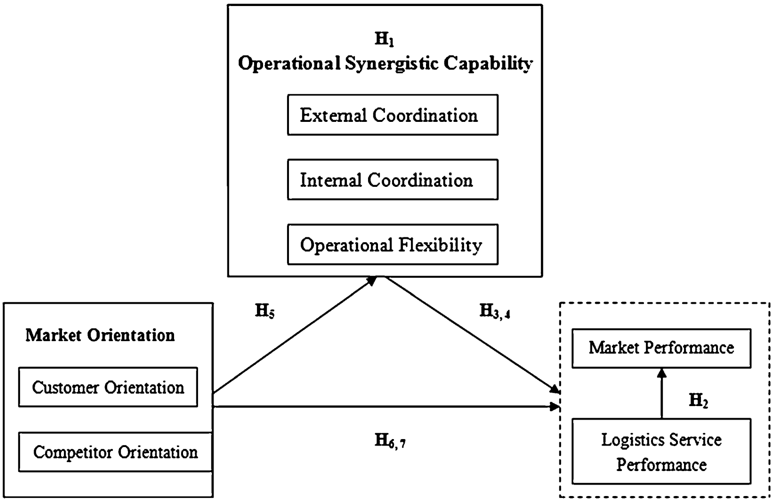


Fig. 34.1 Conceptual model

Performance

In this study, logistics service performance refers to the effect distributing the products or materials to customers with the help of 3PLs service providers. The original reason for companies to collaborate with 3PLs is to improve operational flexibility, logistics performance and even market performance.

In this study, market performance refers to the effect satisfying customers' needs, reacting to environmental changes, seizing the opportunity and improving over all performance with the help of 3PLs service providers. It is shown that a company' performance is affected by some factors like company's market orientation and the external coordination (Narver and Slater 1990; Yeung et al. 2006).

Conceptual Model and Hypotheses

The conceptual model in Fig. 34.1 presents the interrelationship among market orientation, operational synergistic capability and performance. It is proposes that a company's market orientation contributes to the level of operational synergistic capability, which subsequently affects logistics service performance and market performance. In short, the following hypotheses are going to test in this study.

H_1: Operational synergistic capability refers to higher order operational capability due to logistics outsourcing, which is consists of three factors: external coordination between companies and 3PLs, internal coordination within the firm, and operational flexibility. These three factors of operational synergistic capability are integrated coexistence, mutual alternative and complementary.

H_2: Logistics service performance positively affects market performance. That is to say, the better the logistics service performance, the better the performance of the company in the market.

H_3: Operational synergistic capability positively affects market performance. That is to say, the more external coordination, internal coordination, and operational flexibility of the company, the better the performance of it in the market.

H_4: Operational synergistic capability positively affects logistics service performance. That is to say, the more external coordination, internal coordination, and operational flexibility of the company, the better the logistics service performance it presents.

H_5: Market orientation positively affects operational synergistic capability. That is to say, the more customer and competitor oriented of the company, the more external coordination, internal coordination, and operational flexibility it presents.

H_6: Market orientation positively affects market performance. That is to say, the more customer and competitor oriented of the company, the better the performance of it in the market.

H_7: Market orientation positively affects logistics service performance. That is to say, the more customer and competitor oriented of the company, the better the logistics service performance it presents.

Research Methods and Data Analysis

Research Methods

A survey was conducted in Guangdong province aiming at companies collaborating with 3PLs. A sample of 201 companies was successfully recruited from varied industries like manufacturers, retailers, and traders. According to Table 34.1, most of these companies were manufacturers and traders. One possible reason is that manufacturers and traders focus much on logistics than retailers from the distribution perspective. Another likely reason is usually the big or chain stores require less 3PL service.

As shown in Table 34.1, the private-owned enterprises accounted for the most. Due to political and economic reforms and geographic strength of Guangdong province, many entrepreneurs are able to start their own businesses. Therefore, it is acceptable to have a high ratio of private-owned companies and manufacturers, traders in the sample, which reflects the changes and situation in Guangdong province economy. Most of the respondents were senior staff members like general managers, market managers or logistics managers. They were requested to answer a group of questions about company's customer orientation, competitor orientation,

Table 34.1 Characteristics of samples

	All companies		Man. (50.7%)		Traders (38.8%)		Retailers (10.5%)	
	No.	%	No.	%	No.	%	No.	%
Ownership								
State-owned	31	15.4	16	15.7	13	16.7	2	9.5
Private-owned	96	47.8	40	39.2	48	61.5	8	38.1
Collective/joint-owned	21	10.5	15	14.7	4	5.1	2	9.5
Foreign-owned	53	26.3	31	30.4	13	16.7	9	42.9
Employees' Number								
100 or below	69	34.3	17	16.7	42	53.9	10	47.6
100–300	43	21.4	19	18.6	21	26.9	3	14.3
300–500	11	5.5	8	7.8	1	1.3	2	9.5
500–1,000	19	9.5	12	11.8	6	7.7	1	4.8
1,000–5,000	30	14.9	22	21.6	5	6.4	3	14.3
More than 5,000	29	14.4	24	23.5	3	3.8	2	9.5
Working with 3PLs								
1	31	15.4	13	12.8	15	19.2	3	14.3
2	46	22.9	19	18.6	18	23.1	9	42.9
3	37	18.4	19	18.6	14	17.9	4	19.1
4	18	9.0	11	10.8	6	7.7	1	4.8
5 or more	69	34.3	40	39.2	25	32.1	4	19.0
Respondents' positions								
General manager	39	19.4	13	12.7	19	24.4	7	33.3
Market manager	70	34.8	32	31.4	32	41.0	6	28.6
Logistics manager	17	8.5	9	8.8	7	9.0	1	4.8
Others	67	33.3	41	40.2	20	25.6	6	28.6
Not answer	8	4.0	7	6.9	0	0	1	4.2

logistics service performance, market performance, coordination with 3PLs, internal coordination and operational flexibility using a five point Likert type scale ranging from 1 = Strongly disagree to 5 = Strongly agree. Most questions were accommodated from the previous scales (Sinkovics and Roath 2004; Narver and Slater 1990).

Three steps were adopted to analyze the data for testing hypotheses and conceptual model. Step 1, exploratory factor analysis was used to achieve factor structures of market orientation and operational synergistic capability. Furthermore, Pearson correlations and Cronbach's alphas of these research variables were calculated. Step 2, MANOVA is performed to confirm whether business type, ownership, employee number and respondents' position or their interactions have significant difference to the research variables. Step 3, structural equation modeling (SEM) was conducted to examine the interrelationships of these research variables and test the hypotheses.

Factor Analysis

Principal component method with varimax rotation was used to factor items of market orientation and operational synergistic capability separately. A two-factor solution was achieved to stand for market orientation. A three-factor solution was achieved to stand for operational synergistic capability. All remained items reported a loading value greater than 0.50, indicating a plain and incontestable structure. Market orientation is represented by customer orientation and competitor orientation. Customer orientation has 4 items and competitor orientation has 3 items, which explain 61.05% of the variance in market orientation.

Similarly, a 58.82% variance of operational synergistic capability was found to be explained by 6-item external coordination, 4-item internal coordination and 4-item operational flexibility. The composite reliabilities were 0.79 and 0.85 separately for market orientation and operational synergistic capability, which stated a good internal consistency of reported factor structures.

Pearson Correlations and MANOVA

A positive and moderate link was discovered among relative variables in a correlation analysis (see Table 34.2). Besides, all correlations were significant, which suggested a possibility of causal relationship among these research variables.

This study used MANOVA to test simultaneously whether the four background variables (business type, ownership, employees' number, and respondents' positions) have significant different effect and significant cross effect on research variables. The total results showed that the values of Pillai's Trace, Wilks' Lambda, Hotelling Trace for the four background variables were all not significant. So it was concluded that business type, ownership, employees' number, and respondents' positions had no significant effect on research variables. In another word, the sampled companies had similar opinions on research variables.

Structural Equation Modeling

Fine factor structures and significant correlations guarantee proceeding with SEM to explore the mutual relationship among market orientation, operational synergistic capability, logistics service performance and market performance. Firstly, from Fig. 34.2 it is concluded that the conceptual model and actual model was seemed to be the same, which was learned from the data ($\chi^2 = 608.94$, df $= 339$, $p < 0.001$). Secondly, alternative fit indices were performed to evaluate the overall model fit including GFI, RMR, and (χ^2/df). All indices were verified to fit the usual degree of

Table 34.2 Results of Pearson correlations

Variance	Market orientation	Operational synthetic capability	Logistics service performance	Market performance
Market orientation	1			
Operational synthetic capability	0.530**	1		
Logistics service performance	0.412**	0.477**	1	
Market performance	0.411**	0.586**	0.617**	1

Note: ** = $p < .01$

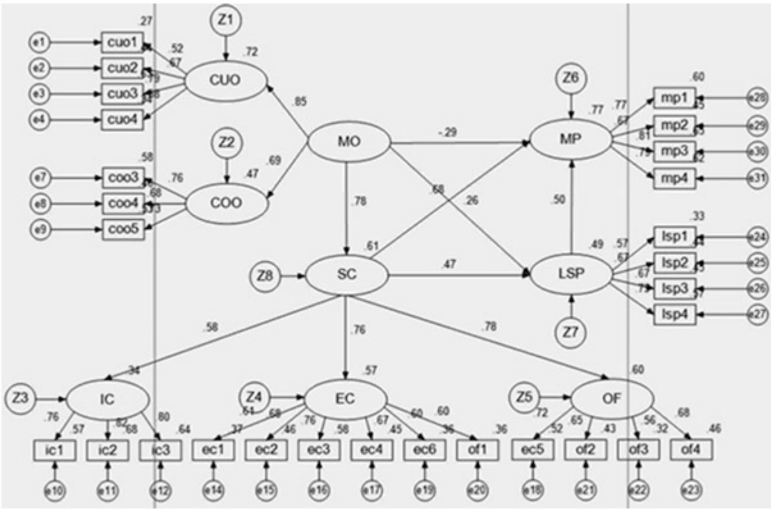


Fig. 34.2 Structural model

Table 34.3 Results of hypotheses

Hyp.	Sta. path coefficient	Factor loading	Standard error	C. R.	P	Result
H_1	0.582	0.710	0.124	5.742	0.000***	Support
	0.756	1.000			0.000***	Support
	0.776	0.779	0.121	6.449	0.000***	Support
H_2	0.503	0.672	0.169	3.964	0.000***	Support
H_3	0.676	0.905	0.308	2.936	0.003**	Support
H_4	0.475	0.476	0.212	2.245	0.025*	Support
H_5	0.784	0.802	0.157	5.115	0.000***	Support
H_6	−0.289				0.166	Not support
H_7	0.261	0.267	0.215	1.243	0.214	Not support

Note: * = $p < .05$, ** = $p < .01$, *** = $p < .001$

acceptances (GFI = 0.83, RMR = 0.06, χ^2/df = 1.80). The conceptual model was proved to be built.

From Table 34.3, factor loading of customer orientation and competitor orientation were significant to market orientation. Similarly, external coordination, internal coordination and operational flexibility loaded significantly onto operational synergistic capability, which were 0.76, 0.58 and 0.78 separately, so H_1 is supported. Market performance was explained by logistics service performance ($\beta = 0.50$, $t = 3.96$, $p < 0.001$), so H_2 is supported too. Operational synergistic capability was verified to significantly affect market performance ($\beta = 0.68$, $t = 2.94$, $p < 0.01$) and logistics service performance ($\beta = 0.48$, $t = 2.25$, $p < 0.05$). Hence, H_3 and H_4 are supported too. Market orientation was found to significantly predict operational synergistic capability ($\beta = 0.78$, $t = 5.12$, $p < 0.001$), but it did not significantly affect logistics service and market performance, Thus, H_5 is supported while H_6 and H_7 are not.

Although market orientation appears to have weak direct effect on logistic performance and market performance, it may be absorbed by operational synergistic capability.

Conclusions

This study contributes to the strategic marketing literature in four aspects. Firstly, it creates and empirically tests the three-factor structure of operational synergistic capability which emphasizes that external coordination, internal coordination and operational flexibility are all important for the company that collaborates with 3PLs. This construct is measures by a multiple-item scale consisting of 13 items. Secondly, market orientation is verified to positively affect operational synergistic capability. It suggests companies to have a closer coordination with 3PLs, internal departments and better operational flexibility to strategically concentrate their resources according to customer needs and competitor activities. Thirdly, operational synergistic capability is found to positively predict logistics service performance and market performance. The operational synergistic capability appears to be a favorable factor of logistics service performance and market performance. Fourthly, logistics service performance positively affects market performance. The better logistics service performance the better market performance is which in some extent tests the importance of logistics to a company.

References

Achrol RS (1997) Changes in the theory of interorganizational relations in marketing: toward a network paradigm. J Acad Mark Sci 25:56–71

Anderson JC, Narcus JA (1990) A model of distributor firm and manufacturer firm working partnerships. J Mark 54(1):42–58

Atuahene-Gima K (1996) Resolving the capability-rigidity paradox in new product innovation. J Mark 69:61–83

Bello DC, Gilliland DI (1997) The effect of output controls, process controls, and flexibility on export channel performance. J Mark 61(1):22–38

Borys B, Jemison DB (1989) Hybrid arrangement as strategic alliances: theoretical issues in organizational combinations. Acad Manage Rev 14(2):234–249

Byrne SM, Javed S (1992) Integrated Logistics Information Systems (ILIS): competitive advantage or increased cost. Council of Logistics Management, Oakbrook

Germain R, Iyer KNS (2006) The interaction of internal and downstream integration and its association with performance. J Bus Logist 27(2):29–52

Hamel G (1991) Competition for competence and inter-partner learning within international strategic alliance. Strateg Manag J 12:83–103

Harris LC, Ogbonna E (2001) Strategic human resource management, market orientation, and organizational performance. J Bus Res 51(2):157–166

Hunt KA (1995) The relationship between channel conflict and information processing. J Retail 71 (4):417–436

Laarhoven PV, Berglund M, Peters M (2000) Third-party logistics in Europe-five years later. Int J Phys Distrib Logist Manag 30(5):425–442

Maloni MJ, Carter CR (2006) Opportunities for research in third-party logistics. Transp J 45 (2):23–38

Mitra S (2006) A survey of third-party logistics (3PL) service providers in India. IIMB Manag Rev 18:159–174

Narver JC, Slater SF (1990) The effect of a market orientation on business profitability. J Mark 54:20–35

Nesheim T (2001) Externalization of the core: antecedents of collaborative relationships with suppliers. Eur J Purch Supply Manag 7(4):217–225

Persaud A (2005) Enhancing synergistic innovative capability in multinational corporations: an empirical investigation. J Prod Innov Manag 22(5):412–429

Qu R (2009) The impact of market orientation and corporate social responsibility on firm performance: evidence from China. Asia Pac J Mark Logist 21(4):570–582

Sin LYM, Tse ACB, Yau OHM, Chow R, Lee JSY (2003) Market orientation and business performance: a comparative study of firms in mainland China and Hong Kong. Eur J Mark 37(5/6):910–936

Singh S (2009) How market orientation and outsourcing create capability and impact business performance. Thunderbird Int Bus Rev 51(5):457–471

Sinkovics RR, Roath AS (2004) Strategic orientation, capabilities, and performance in manufacturer-3PL relationships. J Bus Logist 25:43–64

Skjoett-Larsen T (2000) Third-party logistics: from an interorganizational point of view. Int J Phys Distrib Logist Manag 30(2):112–127

Sternquist B, Huang Y, Chen Z (2010) Predicting market orientation: Chinese retailers in a transitional economy. Int J Retail Distrib Manag 38(5):360–378

Suarez FE, Cusumano MA, Fine CG (1995) An empirical study of flexibility in manufacturing. Sloan Manage Rev 37:25–32

Yeung JHY, Selen W, Sum C, Huo B (2006) Linking financial performance to strategic orientation and operational priorities: an empirical study of third-party logistics providers. Int J Phys Distrib Logist Manag 36:210–230

Zhou ZK, Brown JR, Dev CS, Agarwal S (2007) The effects of customer and competitor orientations on performance in global markets: a contingency analysis. J Int Bus Stud 38:303–319

Chapter 35
Research on the Inventory Model of ERP System in Unstable Demand

Jin-li Zhang

Abstract Based on the cost and profit, considering the unit cost of materials and the material utilization, with the methods of probability theory and mathematical statistics, an ERP inventory control model is proposed under the condition of fluctuating demand. Afterwards, the supply volume and safety stock can be reasonably determined. The rationality and effectiveness of this model is demonstrated from real samples. The model can be applied to and will bring practical guiding significance for the inventory control of modern enterprises.

Keywords Discrete variables • ERP theory • Inventory model • Unstable demand

Introduction

For most organizations in any sector of the economy, Supply Chain Management, i.e., the inventory management from upstream to downstream is a crucial problem (Axater 2007), and having inventories on hand can account for 20–40% of their value per year (Yue Gu et al. 2008). If the inventory is small, it may be out of stock and the enterprise will lose the market opportunity while the sale rapidly increases. On the other hand, if the inventory is lager, it may pay more warehouse costs and emerge opportunity costs (Brown 1967). So, the enterprise must adjust the inventory level to match the demand in order to obtain greater economic benefits (Jiang Wu et al. 2010). The ERP inventory system is rather effective in ensuring the organization supply and reducing the inventory even inventory costs; what's more, it can cut the opportunity cost, save the logistics cost, and improve the competitiveness. Therefore, careful managing inventory level makes the economic sense (Silver et al. 1998; Sherbrtooke 2004; Muller 2003).

J.-l. Zhang (✉)
Business Administration College, Nanchang Institute of Technology, Nanchang, China
e-mail: 493480086@qq.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_35,

ERP (Enterprise Resource Planning) is a set of business management system standards proposed by the famous American Garter Group, Inc. ERP system integrates all of the manufacturing functional areas within an organization by providing a common software platform and shared database (Xiao-jun Wang 2005). It includes sales, production planning, quality management, human resource, workflow, financial accounting, controlling and so on (Xiao-zhuang Zhou 2009). What's more, inventory management is an important subsystem in ERP.

Inventory are stockpiles of raw materials, supplies, components, work in process, and finished goods that appear at numerous points throughout a firm's production and logistics channel (Hui-qiang Yu 2004). Holding inventory has many functions. It can provide the production continuity, improve the custom service, and reduce the risk. But excessive inventory tend to conceal a wide variety of problems (Hax and Canda 1984). Moreover, it is rather costly (Zipkin 2000). For all the reasons, inventory should be reduced or eliminated wherever possible (Guo-fang Song et al. 2002). ERP system can manage the inventory effectively.

Recent progress has been witnessed in former inventory research about continuous and stable demand, while this paper will throw light on the Inventory management in discrete unstable demand.

Inventory Model of the Discrete Variables in Unstable Demand

Description of Unstable Demand

Assume the firm's production capacity is fixed in the period.

Let

Q = productivity,
r = demand,
k = overage price per unit,
h = inventory cost per unit,
s = production cost per unit.

To minimum the cost and maximum the profit, we must decide the reasonable Q.

Build the Model

1. The newsboy model considering the cost
   (a) If $Q \geq \mathrm{r}$, the firm can't sell all products, the cost is

$$\sum_{\mathrm{r}=0}^{Q} \mathrm{P}(\mathrm{r}) \geq \frac{\mathrm{k}-\mathrm{s}}{\mathrm{k}+\mathrm{h}} \tag{35.1}$$

(b) If r > Q, the products must be stockout, the opportunity cost is

$$\sum_{r=Q+1}^{\infty} k(r - Q)P(r) \tag{35.2}$$

The expected costs $C(Q)$ can be expressed as

$$C(Q) = \sum_{r=0}^{Q} h(Q - r)P(r) + \sum_{r=Q+1}^{\infty} k(r - Q)P(r) + sQ \tag{35.3}$$

To find the optimal solution we can use

$$C(Q) \le C(Q + 1) \tag{35.4}$$

$$C(Q) \le C(Q - 1) \tag{35.5}$$

Calculating, the model about Q

$$\sum_{r=0}^{Q-1} P(r) \le \frac{k - s}{k + h} \le \sum_{r=0}^{Q} P(r) \tag{35.6}$$

2. The newsboy model considering the profit

(c) If $Q^{'} \ge r$, the firm can sell part of all products, the excepted profit is

$$\sum_{r=0}^{Q'} [kr - h(Q' - r)]P(r) \tag{35.7}$$

(d) when $r > Q'$, the firm can sell all products, the excepted profit is

$$\sum_{r=Q'+1}^{\infty} kQ'P(r) \tag{35.8}$$

The expected profit R (Q') can expressed as

$$R(Q') = \sum_{r=0}^{Q'} krP(r) - \sum_{r=0}^{Q'} h(Q' - r)P(r) + \sum_{r=Q'+1}^{\infty} kQ'P(r) - sQ' \tag{35.9}$$

To find the optimal solution we can use

$$R(Q' + 1) \le R(Q') \tag{35.10}$$

$$R(Q' - 1) \leq R(Q') \tag{35.11}$$

Calculating, the model about Q'

$$\sum_{r=0}^{Q'-1} P(r) \leq \frac{k - s}{k + h} \leq \sum_{r=0}^{Q'} P(r) \tag{35.12}$$

From now, the Q in the minimum cost is equal to the Q' in the maximum profit (Porteus 2002; Chikán 1990). When the profit get the largest, the cost get the least at the same time, mark Q^* as the optimal production.

Decide Safety Stock

In fact, the materials can't be used 100%. It's inevitable to produce less quality products or deteriorations. Assume the material utilization is γ, the safety stock is necessary, and it is decided by the unstable demand, stockout costs and holding costs. The production should be satisfied $Q_p = Q^*/\gamma$, so as to meet the supply Q^*. Then the total supply will be $Q^* + SS$, that is, $\gamma Q_p + SS$, when the safety stock is considered.

(e) when $\gamma Q_p + SS \geq r$, the expect profit is

$$\sum_{r=0}^{\gamma Q_p + SS} \left[kr - h\left(Q_p + SS - r\right)\right] P(r) \tag{35.13}$$

(f) when $r > \gamma Q_p + SS$, the expect profit is

$$\sum_{r=\gamma Q_p + SS + 1}^{\infty} k\left(\gamma Q_p + SS\right) P(r) \tag{35.14}$$

The cost about material utilization is: $h(1-\gamma)Q_p$

The profit can be expressed as

$$R\left[Q_p, SS\right] = kE(r) - \left\{ \sum_{r=0}^{\gamma Q_p + SS} h\left[\gamma Q_p + SS - r\right] P(r) + \sum_{r=\gamma Q_p + SS + 1}^{\infty} k\left[r - \gamma Q_p - SS\right] P(r) + h(1 - \gamma) Q_p + sQ_p \right\} \tag{35.15}$$

To mark the cost as C (Q_p, SS)

$$C(Q_p, SS) = \sum_{r=0}^{\gamma Q_p + SS} h[\gamma Q_p + SS - r]P(r) + sQ_p + h(1-\gamma)Q_p \tag{35.16}$$

So, we can conclude

$$R(Q_p, SS) = SE(r) - C(Q_p, SS) \tag{35.17}$$

From those, the profit and the cost can get the optimal solution meanwhile. Consider minimum cost, it should be subjected to

$$C(Q_p, SS) \leq C(Q_p, SS + 1) \tag{35.18}$$

$$C(Q_p, SS) \leq C(Q_p, SS - 1) \tag{35.19}$$

So, safety stock and optimal production Q_p should be subjected to (35.21)

$$\sum_{r=0}^{\gamma Q_p + SS - 1} P(r) \leq \frac{k}{k+h} \leq \sum_{r=0}^{\gamma Q_p + SS} P(r) \tag{35.20}$$

As a result, we can obtain

$$\begin{cases} \sum_{r=0}^{Q^*-1} P(r) \leq \frac{k-s}{k+h} \leq \sum_{r=0}^{Q^*} P(r) \\ \sum_{r=0}^{\gamma Q_p + SS - 1} P(r) \leq \frac{k}{k+h} \leq \sum_{r=0}^{\gamma Q_p + SS} P(r) \\ Q_p = \frac{Q^*}{\gamma} \end{cases} \tag{35.21}$$

Case Study

X is a large pharmaceutical enterprise with advanced production equipments and management systems. It has professional processing to produce excellent quality medicines. But inventory management system is traditional, and inventory cost is high for a long time. Finally, we reduce the inventory cost by the discrete inventory model of ERP in unstable demand, and enhance the enterprise competitiveness.

Take X enterprise' Amoxicillin Capsules for example. The average cost per unit is 230 yuan, the price per unit is 1,000 yuan, the inventory cost per unit in a month is 5 yuan, the capsule deadline is 2 years, so depreciation per unit in a month is 41.7 yuan.

Take the inventory data in 2010 for research. It is shown in Table 35.1.

Table 35.1 Amoxicillin capsules inventory data in 2010

Month	Demand	Planned production	Production	Utilization (%)	Initial stock	Receipts	Library
1	1,265	1,300	1,248	96	705	1,248	1,265
2	1,092	1,200	1,140	95	688	1,140	1,092
3	1,276	1,200	1,116	93	736	1,116	1,276
4	1,338	1,300	1,222	94	576	1,222	1,338
5	1,396	1,400	1,300	95	460	1,330	1,396
6	1,403	1,500	1,455	97	394	1,455	1,403
7	1,491	1,500	1,440	96	446	1,440	1,491
8	1,574	1,600	1,552	97	395	1,552	1,574
9	1,687	1,700	1,666	98	373	1,666	1,687
10	1,651	1,800	1,728	96	352	1,728	1,651
11	1,589	1,800	1,746	97	429	1,746	1,589
12	1,518	1,700	1,632	96	586	1,632	1,518

Take the 100 as the group range, the demand probability is shown in Table 35.2 and the material utilization is shown in Table 35.3.

Calculating:

1. the cost per unit: c = 230 yuan
2. the sale per unit: k = 1,000 yuan
3. the holding cost per unit and mouth: h = 5 + 41.7 = 46.7 yuan
4. the expect utilization of material:

$$\begin{aligned}\gamma &= 93\% \times 0.08 + 94\% \times 0.08 + 95\% \times 0.17 + 96\% \times 0.34 + 97\% \times 0.25 \\ &\quad + 98\% \times 0.08 \\ &= 96\%\end{aligned}$$

5. the optimal planned products without utilization is:

$$\frac{k - s}{k + h} = \frac{1000 - 230}{1000 + 46.7} = 0.74$$

$$\sum_{r=0}^{1450} P(r) = 0.08 + 0 + 0.17 + 0.17 + 0.17 = 0.59$$

$$\sum_{r=0}^{1450} P(r) \leq \frac{k - s}{k + h} \leq \sum_{r=0}^{1550} P(r)$$

$$Q* = 1550,$$

6. the optimal planned products with utilization is:

$$Q = \frac{Q^*}{\gamma} = \frac{1550}{0.96} = 1615$$

Table 35.2 Probability distribution

Group range	Middle	Count	Probability
1,000–1,100	1,050	1	0.08
1,100–1,200	1,150	0	0.00
1,200–1,300	1,250	2	0.17
1,300–1,400	1,350	2	0.17
1,400–1,500	1,450	2	0.17
1,500–1,600	1,550	3	0.24
1,600–1,700	1,650	2	0.17
In total	/	12	1.00

Table 35.3 Material utilization

Utilization (%)	Count	Probability
93	1	0.08
94	1	0.08
95	2	0.17
96	4	0.33
97	3	0.25
98	1	0.08

7. the safety stock is:

$$\frac{\mathrm{k}}{\mathrm{k}+\mathrm{h}} = \frac{1000}{1000+46.4} = 0.96$$

$$\sum_{\mathrm{r}=0}^{1550} \mathrm{P(r)} = 0.08 + 0.08 + 0.17 + 0.33 + 0.25 = 0.92$$

$$\sum_{\mathrm{r}=0}^{1650} \mathrm{P(r)} = 1$$

$$\sum_{\mathrm{r}=0}^{\gamma Q_{\mathrm{p}}+SS-100} \mathrm{P(r)} \le \frac{\mathrm{k}}{\mathrm{k}+\mathrm{h}} \le \sum_{\mathrm{r}=0}^{\gamma Q_{\mathrm{p}}+SS} \mathrm{P(r)}$$

So, $\gamma Q_{\mathrm{p}} + SS = 1{,}550 + SS = 1{,}650$, that is $SS = 100$.

Take those data for application in first half year of 2011, the original inventory data is illustrated in Table 35.4, and updating inventory data by ERP model is shown in Table 35.5.

The planned production is calculated by (1,615 + safety stock – initial stock)/utilization;

Supply is planned production times utilization;

The initial stock is equal to last period ending stock;

Table 35.4 Original inventory data

Mouth	Demand	Plan production	Production	Utilization (%)	Initial stock	Receipts	Library
1	1,463	1,600	1,536	96	700	1,536	1,463
2	1,246	1,500	1,455	95	773	1,455	1,246
3	1,483	1,400	1,358	93	982	1,358	1,483
4	1,567	1,400	1,372	94	857	1,372	1,567
5	1,676	1,500	1,470	95	662	1,470	1,676
6	1,729	1,700	1,649	97	456	1,649	1,729

Table 35.5 Updated inventory data

Mouth	Demand	Plan production	Utilization (%)	Supply	Safety stock	Initial stock	Optimal cost	Original cost
1	1,463	1,057	96	1,015	100	700	11,768	36,099
2	1,246	1,524	97	1,478	100	252	22,603	45,859
3	1,483	1,282	97	1,244	100	484	11,442	40,022
4	1,567	1,531	98	1,501	100	245	8,359	30,915
5	1,676	1,600	98	1,568	100	179	3,316	21,295
6	1,729	1,713	97	1,661	100	71	140	17,559

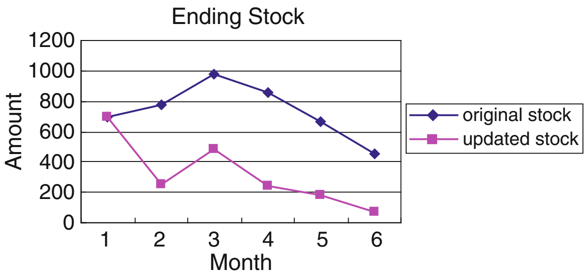


Fig. 35.1 Comparison of two inventory levels

Inventory cost is the ending stock multiply inventory cost per unit, that is h; The two different inventory level distributions are compared in Figs. 35.1 and 35.2.

From those comparisons, it is clear that the updating cost by ERP inventory model is 57,628 yuan, which is much less than original cost by 134,121 yuan and superior to original inventory control.

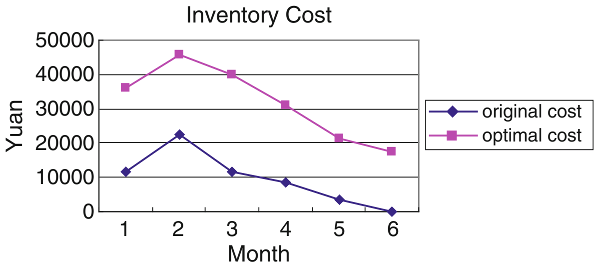


Fig. 35.2 Comparison of two inventory costs

Conclusion

The supply is determined by demand or orders in ERP inventory management, so the supply can't be too large or too small in order to avoid huge cost and stockout. We must make optimal inventory control model to meet the market with a low cost.

At last, the ERP inventory control model, which is based on the unstable demand, considers the factors of the production cost and material utilization and applies probability theory and mathematical statistics to decide the optimal supply and safety stock, is an effective way to reduce the inventory cost. This model can not only reduce the inventory cost but also avoid the risk of stockout and ensure the supply. What's more, it can improve the customers' service. In practice, it has been proved that the model can reduce the inventory account and improve the enterprise management. It has become a trend to put ERP system into practice in modern business.

References

Axater S (2007) Inventory control, 2nd edn. Tsinghua University Press, Beijing, pp 1–2

Brown RG (1967) Decision rules for inventory management. Holt, Rinehart and Winston, New York, pp 10–12

Chikán A (ed) (1990) Inventory models. Kluwer Academic, Boston, pp 104–107

Guo-fang Song, Jie Yu, Er-shi Qi (2002) The research about inventory control based MRPII. Chin J Mech Eng 13(24):2141–2143 (In Chinese)

Hax A, Canda D (1984) Production and inventory management. Prentice-Hall, Englewood Cliffs, p 47

Hui-qiang Yu (2004) The strategy research on inventory control in supply chain. Ph.D. dissertation, Chongqing University, Chongqing (In Chinese)

Jiang Wu, Jin-wang Huang, Li-ping Fu (2010) Professional English for logistics. China Machine Press, Beijing, pp 54–56

Muller M (2003) Essentials of inventory management. AMACOM, New York, p 56
Porteus EL (2002) Stochastic inventory theory. Stanford University Press, Stanford, p 178
Sherbrtooke CC (2004) Optimal inventory modeling of systems, 2nd edn. Kluwer Academic, Boston, p 98
Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling, 3rd edn. Wiley, New York, p 67
Xiao-jun Wang (2005) Research on component technology and inventory management in ERP system. Ph.D. dissertation, Huazhong University of Science and Technology, Wuhan (In Chinese)
Xiao-zhuang Zhou (2009) Research on JIT inventory control in manufacturing. Ph.D. dissertation, Tongji University, Shanghai (In Chinese)
Yue Gu, Li-li Zhang, Zhi-li Zhang (2008) Professional English for logistics. Shanghai Jiaotong University Press, Shanghai, p 71
Zipkin PH (2000) Foundations of inventory management. McGraw-Hill, Singapore, p 98

Chapter 36
Helix of Logistics

Dian-jun Fang and Klaus Spicher

Abstract The paper de scribes the evolution of logistics and supply chain management in different business environments and identifies the structure of the driving forces. A cyclic development structure along technology improvements will be identified and illustrated as a 3D development cycle ("Helix of Logistics"). The results are based on several research projects which are supported by the German Federal Government.

Keywords SCM • Logistics • Helix of logistics • Development cycle of logistics

Foreword

In business literature the term "Helix" was introduced by (Fine 1998) in 1996 while analyzing Value Chain Dynamics and Rapid Response Capabilities of industries. In spite of utilizing the same visualization model (term) there are no conceptual similarities compared to the authors' findings presented in this paper.

D.-j. Fang (✉)
Department of Mechanical Engineering, CDHK of Tongji-University, Shanghai, China
e-mail: fang.dianjun@cdhk.tongji.edu.cn

K. Spicher
Department of Enterprise Logistics, Fraunhofer Institute for Material Flow and Logistics, Dortmund, Germany

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_36,

Introduction

The "Faces" of Logistics

Depending on the specific perspective, the role of logistics can be seen in different ways. For example, a logistics service provider (LSP) considers logistics as a "product" while a producer potentially considers logistics as a "cost cutting tool" or "competitive factor". Moreover, an economist may regard logistics as a location attribute as part of a certain infrastructure. Logistics can even become an issue of added value between traders and producers. The following Fig. 36.1 illustrates the different faces of logistics.

According to this view, the meaning of logistical competence varies for the involved players. In this paper, production oriented companies are put in the focus so that the logistical competence is defined as the "ability to organize the business processes efficiently in line with logistical principles".

Logistics and Supply Chain Management as Part of the Business Structure

In general, the role of logistics and supply chain management within a company is determined by specific product and market requirements. Therefore, the logistical and SCM competence differs between industries. The pharmaceutical, automotive and FMCG industry ("fast moving consumer goods") considered logistics as an important discipline the first. Nowadays, these industries are ahead in their logistical competence and serve as best practices for other industries. These industries are following and adapting logistical principles. As a consequence, each industry has its own logistical competence profile. Figure 36.2 illustrates the development graphically.

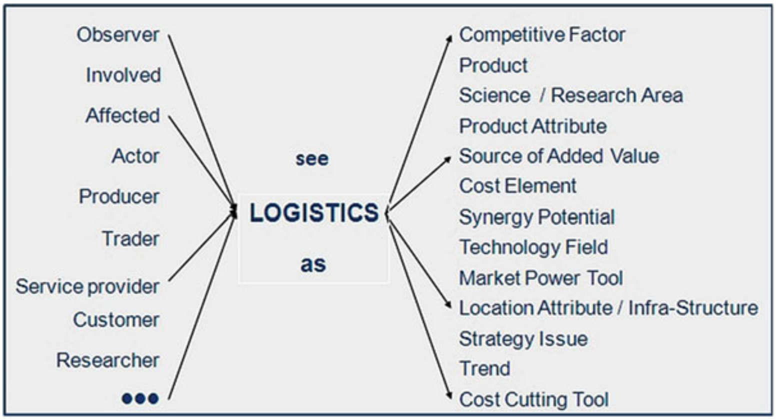


Fig. 36.1 The faces of logistics

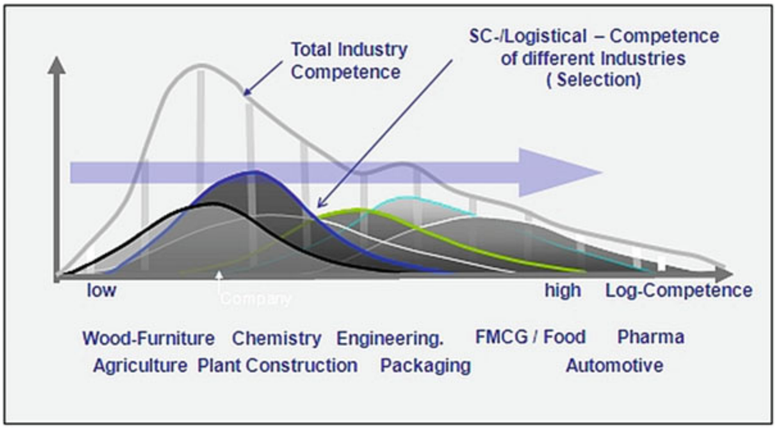


Fig. 36.2 Logistical competence of industries

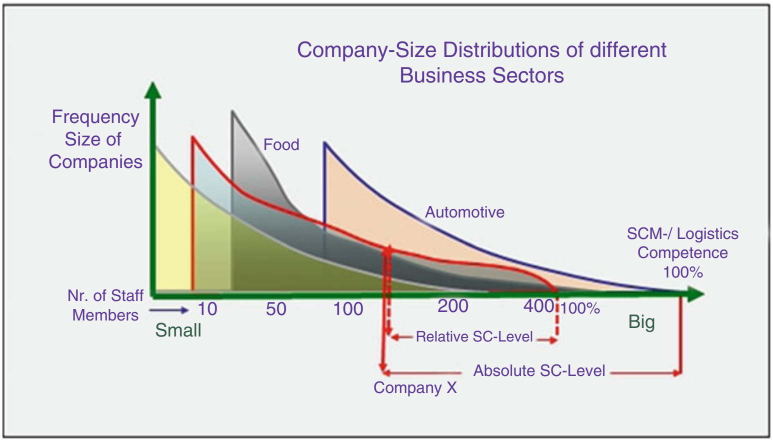


Fig. 36.3 Logistical- and SCM-competence of companies

In Fig. 36.2, each "distribution" represents an industry, consisting of all companies belonging to this industry. The companies of each industry are sorted according to their logistical competence. So, the high-end of each "distribution" represents the logistically most competent companies. The shapes of the "distributions" and the location along the competence axis differ due to product-related logistical requirements and regional economy structure.

As a matter of fact, the size of company also determines the logistical competence of a company. Due to the organizational structure and capacity restrictions (e.g. infrastructure and human resources), small and medium sized companies are limited in their attempts to drive logistical progress forward. The influence of a company's size in terms of employees on the logistical competence can be seen in Fig. 36.3.

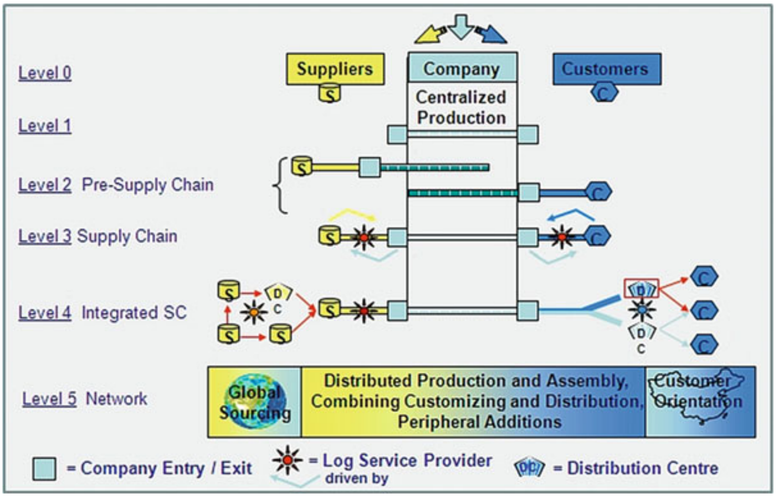


Fig. 36.4 Levels of logistics-/supply chain competence

Levels of Logistics and Supply Chain Competence

The logistics and supply chain competence of a company can be measured according to a five level approach. Companies that are not considering logistics as a relevant issue at all are part of Level 0. Level 1 describes companies that have a basic understanding of logistics and are at an initial phase of implementing logistical principles. Companies with some logistical know-how and standard cooperations with suppliers and customers are considered at level 2 of the competence scale. Level 3 describes companies that have supplier and customer cooperations supported by logistics service providers. Companies operating integrated supply networks with logistics service providers and logistical principles like LSP-based delivery services or vendor-managed inventory concepts are considered at level 4. Finally, production networks with integrated sourcing, planning, production and distribution are classified as level 5. Following Fig. 36.4 illustrates the levels of logistics and supply chain competence graphically.

In order to further classify the level of logistical competence, the authors have developed a methodology to classify small and medium sized production companies up to 400 employees according to their “Supply Chain Fitness” (Spicher 2009). Based on this concept a methodology for measuring of the ‘Supply Chain Fitness’ of small and medium sized production companies was developed by Koch (2010).

Why Did Logistics Become a Long-Term Trend? – The Helix Cycle of Logistics

The helix (spiral) has widely been used for the visualization of business development. In this article, the authors use the helix model to describe the development of logistics in a 30-year period of business trends. This "Helix of Logistics", shown in Fig. 36.5, provides a rough understanding of logistics as a business trend.

We start the description of the development of logistics as a business trend in the year 1970 (a company in the centre of the helix). Following the arrows in clockwise direction, we find a sequence of business trends influenced the development of logistics. First organizational experiments and management principles emerged in the early 1970s. Some examples for it are the Harzburger model and the Management by Objectives (MbO). Those were followed by the development of direct costing. Throughout the 1970s, quantitative methods (Operations Research – OR) became supportive tools for managerial decisions. The quality issue (also known as the "Japanese challenge") was mastered by further managerial activities.

In the middle of the 1970s traditional, departmental rationalization did not offer significant potentials any more. New rationalization conceptions were needed urgently. "In-House Logistics" was the answer. Savings and synergies could be realized by integrating business activities (processes).

By the end of the 1970s, the first computer integrated system like Computer Aided Design (CAD) or Computer Integrated Manufacturing (CIM) appeared. They opened the way for further system developments. In the following, Production

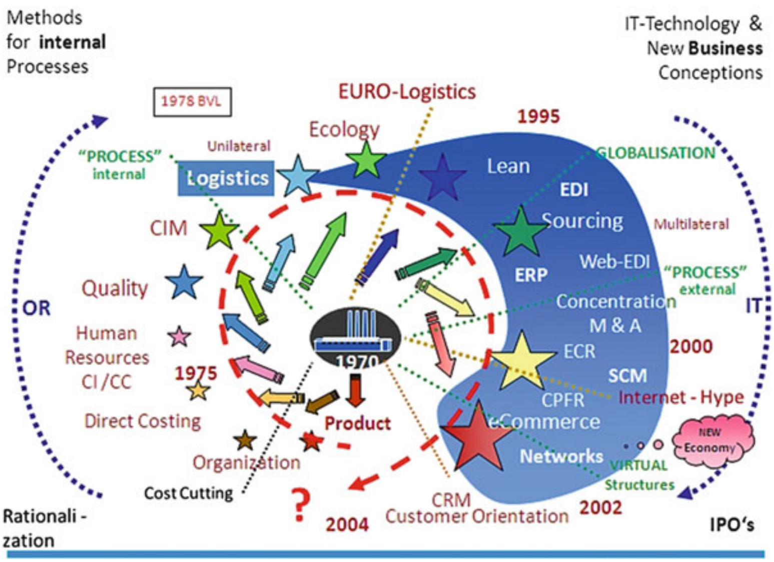


Fig. 36.5 30 years business-trends – development of logistics

Planning Systems (PPS) and MRP-Systems (Material Requirement Planning and Manufacturing Resource Planning) collected high attention.

Taking a look at the development of information technologies, the Time Sharing Option (TSO) concept by IBM represented the standard of decentralized computing. The first ancestors of modern Personal Computers (PCs), Commodore, Amiga and Atari appeared on the market. Office computing in Germany was dominated by Midrange Computing (e.g. Nixdorf, Philips, Adler-Triumpf). World-wide remote computing e.g. was offered by Honeywell-Bull timesharing. In Germany, comparable progress in information technology was prevented by the post monopoly.

Before what we now know as logistics was called "Logistics", the basic idea was called "cross departmental integration approaches". This concept offered new synergy potentials: The automotive industry forced their suppliers to implement more efficient processes (e.g. telefax communication). The FMCG-industry (especially food companies) started the development of operational in-house logistics. It is interesting to mention that the big trade companies did not even think about logistics at that time. Reducing costs was simply achieved by using their huge market power to put high pressure on purchasing price – as long as suppliers could afford reducing the prices. This gave trade companies a rather easy living. The big trade companies focused their effort on extending their outlet network and testing shop concept improvements. At that time, the customizing of products became an issue.

The foundation of the German Logistics Society (BVL) in 1978 finally represents the establishment of "Logistics" as an integral part of business and research activities. Thus, this event marks the beginning of the blue cloud in Fig. 36.5 representing the growing impact of logistics.

The period of time from year 1980 to about 2000 can be seen as a first "Helix Cycle" of logistics. A helix cycle is defined as a sequence of business trends along technology progress, business needs and supportive scientific methods. Diminishing returns will cap the helix development. Therefore the capped (convergent) helix structure – represented by "Trochus stellatus" – serves as a visualization instrument. Each "turn" represents one development cycle.

The key words displayed in the four corners around the "Helix of Logistics" summarize the development:

- **Rationalization**:
  The early development was mostly affected by the rationalization trend. Ideas and concepts were based on Tayloristic approaches
- **Methods for supporting internal processes**:
  The following development was highly influenced by the emergence of operations research methods and business process view (Olhager 2010)
- **IT-technology & new virtual (internet-based) business concepts:**
  The use of IT and internet based business concepts led to new logistics concepts
- **IPO's (Initial Public Offerings):**
  The development in the new millennium based on apparent new technology product opportunities ("New Economy")

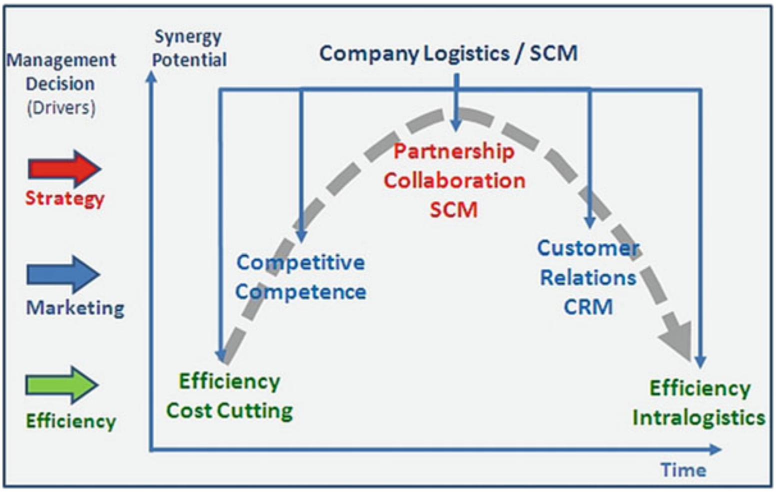


Fig. 36.6 Development cycle of logistics/SCM

Over time the role of logistics in business changed considerably. Starting in the late 1970s as a rationalization approach, logistics became a competitive factor (Fig. 36.6). In the next step of development the role of logistics turned into a strategic issue and supported the supply chain being the basis for exploiting additional synergies. One reason for making logistics an important business trend is given by the fact that marketing successfully utilized logistics as a competitive issue. All major business trends are based on marketing. In the late 1980s one marketing strategy was the offering of incentives to support sales. At that time ecology based on eco-balances became a short term dominating marketing issue. But delivery time and distribution services offered a better and a more simple USP. Finally, JiT (Just-in-Time) and 24 h services or even shorter became dominant and thus time-oriented logistics became a major trend. The figure below visualizes the development cycle of logistics and supply chain management (Tan 2001), (Kuhn and Hellingrath 2002).

After the first helix cycle of logistics (covering the period from the 1970s until the beginning of the millennium), the second helix cycle of logistics starts around the year 2005. Following Fig. 36.7 visualizes the second helix cycle graphically.

The red dotted arrow indicates recent developments in the second helix cycle until now. The comparison between the first and second helix cycle reveals significant similarities. The key similarities are:

– The first helix cycle (see Fig. 36.5) started integrating and synchronizing processes inside the companies (e.g. in-house logistics). Quantitative methods (e.g. OR) were used to improve and optimize logistics, whereas data availability and quality was a problem. The traditional rationalization potentials seemed to be exploited. Quality and computer technologies were the dominating issues and logistics became the new key to rationalization. Now, in the second cycle,

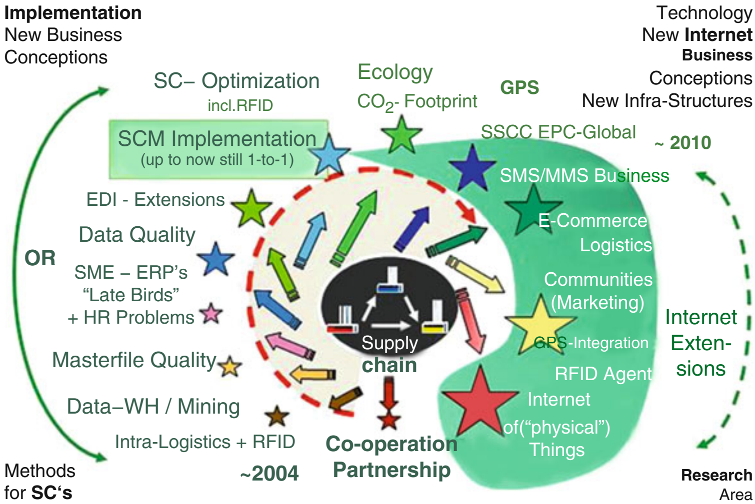


Fig. 36.7 Second helix cycle of logistics/SCM

powerful IT-structures have been implemented and the lack of data quality is getting obvious. For instance, ERP-systems tend to produce "junk results" because of lacking consistent data maintenance, organizational changes and market requirements. Again, companies are facing a data problem now.

– In the first cycle new organizational structures (e.g. matrix or divisional organizations, profit- and cost centers) have been developed. Now, these company structures have to be reorganized due to developments like outsourcing or virtual company structures (Williamson 2008). Moreover, companies – especially in western countries – are facing relevant problems at the recruitment of qualified staff at the same point in the cycle time. So, corporate identity again is problem initiating HR-programs for developing and ensuring expertise – at least in western countries
– In the field of In-House logistics – which is now called intra-logistics – OR-methods are used again for optimization problems. The applications of basic methods that are integrated in most ERP-Systems are no longer sufficient. While OR-methods for optimizing single supply chains are under development there is a lack of adequate methods for supply nets. Simulation methods are the key tool for assessing supply net operations.
– Just at the same point in cycle-time, ecology became an issue in the second helix cycle again. While eco-balancing was discussed in cycle one, CO2-footprints and global warming are in focus now.
– After an incubation time of 15 years or more, RFID-Solutions now have become operational. Open-ID-Centers present many options for improvements for trade (e.g. GS1) and production companies (Schmitt et al. 2007).
– In the past, most SC-cooperations were set up as 1–1 relations. At the moment, cooperations are being based on 1–n relations. But data integration still suffers

from managerial hesitations. Therefore, effective n–n relations seem to be unrealistic (at least as long as shareholder value drives business).

– The implementation of in-house logistics (cycle 1) now compares with SCM/SC-Net cooperation. Following the same development, this process is swapping from the "early birds" (trend leaders) to the "followers" (SME's). Many technical, organizational and relational preconditions (like CRM) have been installed and paved the way for tighter co-operations. The "early birds" are starting optimization and tuning their systems, while the "followers" will apply standard methods and procedures.

Obviously, the basic problems behind logistics and supply chain management in general do not change over time. The differences are based on the fact that now we are discussing supply chains with a much higher level of (IT-) technology instead of individual companies. This insight enables the development of "future scenarios".

Future of Logistical Industry Profiles

From an industry point of view there are two structured approaches for forecasting technology-based trends:

1. There are "lead industries" that apply more advance technologies due to product and market requirements which are also relevant for identifying benchmarking candidates
2. The helix-approach allows forecasting solutions based on revolving similar problem structures in the past as the same problems require the same or similar remedies. It is to be noted that in this case the 'rotational' speed of the Helix has to be considered (Fig. 36.8).

Figure 36.8 demonstrates the idea of leading industries. Each coloured sector represents the logistical/SCM competence of all companies belonging to the sector. For instance FMCG and automotive represent the leading industries for the electronics sector.

Future of Internet

Key future trend will be **"Internet of ("physical") Things" (IoT)**. Main idea is to create self-organizing material flow. Moreover, the Internet of Things will be the driver for multi-dimensional communication processes and has a high potential for becoming an important part of business strategies. In connection with advanced RFID-Technology IoT offers great business chances.

As SC-Implementations require a new level of scientific methods, **research** in involved divisions is required and its importance for practical solution increases.

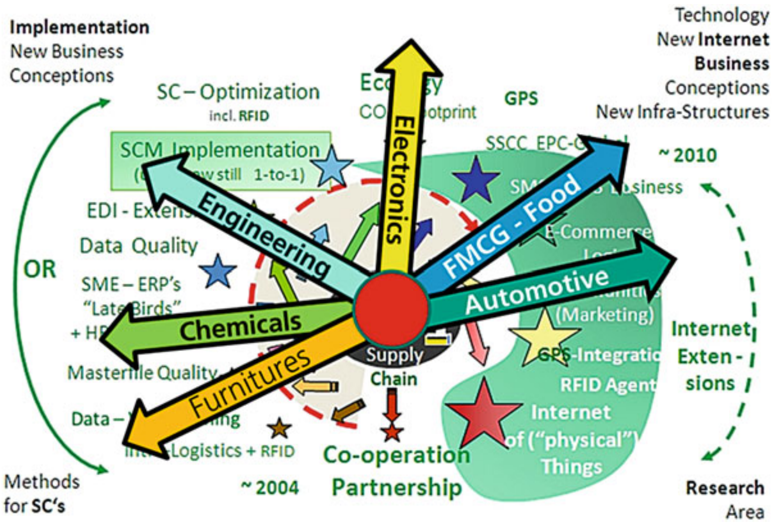


Fig. 36.8 Business-future of logistics

Systems that are able to adapt dynamically will set a future standard. Therefore it might be necessary to develop new simulation programming languages for supply net simulations. In current business a trend towards advanced optimization and simulation methodologies can be extinguished.

There is a high correlation between the current publicity of IoT and the correspondent occurrences during the new economy era. Based on the aforementioned the authors forecast a new drive for the next product generation relying on IoT technology that will lead to a second "New Economy" as maturity of IoT-related products increases. The learning that can be extracted from the new economy experience (in 2000/2001) tend to be limited.

The blue cloud of helix cycle 1 states "**lean, EDI and Sourcing**" as development principles. In future the LEAN-Approach will be applied to the management of supply chains (Baudin 2004; Hellingrath et al. 2007). The so called "ubiquitous computing" (as part of the Internet of Things) might represent the "EDI" in B2C-business, linking consumers with all kinds of companies.

While **marketing** tries to identify real time **consumer behaviour**, the future of technology enables to link companies with home equipment. An example could be an RFID-chip in the refrigerator that selects the suppliers and orders missing products.

The structures and social impact of Internet 3.0 goes beyond of the scope of this paper. Therefore this aspect is omitted.

Summary

Logistics and of course SCM can be understood in various ways. The paper presents an overview about different perceptions and describes basic intuitive relations between logistical competence and company size as well as affiliation to industries. The relevant business trends over the last 30 years then are analyzed and the drivers are scrutinized. The question why logistics and SCM became a mega trends are answered. The result of analysis provides some insight in the structures of business development, which can be used for general business trend forecasting.

References

Baudin M (2004) Lean logistics – The nuts and bolts of delivering material and goods. Productivity Press, New York

Fine CH (1998) Clockspeed: winning industry control in the age of temporary advantages. Basic Books, Auflage

Hellingrath B et al (2007) Logistik in der Automobilindustrie – Innovatives Supply Chain Management für wettbewerbsfähig Zulieferstrukturen. Springer, Berlin/Heidelberg

Koch D (2010) Supply chain fitness. VDM, Saarbrücken

Kuhn A, Hellingrath B (2002) Supply chain management – Optimierte Zusammenarbeit in der Wertschöpfungskette. Springer, Berlin/Heidelberg/New York

Olhager J (2010) The role of the customer order decoupling point in production and supply chain management. Comput Ind 61:863–868

Schmitt P, Thiesse F, Fleisch E (2007) Adoption and diffusion of RFID technology in the automotive industry. In: 15th European Conference on Information Systems (ECIS 2007), E-DIGIT by SIGADIT, St.Gallen, Switzerland

Spicher K (2009) Supply chain fitness, Research Project, Lo-NET-Co-Institute, Business and Information Technology School, Iserlohn, unpublished

Tan KC (2001) A framework of supply chain management literature. Eur J Purch Supply Manag 7:39–48

Williamson OE (2008) Outsourcing: transaction cost economics and supply chain management. J Supply Chain Manag 44:5–16

Chapter 37
Research on Risk Identification and Control of Medicine Supply Chain

Hong-qi Wang, Xiang Gao, and Shan-shan Wang

Abstract With the deepening of medical and health system reform in China, it is necessary to strengthen risk management of medicine supply chain so as to improve the medicine distribution level and cut down the medicine price, and increasingly great concern has been aroused by government, pharmaceutical industry and society. In light of the complexity and uncertainty of medicine market, this paper makes analysis on the composition of medicine supply chain and its risks, constructs a risk identification hierarchy structure of medicine supply chain, and then designs the risk control model. This paper aims at providing support for medicine supply chain to reduce the risks and increase the operational level.

Keywords Medicine supply chain • Risk identification • Risk control

Introduction

In the tangled warfare of Chinese medical market, there are intensified competitions among pharmaceutical companies which lead to the abnormal competitive costs shifting to the consumers, therefore, how to optimize the medicine circulation and further reduce medicine price have become the focus both for government and for pharmaceutical industry. In the pharmaceutical industrial competition which has transformed from the single company or group competition to the alliance

Sponsors: National Natural Science Fund (71173062), Humanity and Social Science Project of Ministry of Education (10YJC630246), Natural Science Fund of Heilongjiang Province (QC2011C063), Scientific and Technological Project of Heilongjiang Province (GZ11D209), Postdoctoral Science-research Developmental Fund of Heilongjiang Province (LBH-Q10063)

H.-q. Wang (✉) • X. Gao • S.-s. Wang
School of Management, Harbin University of Science &Technology, Harbin, People's Republic of China
e-mail: wanghongqi36@126.com; wssangel@sina.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_37, © Springer-Verlag Berlin Heidelberg 2013

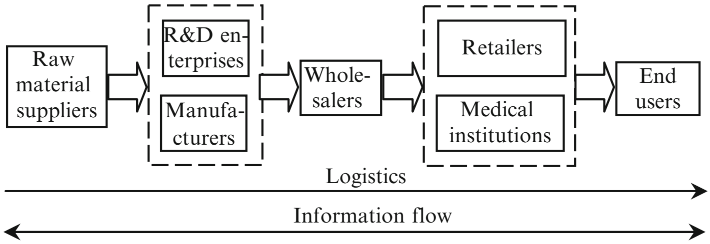


Fig. 37.1 The composition of medicine supply chain

competition, a medicine supply chain of high efficiency and low cost is playing an increasingly important role. Due to the special function of medicine compared with other commodities which is featured by curing the sickness and saving the lives, there are higher demands for the supply of medical raw materials as well as the medicine preservation and timely medicine supply; meanwhile, the great complexity and uncertainty of medical market bring high risks to the medicine supply chain. Therefore, to quickly identify the risks of medicine supply chain and effectively control the risks to the lowest level are beneficial to accelerating the medicine circulation, reducing the medicine price and solving the contradictions between medicine supply and demand.

Analysis on the Composition and Risk of Medicine Supply Chain

Medicine supply chain is a complete medicine supply network from the raw materials supply to the medicine sales terminal which is composed of the pharmaceutical companies, related institutions, logistics companies and end users, as shown in Fig. 37.1.

In the medicine supply chain from raw material suppliers to end users, each member accounts for each node of supply chain, in which medicines are generally sold to the end users by hospital or pharmacy. In such operational process, supply chain can't run effectively and smoothly without a modern logistics system, while in the network environment, resource sharing, management decision making and coordinated operation of each node in supply chain can be achieved through information flow, so logistics and information flow are the key factors that influence the stability and performance of supply chain. The operation of medicine supply chain is influenced by a lot of favorable and unfavorable factors, thus the behavior of each body in supply chain, the smoothness of logistics and information flow as well as the uncertainty of market environment commonly cause the medicine supply chain risks namely the interest loss or the possibility of loss compared with the objective.

Learning from the literatures and according to the characteristics of China's pharmaceutical market and the development state of medicine supply chains, medicine supply chain risks can be departed into nine types including R&D, quality, demand, logistics, information, collaboration, policy, law and competition (Shen et al. 2009).

R&D Risk

R&D risk refers to that new medicine can not achieve the expected effect, or fail to be developed so that new medicine is unable to be continuously introduced due to the high investment, high risk and long R&D cycle. New medicine development is a long and complex engineering, so successful development of new medicine will be strongly related to the operational efficiency and performance of the entire medicine supply chain.

Quality Risk

Quality risk is the risk related to the production characterized with low quality or negative medicine effect that bring harm to the human health which is caused by raw materials, manufacturing process, production safety and technical personnel's operational activities.

Demand Risk

Demand risk refers that the medicine fails to meet the demand or there is medicine backlog because of changes in customer demand. Changes in customer demand include periodic fluctuations of part seasonal medicine demand, sharp demand increase or decrease of medicine caused by public emergencies and so on (Shen et al. 2009).

Logistics Risk

Logistics risk means that due to the imperfect logistics and distribution system, or impacts of natural disasters and emergencies, the delivery time, storage time, storage temperature and so on are unable to reach the medicine management standards which result in the medicine damage during storage and transportation, or failure of timely delivery. The specificity of medicine determines its particularity for storage and transportation, and proposes more stringent requirements for medicine logistics and distribution system.

Information Risk

Information risk is the phenomenon of information asymmetry or information distortion because each node in supply chain can not effectively share information in the information bidirectional transmission process from raw material suppliers to end users. From the view of end users, the information risk is information asymmetry which makes the hospital almost determine the medicine needs without understanding the real requirements of patients. From the view of medicine developers and manufacturers, because they are in the front of medicine supply chain and nearly fail to access market information, they can not accurately determine the direction of technology development, adjust product output, arrange the logistics and make market forecast which lead to their inferior positions in the whole supply chain in the aspects of medicine supply capability, cost and so on.

Collaboration Risk

Collaboration risk refers to the incomplete collaboration degree of supply chain members or the vicious competition among members due to credit and information barrier in their resource sharing and interaction process (Faemsl et al. 2010), which result in absence of resource optimal allocation, low operational efficiency and profitability, and furthermore lead to the lack of overall competitive advantage of supply chain.

Policy Risk

Policy risk means that due to the government regulations on pharmaceutical industry by introducing various policies such as medicine price reduction control, new rural cooperation and the construction of two networks which result in the cost rise, profit decrease and necessary adjustment of business for medicine supply chain, thereby affecting the timely and adequate supply of medicine (Shen et al. 2009; Sachs et al. 2008).

Legal Risk

Legal risk refers to that the operating activities in medicine supply chain cannot comply with the law's changes and new requirements, or the contracts of medicine supply chain are unable to be executed because of conflicting with the laws and regulations. To reflect the requirements of the times, government has constantly introduced various laws and regulations to normalize medicine R&D, production and business activities, so the medicine supply chain must grasp and conform to the requirements of laws and regulations in time (Shen et al. 2009).

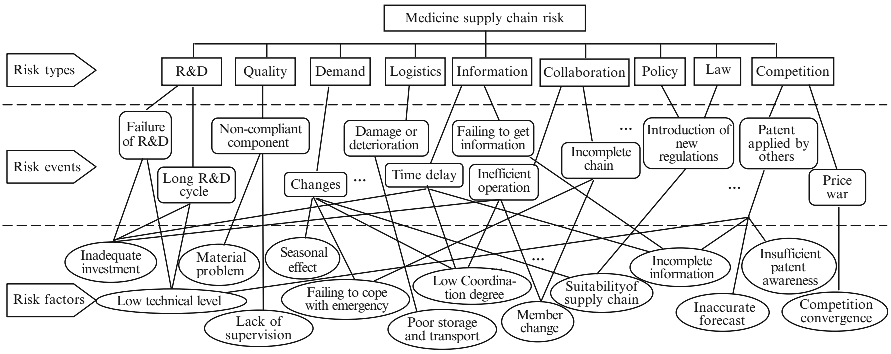


Fig. 37.2 Identification hierarchy structure of medicine supply chain risk

Competition Risk

Competition risk means that one medicine supply chain may face competitive pressures of other similar medicines in price, function and other aspects, and it may compete with several external medicine supply chains.

The Identical Hierarchy Structure of Medicine Supply Chain Risk

By referencing the literatures, the process of identifying medicine supply chain risk is as follows: firstly identify risk events, and then find out various factors that lead to the risk events, finally classify the various types of risk events (Shao and Lin 2010), as shown in Fig. 37.2.

Figure 37.2 shows part of the risk events and risk factors in medicine supply chain, for different types of medicines and their supply chains, the risk events and risk factors are also different. As is shown in Fig. 37.2, the medicine supply chain risk consists of a range of different types of risk events, and various risk factors lead to the risk events; in which a variety of factors may lead to a certain risk event and a risk factor may result in multiple risk events. For example, the inadequate investment may lead to the failure and long cycle of new medicine development which makes the supply chain miss opportunities and operate in poor efficiency. In addition, the not enough investment, inadequate degree of coordination among members and the changes of members are the main factors leading to inefficient operations of supply chain. Therefore, the essence of identifying medicine supply chain risk is to further find out risk factors from different risk events to provide basis for risk control. Because these risk factors are the sources of risk events or losses, they are the basic objects of risk control for medicine supply chain (Shao and Lin 2010).

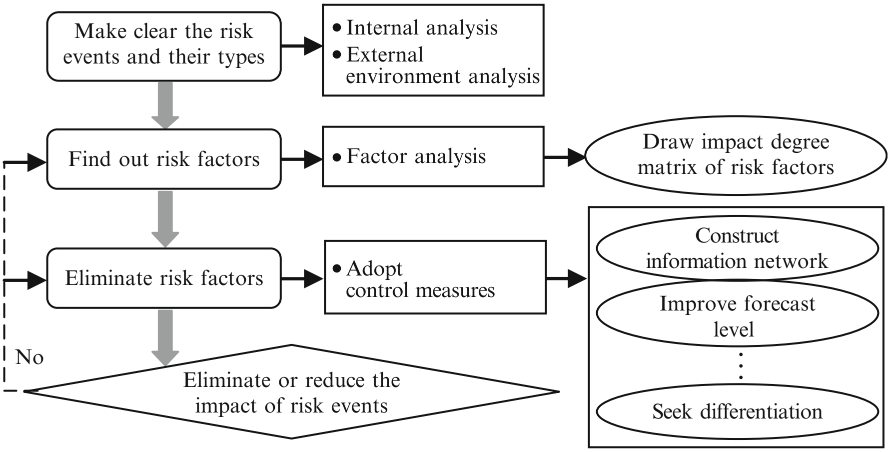


Fig. 37.3 The risk control model of medicine supply chain

Risk Control Model and Measures of Medicine Supply Chain

Risk Control Model of Medicine Supply Chain

The medicine supply chain risk control is to adopt control measures to eliminate risk factors after finding out risk factors, thus the risk can be reduced. The risk control model of medicine supply chain is shown in Fig. 37.3.

After analyzing internal and external environment and conditions of medicine supply chain and making clear the risk events, there is need to make a further factor analysis to identify risk factors, draw an impact degree matrix of risk factors to understand risk factors' impact degree on risk events, take some control measures to eliminate or reduce the impact of risk factors, and ultimately achieve the goal of eliminating risk or reducing the probability of risk events.

Impact Degree Matrix of Medicine Supply Chain Risk Factors

After finding out the risk factors, the impact degree matrix of risk factors should be drawn so as to grasp the key factors, as shown in Table 37.1.

In Table 37.1, the impact degree values for all risk factors that belong to a same risk event sum to 100, and a larger value of a single risk factor's influence on the risk event indicates that the factor has a greater impact on the risk event which should be regarded as the focus of risk control.

Table 37.1 Impact degree matrix of risk factors

Impact degree / Event — Factor	Risk event 1	Risk event 2	Risk event 3	...	Risk event *m*
Risk factor 1	60		80		30
Risk factor 2		100			50
⋮			20		
Risk factor *n*	40				20

Control Measures of Medicine Supply Chain Risk

According to the general characteristics of the medicine supply chain, risk control measures can be taken as flows, in which what should be focused on are quality risk, information risk and collaboration risk.

1. *R&D risk control:* The R&D companies in medicine supply chain need long-term and sustained investments, if possible, they should apply for the patent when there is a more satisfactory result in medicine effect or production process. In this process, the patent map analysis tools can be used to formulate R&D strategies in order to determine the time and objective of R&D, resource distribution structure as well as specific development, application and implementation tactics of patent (Wang and Tian 2010).
2. *Quality risk control:* As mentioned earlier, quality risk is related to the production, so not only the production process should be managed, but also the source in the front of supply chain should be controlled, and the timely feedback in sales process is necessary. The main points of quality risk control of supply chain are shown in Fig. 37.4.
   In the link of raw material purchase, the supplied raw materials must get approval of use in order to control the medicine quality from source. Besides, the incoming raw materials should be strictly examined according to the standards and requirements. In the process of medicine production, pharmaceutical machinery, medical formula and manufacturing process should be strictly in accordance with GMP standard, and all production and inspection records should be arranged I n file to ensure the pharmaceutical manufacturing process error-free and pollution-free. If conditions permit, pharmaceutical production monitoring system should be established, thereby increasing off-site supervision capability. In the sales link, the supervision system and medicine recall system should be built up to reply to hidden dangers and undesirable reactions.
3. *Demand risk control:* Medicine supply chain must strengthen the customer relationship management and seriously seek the patients' needs and feedback

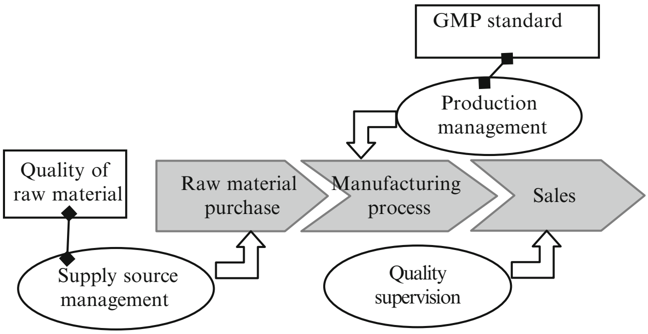


Fig. 37.4 The main points of quality risk control of medicine supply chain

information; simultaneously medicine distributors may also respond to market demands timely by establishing flexible stock.

4. *Logistics risk control:* Logistics risk should be controlled from two ways including quality and speed.

   ① Guarantee the logistics quality. For pharmaceutical companies, sellers and other medicine business institutions, the medicine circulation including medicine purchase, warehouse-in inspection, storage, sales and service must be in strict management according to GSP standard, so that the hardware, software and business practices of medicine business units can meet the requirements to ensure the medicine quality in circulation. Logistics enterprises should establish the assessment and prevention system on the uncertainty impact of natural environment so as to prevent or reduce disruption of logistics tasks caused by flooding, fires and other natural disasters.

   ② Improve the speed of logistics services. The bar code technology can be used to improve logistics speed. When a medicine supply chain's transportation, packaging, handling and other logistics services are executed by a number of logistics service providers, in order to avoid the risk transmission among logistics enterprises, close cooperation and synergistic development among the logistics enterprises should be maintained (Li et al. 2010).

5. *Information risk control:* Information risk can be prevented from the following three aspects.

   ① The status of hospital in presentation of patients' demands must be changed, and hospital should strengthen exchanges and communications with patients by utilizing their professional advantages thus establishing a good relationship between health care staff and patients, understanding the needs of patients, establishing patients' files and feeding back information to the upstream businesses in medicine supply chain (Jiang et al. 2008).

   ② For pharmacies, in the course of medicine sales, information on medicine sales should be arranged, analyzed, and forecasted in order to provide basis for pharmaceutical production and inventory decision.

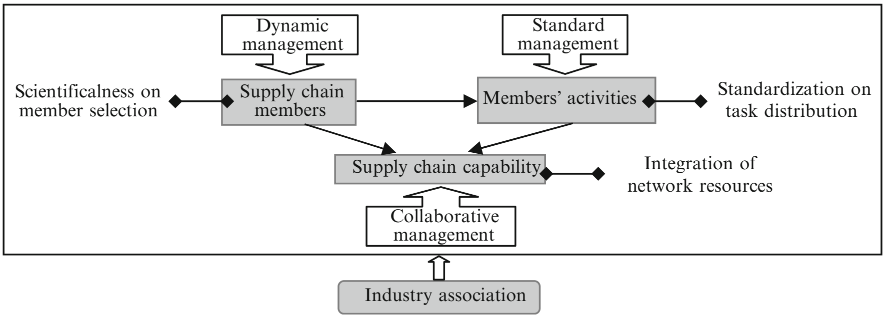


Fig. 37.5 The collaboration risk management focus of medicine supply chain

③ An information system of supply chain ought to be established both for each member and for the network of supply chain. For pharmaceutical companies, ordering and inventory systems for hospitals and medicine distributors should be set up so as to learn sales information and guide the replenishment and sales. For the logistics system, logistics and distribution system should be perfected to speed up the medicine circulation speed and to reduce error rate. For hospitals, the establishment of information management system and the use of bar code technology for managing medicine incoming and outgoing inventory will help constructing new upstream and downstream relationships so that the needs of patients and medicine storage state can be rapidly grasped (Chen and Chen 2009). For the entire medicine supply chain, the use of information technology can enhance supply chain network management level, thus contributing to the optimization of resource allocation and supply chain scientific decision as well as the improvement of supply chain efficiency.

6. *Collaboration risk control:* The management focus of collaboration risk can be seen from Fig. 37.5.

① In light of the dynamic development needs of supply chain, the mechanism for selecting members of supply chain is to be constructed so that complementary enterprises or organizations will be introduced. In order to maintain supply chain stability, it is important to consider the relation capital, cultural compatibility and credibility (Chen and Sheng 2009). Besides, a database of backup participants should also be developed to timely supplement the supply chain's missing or weak links.

② A clear division of tasks and the behavior standard of supply chain make all members accomplish their missions in quality and quantity according to the schedule.

③ Building up effective channels such as information platform for the resource sharing of supply chain will contribute to the effective integration of supply chain network resources, thus it will reduce transaction costs, improve operational efficiency and effectiveness of collaboration as well as enhance the overall capacity of supply chain.

④ Pharmaceutical industry association should play a coordinating and guiding role in recommending partners to supply chain, monitoring supply chain activities, counting up and publishing industrial information, organizing medical exhibitions and fairs, etc. When supply chain members encounter serious problems, the industry association should help providing solutions to them (Zhang and Wang 2010).

7. *Policy and law risk control:* Medicine supply chain should pay close attention to the dynamic policies, laws and regulations of its resident region, strengthen the utilization of relevant policies and adapt to laws and regulations. On the one hand, supply chain should seize opportunities, obtain policy support and adjust business, behavior and management methods in response to the development requirements; on the other hand, it should better bear the social responsibilities including complying with business ethics, product safety, resource conservation and environmental protection (Meng et al. 2010). Meanwhile, in the course of providing support for medicine supply chain, the industry association should timely feed back the problems and requirements to the relevant government departments so that the formulation of planning, policies, laws and regulations of government are more in line with the needs of medicine supply chain and much closer to the global pharmaceutical industry standards.
8. *Competition risk control:* In response to the rapidly changes of industrial environment and challenges from competitors, medicine supply chain should pay close attention to industrial technology and market trends, and enhance prediction ability in order to understand the development trend. Also, the supply chain should know the competitors' dynamics and seek differentiations so as to occupy the favorable position in medicine competition.

Conclusion

At present, for most medicine supply chains, the low level of risk management is the main reason for low performance, high price, incardination between supply and demand as well as imperfect health care system, which has also become the main problem for supply chain's sustainable development. As the medicine supply chain risk does not attract enough attention, strengthening the risk management is of significance both for the national health care reform and for the human health. This paper first makes an analysis of composition and risks of medicine supply chain, then it proposes risk identification hierarchy structure, at last it designs the risk control model and relative measures, which may provide reference for medicine supply chain risk management. Although this paper has made a preliminary exploration in medicine supply chain risk management, it is only limited to qualitative description, in the future the quantification and the early warning system of risk needs to be constructed by use of quantitative methods and information technologies.

References

Chen ZR, Chen S (2009) Research on the effect of information technology in the supplying chain of medicine. Mod Hosp 1:1–2

Chen Y, Sheng BB (2009) Empirical research on relation stability of supply chain alliance. Manage World 11:178–179

Faemsl D, Janssens M, Looy BV (2010) Managing the co-operation-competition dilemma in R&D alliances: a multiple case study in the advanced materials industry. Creat Innov Manag 19 (1):3–22

Jiang LL, Xu MD, Li XH, Zhao SJ (2008) Significance of customers' demand-driven in the management of drug supply chain. China Pharm 1:5–7

Li Q, Zhang SZ, Wu QQ (2010) Analysis on formation mechanism of default risk in logistics service supply chain. Econ Manag 6:61–64

Meng J, Tang XW, Ni DB (2010) Safety responsibility strategy of manufacturer-retailer supply chain alliance based on profit distributive. J Ind Eng Eng Manag 1:124–128

Sachs T, Tiong RLK, Wagner D (2008) The quantification and financial impact of political risk perceptions on infrastructure projects in Asia. J Struct Financ 13(4):80–104

Shao Q, Lin XY (2010) Risks evaluation on international petroleum engineering project based on ANP. Sci Technol Prog Policy 11:127–130

Shen K, Li CD, Xing XH (2009) Risk management in Chinese pharmaceutical supply chain. J Xi'an Univ Electron Sci Technol (Soc Sci Edn) 3:98–103

Wang SS, Tian JX (2010) Research on the patent strategy establishment method of R&D alliance based on the patent map. Stud Sci Sci 6:846–852

Zhang M, Wang DP (2010) Analysis on knowledge service mode of agile supply chain based on knowledge market. Sci Technol Prog Policy 12:125–127

Chapter 38
The Implementation of Green Supply Chain Management in Chinese Food Industry: A Multi-case Study

Rui-dong Chang, Yi Zhang, and Yu-long Chen

Abstract As it concerns more than one billion people, Chinese food manufacturing industry is on a large scale and adopting green supply chain management (GSCM) in this industry is significant to environmental protection. This paper aims at providing information on the implementation of GSCM in Chinese food industry. Using multi-case study on five case enterprises, this paper analyzed the practical experience and difficulties of the GSCM implementation in four aspects, namely green procurement, green manufacturing, green logistics and green marketing. The results show that sample enterprises did well in green procurement and green marketing while the green manufacturing and green logistics have encountered some objective difficulties and still call for improvement. The joint effort of the government and food enterprises needs to be formed to ameliorate the implementation situation of GSCM in Chinese food industry.

Keywords Chinese food industry • Green supply chain management • Implementation • Multi-case study

Introduction

The energy intensity, measured by energy consumption per unit GDP of China is 2.4 times of the world average. China pledges to reduce the CO_2 emission per unit of GDP by 40–45% in 2020 compared to the level of 2005 (Zhen-Yu Zhao and Lei-Lei Fan 2011). In order to achieve the emission reduction targets, China has constantly popularized the sustainable development concept. Academic and corporate interest in sustainable supply chain management has risen considerably in

R.-d. Chang (✉) • Y. Zhang • Y.-l. Chen
School of Economics and Management, North China Electric Power University, Beijing 102206, P. R. China
e-mail: changruidong@ncepu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_38,

recent years (Joseph Sarkis et al. 2011). In manufacturing enterprises, green supply chain management (GSCM) has got widespread concern, because it merges environmental protection into the entire manufacturing process (Seuring and Muller 2008). According to "China Procurement Development Report 2011", 56% of the surveyors in manufacturing system decide to implement GSCM concept in the next 2 years (China Association of Logistics and Purchasing 2011). Food manufacturing is on a large scale which means implementing GSCM in this industry is of great significance to the world's carbon reduction.

However, the majority existing empirical researches on GSCM are mostly based on the samples of foreign enterprises (Luo and Wang 2003). Few literatures systematically studied the GSCM under the Chinese food companies' background. In what areas did some food companies adopt GSCM; what problems did their GSCM practices encounter? This paper attempts to answer these questions preliminarily. Multi-case analysis is an important method of management issues. Based on data collection and telephone interviews, this paper selected five enterprises using the multi-case analysis to study the implementation of GSCM in Chinese food industry. Based on a theoretical model of GSCM in Chinese food industry, this paper then conducted a multi-case study of four major aspects, namely green procurement, green manufacturing, green logistics and green marketing. The key factors, implementation and problems of GSCM in Chinese food industries are identified, summarized and analyzed in this paper which can be referred by more enterprises in the future.

The Analysis of the Implementation of GSCM in Chinese Food Industry

There are two methods about multi-case studies: (1) summarize findings to find some useful information to form a theoretical framework under no guidelines of existing theoretical framework; (2) under a new or existing theoretical framework, research the sample companies (Li Fei et al. 2009). This paper adopted the second method, namely first put forward a theoretical framework and then analyzed the sample companies. Reference to Professor Wang Yingluo' GSCM conceptual model (Wang Yingluo et al. 2003), combined with the reality of Chinese food industry, this paper established a theoretical model of GSCM in the food industry as shown in Fig. 38.1.

This theoretical model incorporates the key aspects of GSCM into the existing operation level of GSCM model. Because the concept of green design needs to be achieved by green procurement, green manufacturing, green logistics and green marketing, green design is omitted in this model.

The next step of the multi-case study is to choose the cases. The principles of ideal cases in this paper are as follows.

- Established more than 5 years
- Adopted GSCM
- Chosen as the national green food enterprises by experts selected by the Chinese Green Food Association.

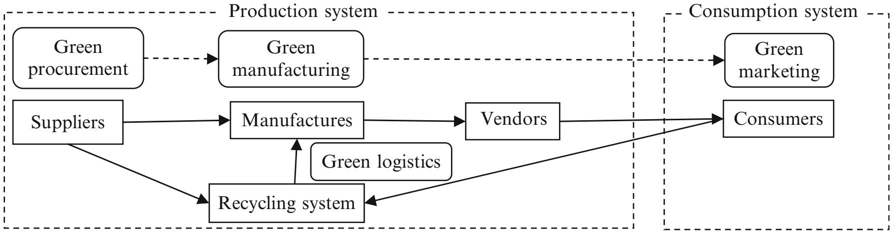


Fig. 38.1 The GSCM concept model of Chinese food industry

Table 38.1 The basic information of the analytical cases of GSCM in this paper

Enterprises	Established year	Industry segments	Location of headquarters
Kweichou Moutai Co.Ltd.	1999	Alcohol	Guizhou
GuiTang Co.Ltd.	1993	Carbohydrate	Guangxi
Wondersun Dairy Co.Ltd.	1996	Dairy products	Heilongjiang
Beidahuang Beilv Food Co.Ltd.	2005	Vegetable	Heilongjiang
Ginsber Beer Co.Ltd.	2000	Alcohol	Jilin

Table 38.1 summarized the basic information of the cases in this paper. The following sections will analyze four aspects about the five chosen enterprises respectively, namely green procurement, green manufacturing, green logistics and green marketing.

Green Procurement

The green procurement of the cases is summarized in Table 38.2. The above enterprises, adopting green procurement program, strictly controlled the safety of the raw material source. In order to improve the quality of raw material, some cases set up their own raw material bases. Through that way, the whole process of access to raw materials can be under the supervision of the enterprise as much as possible. For example, because the consuming group of Wondersun Dairy Co. Ltd is mainly infants, the safety of raw materials should be paid more attention to. While implementing supervision and management system internally, the enterprise considered the external local conditions and developed their own geographic advantages to set up raw material bases in one of the world's last three major black soil zones. Furthermore, the use of new techniques has been promoting the development of enterprises. For instance, Beidahuang Beilv Food Co. Ltd used advanced planting technique, fine field management technique and biological disinfestations technique to improve the security of raw material. In order to further standardize the raw material, the sample enterprises also detect and evaluate the raw materials with appropriate systems of supervision. Ginsber Beer Co.Ltd. established a strict safety assessment process of raw materials and a method of testing pesticide and heavy metal.

Table 38.2 Green procurement implementation of the cases

Company name	Safety	Cooperation
Kweichou Moutai Co.Ltd.	Newly built organic raw materials base The information management system, covering all aspects from seeds to manure, enhances the safety of the raw materials	The company holds National Supplier Conference of Moutai every year. In 2011, the conference summed up the achievements and problems of materials procurement. Suppliers from around the country promised to control quality strictly
GuiTang Co. Ltd.	The company built the modern sugarcane park and recommended famers to use provided seeds. In this way, the resource of the procurement is safe and reliable	Considering the profit of the farmers, the company purchases improved seeds of high price and sells them to farmers at a lower price
Wondersun Dairy Co. Ltd.	The pasture located in one of the world's remaining three black soil areas which are far away from pollution. The good environment is the foundation of the high-quality raw milk The company established immunity quarantine files for the cows	The company will pay the suppliers on the basis of quality test results. Therefore, the suppliers will compete for better quality of their milk
Beidahuang Beilv Food Co. Ltd.	It owns a huge plant base and cold storage Skilled in seed cultivation technique, advanced planting technique, fine field management technique and biological disinfestations technique. Using pollution-free fertilizer	Company adopts the "company + base" agriculture industrial model. Plant, produce and process on their own
Ginsber Beer Co.Ltd.	They passed the water certification to make sure that the procedures of production were pollution-free Having established a strict safety assessment process and testing method of green raw materials. The main raw materials are from the green base	Cooperated with many suppliers from around the world. The barley is from Canadian and Australian production bases. The rice is from Heilongjiang green food paddy rice production base. Hops are from Xinjiang production and construction corps green base

The enterprises have deepened the relationships with the raw material suppliers through further cooperation. In order to acquire raw materials which are of high quality and more suitable for their enterprises, they should consider more about the supplier's profit. Take GuiTang Co.Ltd. for example. The enterprise purchases improved seeds but sells them to farmers at a lower price. During the planting time, the company keeps in touch with the farmers to find and correct plant problems in time. This kind of cooperation can not only guarantee the quality of raw materials but also improve the competitiveness of the suppliers.

Table 38.3 Green manufacturing implementation of the cases

Company name	Clean energy	Clean production processes
Kweichou Moutai Co. Ltd	None for the present	Make use of waste lees in a circular economic approach, thus making Moutai step into a pollution-free and clean production track
GuiTang Co. Ltd.	A certain percent of electricity is generated by industrial waste	Make cane molasses produced by the sugar into alcohol and the waste produced by the alcohol into fertilizer which is back to the cane fields
Wondersun Dairy Co. Ltd	None for the present	Treatment of exhaust gas: the use of Surge-watered turbine and Venturi granite water film dust collector makes dust removal efficiency over 97%
		The cooling water circulation device makes water recycling rate exceeding 60%. It saves about 600,000 t of water annually
		Treatment of residues: the company purchases the hollow brick machine to turn residues into hollow bricks for constructing the workshop, thus following their basic principle of turning waste into treasure
Beidahuang Beilv Food Co.Ltd.	None for the present	Full range of industrial, agricultural technology and scientific management system. Vegetable planting technology of Japan, processing technology of Taiwan, the domestic first-class processing equipment, first-class refrigeration system and advanced post-mature processing technology ensure the safety of the north green vegetables
Ginsber Beer Co.Ltd.	None for the present	In order to ensure green production, the company invests 70 million Yuan to complete more than 30 kinds of upgrading of technology equipment and facilities
		Develop a series of safety assessment processes of raw materials. Establish a set of detection methods of pesticide residues, heavy metals, harmful anions and mycotoxin

Green Manufacturing

Table 38.3 shows the information of green manufacturing of the cases. The above case enterprises didn't do very well in the use of clean energy in their green manufacturing sector. There are two reasons accounting for this issue. The first one is that Chinese clean energy started later than Western countries. Although the government emphasizes and invests a lot on clean energy, it is still in the developing phase in China (International-energy.com 2012; Wen Liu et al. 2011). The second is the technological innovation of the food manufacturing industry is inadequate. Take Moutai for example. If the left lees can be used for fuel and energy production, not only can Moutai use resources to the maximize degree, but also it can reduce environmental pollution and solve the problem of energy shortage (Jiangpen Ag 2008). GuiTang Co.Ltd. sets an example for the rest of the above case enterprises in using clean energy.

The above case enterprises are common in adopting the concept of circular economy in the production process. Take GuiTang Co.Ltd. for example. Its cane molasses produced by the sugar plays a great part in making alcohol; the waste produced by the alcohol then serves as the cane fields' fertilizer, which has formed a closed loop chain. So does the Wondersun Dairy Co.Ltd. It uses its cooling water circulation device to the most, making water recycling rate exceed 60% and at the same time saving about 600,000 t of water per year.

Green Logistics

Table 38.4 shows the green logistics of the cases. Due to the lack of logistics infrastructures, the transportation is difficult. The above case enterprises are trying to strengthen the logistic conditions through a variety of ways. For example, in order to support the transportation of the products, GuiTang used 41.8 million to purchase 100% shareholding of Anda Logistics Company. Wondersun Dairy Co., Ltd. plan to set up Wondersun Logistics Company in 2012. Furthermore, the enterprise established a quality tracking system to ensure quality throughout the life cycle of each product. Forward-logistics is obviously important to the enterprise; however, most companies still do not have the concept of backward-logistics. Though Kweichou Moutai Co.Ltd. has the recycle channel for bottles, many counterfeit product manufacturers get the bottles to make counterfeit wine. Today, more and more people recognize the importance of circular economy, and in the future the backward-logistics will become the focus in the resource planning.

Green Marketing

The above case enterprises all pay much attention to image advertising as shown in Table 38.5, setting green products as their core competitiveness. They make extensive use of the website, TV and other media. Take Heilongjiang Beidahuang Beilv Food Co.Ltd. for example. The company uses various ways to publicize its corporate image, so it is able to get cross-border orders from the United States, Canada, South Korea and other countries. Ginsber Beer Co.Ltd. also has its characteristics. It sets up environmental professional department 10 years ago for the purpose of adapting itself into GSCM. The department is occupied in research, management and enhancing the company's green manufacturing and technological upgrading work. The price has little effect on green products. The price of most green products corresponds with normal goods (except Moutai). Like Wondersun

Table 38.4 Green logistics implementation of the cases

Company name	Forward-logistics	Backward-logistics
Kweichou Moutai Co.Ltd.	Moutai Town has not built the highway so the transportation is extremely difficult. During busy time, they even used military vehicles to convey the product	The recycling of Moutai bottle is difficult to return to the factory. A lot of them flow to counterfeit product manufacturers
GuiTang Co. Ltd.	Because of the large amounts of raw materials and products every year, the enterprise needs to solve the storage problem urgently. GuiTang used 41.8 million to purchase 100% shareholding of Anda Logistics Company	None for the present
Wondersun Dairy Co. Ltd.	The enterprise plans to set up Wondersun Logistics Company in 2012 to ensure the product quality during transport Establish a record and traceability program and every batch of products can retrospect to the origin place of raw milk, raw materials suppliers, the storage location and shipping whereabouts	None for the present
Beidahuang Beilv Food Co. Ltd.	Through the TBS system, consumers can check up the original place of the product, specific information of the raw material producers, packagers and retailers	None for the present
Ginsber Beer Co.Ltd.	Use ERP Enterprise Resource Planning to plan suppliers	None for the present

Table 38.5 Green logistics implementation of the cases

Company name	Green image	Green pricing
Kweichou Moutai Co.Ltd	Publicizing green organic Moutai wine through advertising Moutai Town holds production safety & environmental protection training meeting regularly	Luxury brands with high price
GuiTang Co.Ltd.	Develop its own green image through the promotion of circular economy	Moderate
Wondersun Dairy Co.Ltd	Advertising Educate the staff on the environmental protection knowledge	Moderate
Beidahuang Beilv Food Co.Ltd.	Positively propaganda got the cross-border orders from the United States, Canada, South Korea and other countries	Moderate
Ginsber Beer Co. Ltd.	In order to meet the needs of green environmental protection and energy conservation, Ginsber Beer Co. Ltd. established its environmental professional departments 10 years ago	Moderate

milk powder (version Gold parental wisdom, section Introduction) for 0–6 months babies. (400 g/bag) priced 35 Yuan/bag. It's because the food industry is highly competitive in the Chinese market and Chinese consumers pay more attention to price, if they think one goods is overpriced, they can turn to other alternatives. But there is also an exception – the price of Moutai is high, that's because the unique and complex production processes make it a naturally luxury property.

Conclusions

For the purpose of reducing carbon emissions and the cost of environmental governance, many food enterprises plan to adopt the GSCM in the near future. As a multi-case study, this paper selected five food companies which have adopted GSCM to analyze the implementation situation of their GSCM practice. Based on a GSCM model of Chinese food industry, the case enterprises' green procurement, green manufacturing, green logistics and green marketing are summarized and analyzed. The results show that: (1) The case enterprises do well in green procurement. They ensure the green and safety of raw materials through the establishment of their own green food base and a series of technological equipment and management systems. Meanwhile they also give full consideration to the interests of the suppliers, and cooperate with them actively; (2) The five case enterprises adopted the concept of circular economy in their green manufacturing. However, due to the development status of Chinese renewable energy and the lack of innovation, only one company (GuiTang Co.Ltd.) has adopted clean energy; (3) The case enterprises' logistics situation is not so optimistic, which is resulted from Chinese imperfect logistics infrastructures. Many companies purchase logistics companies or set up their own logistic companies to strengthen their own forward-logistics. But till now, only Moutai has backward-logistics, and its implementation encounters the problem of counterfeit manufacturing; (4) The above case enterprises all take "green" as their core competitiveness and vigorously publicized it through a variety of ways. But due to the fierce competition in the food industry, the price of most green food corresponds with ordinary goods.

This study can be used as a practical reference both for the domestic managers and foreign investors relevant to the Chinese food industry and logistic system.

Acknowledgement This paper is supported by "Humane Social Science Fund Project of Education Ministry-Study on the dynamic game optimization model and risk control of Agricultural products logistics supply chain" (NO.11YJC790086). and "the Fundamental Research Funds for the Central Universities-Study onjoint modes and mechanism of agricultural products logistics docking mode". The authors would like to thank the Prof. LI Xiao-yu and the anonymous reviewers for their useful comments on an earlier version of this paper.

References

China Association of Logistics and Purchasing (2011) China procurement development report (in Chinese). China Logistics Publishing House, Beijing

International-energy.com. (2012) The development of Chinese clean energy requires more investment from the government (in Chinese). Available at: http://www.in-en.com/finance/html/energy_08220822471324054.html. 20 Mar 2012

Jiangpen Ag (2008) Solid-state fermentation to produce fuel ethanol use maotai vinasse [D]. Guizhou University, Guiyang (in Chinese)

Joseph Sarkis, Qinghua Zhu, Kee-hung Lai (2011) An organizational theoretic review of green supply chain management literature [J]. Int J Prod Econ 130:1–15

Li Fei, Wang Gao, Yang Bin, Ma Baolong, Lin Jian, Zhaojunjie Chenhao (2009) A high-speed development legend-based on 10 enterprises multi-case study [J]. Manage World 2:38–51 (in Chinese)

Luo Dingti, Wang Yijun (2003) Current situation research for green supply chain management in China [J]. J Hunan University of Technology (Social Science Edition) 16(3):1–6 (in Chinese)

Seuring S, Muller M (2008) From a literature review to a conceptual framework for sustainable supply chain management [J]. J Cleaner Prod 16:1699–1710

Wang Yingluo, Wang Nengmin, Sun Linyan (2003) The basic principles of green supply chain management [J]. Eng Sci 5(11):82–87 (in Chinese)

Wen Liu, Henrik Lund, Brian Vad Mathiesen, Xiliang Zhang (2011) Potential of renewable energy systems in China [J]. Appl Energy 88(2):518–525

Zhen-Yu Zhao, Jian Zuo, Lei-Lei Fan, George Zillante (2011) Impacts of renewable regulations on the structure of power generation in china-a critical analysis [J]. Renew Energy 36(1):24–30

Chapter 39
Logistics Capability and Performance of Container Ports: An Empirical Research Basing on SEM

Jin-shan Dai, Han-bin Xiao, and Ting-ting Cui

Abstract Container ports expect more competitive advantages and performance improvement on their extinctive logistics capabilities in the circumstance of ongoing integration of supply chain and port fields. Whereas, the connotation and denotation of port logistics capabilities and port performance have been undergoing significant changes. Meanwhile, the competition between container ports is presented in multitiered and wide-ranging arena. This research focuses on container ports and conceptualizes port logistics capability from five dimensions (positioning, integration, infrastructure, operation and agility) and port performance from four aspects (productivity, finance, social and satisfactory performance), then tests the relationships among port logistics capability, competitiveness advantages and performance. Data from 30 container ports and 181 responses and results from structural equitation modeling indicate that the comprehensive improvement of port logistics capability can directly raise port efficiency and effectiveness performance concurrently. Moreover, via the competitiveness advantages in market, port logistics capability has an indirect positive impact on performance.

Keywords Container logistics • Container ports • Port competitiveness • Port performance • Structural equation modeling

Introduction

Modern ports are undergoing the shift from gateway to logistics hub (Robinson 2002). Logistics service, which having the instinctive close connection with customers, is increasingly regarded as the one of the main new sources for corporate differentiation strategy especially in the global wide and time-based competition.

J.-s. Dai (✉) • H.-b. Xiao • T.-t. Cui
School of Logistics Engineering, Wuhan University of Technology, Wuhan, China
e-mail: jinshan.edu@gmail.com; xhb@whut.edu.cn; cuitinglanbing586@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_39,

The development and practice of ports indicate that port is growing to be a key and functional element in the chain of logistics services with a trend of supply chain integration, namely, the 4th generation port which based on logistics and supply chain. Therefore, it is necessary to rethinking of port and its logistics from the view of supply chain.

Serving as a productive unit, port service is evolving to customer orientation, namely, gaining competitive edge by attracting the customers and satisfying the stakeholders, and eventually obtaining expected performance. The port stakeholders mainly include shipping lines, consignees, international freight forwards, ship operators, logistics managers and etc. In order to improving the performance whole dimensionally, ports need to explore the unique predominance in logistics business and establish the advantages in competitive market and related community.

Currently, there are consensuses in port logistics and related performance research, that port logistics capability possess an effect on performance and the level of port logistics capability can influence the location of ports on target logistics and shipping market. The research is undertaken with the purpose to investigate the effects and also the extent of effect of port logistics capability on performance besides discussing the composition of this capability and their difference in influencing effect, direction on the performance. It is followed by description of the research framework for the instrument and methodology which is chosen via an empirical investigation and data analysis using confirmatory factor analysis (CFA) providing by structural equation modeling (SEM). The results are discussed about limits and further research in port logistics area.

Framework and Hypotheses

Port Logistics Capability

Representing the power of providing service for customer of port as a whole, logistics capability can be constructed from the five dimensions: positioning, integration, infrastructure, operation and agility.

1. Positioning

   Positioning involves the self-location of logistics development target and choice of strategy. From Olavarrieta and Ellinger's view, the logistics competency approach can be regarded as a key strategic resource for acquiring sustained competitive advantage when resources are valuable, scarce and difficult to imitate (Olavarrieta and Ellinger 1997). The positioning can be described by the sub-items of strategy, supply chain, network and organization.

   The definition of port strategy power refers from the finding of Michigan State University Global Logistics Research Team Bowersox et al. (1995), in which the strategic positioning is the essential starting point to logistical excellence, and world class firms view logistics positioning competency as a differentiator that can lead to competitive advantage. Supply chain refers the alignment of logistics resources through channel alliances Bowersox et al. (1995). Network embodies the structure and deployment of physical resources, e.g., the layout of business and capital world widely. Organization capability reflects the structure and deployment of human resources (Gilmour 1999) besides the governance model for ports such as privatization (Notteboom 2002).

2. Integration
   Integration competency measures the degree to which logistics tasks and activities within the port and across the supply chain are managed in a coordinated fashion. Typically, the port integration can be evaluated by the integration of information and communication (ICT), the integration of multimodal transportation (MOD), and the integration of supply chain (SCI).

   ICT refers to the application of IT to facilitate the data exchange and share. As distribution channel be larger and larger, the information flow play more and more important role in logistics context (Closs et al. 1997). Integration of MOD of container ports, ensuring the seamless connection between kinds of transport modes, also guarantying the reliability and availability of logistics service, is always the main focus of academic research, e.g. Robinson (2002), Paixão and Marlow (2003), and Bichou and Gray (2005). Port SCI competency is accompanied with the upward trend of business integration and cooperation between ports with other partners in the supply chain.
3. Infrastructure
   According to the resources-based view (RBV), the level of operation and development of ports logistics business is depend on the utilization of their resource. Estache et al. 2005, made a conclusion by case study that the reform in port infrastructure can lead to an obvious promote in port performance. The hardware elements which consist of the infrastructure of ports mainly include berths and water front, devices for material handling and facilities for warehouse and yard.
4. Operation
   Operation competency of port, also regarded as managerial competency, is related with the production and operation management which is accompanied with material handling and logistics service providing. Basing on the literature, the operation capability of port can be coded into four parts: standardization, measurement, innovation and value-added ability.

   MSUGLRT regarded standardization as one of the key elements for logistics capabilities and conceptualized it as the establishment of common policies and procedures to facilitate logistics operations Bowersox et al. (1995). As for container ports, measurement capability counts the operational competency in process and functional assessment and bench marking (de Martino et al. 2009). Innovation competency weighs the vitality of port in technical creation, management model and service innovation. Value-added ability caters to the prominent trend that logistics industry pays more attentions to the service-orientation activities besides providing traditional cargo and ship related treatment (de Martino et al. 2009).

5. Agility
   Borrowed from definition of MSUGLRT for logistics agility, port agility competency represents the port ability of providing flexible logistics services in the ever-changing market. It is a kind of time-related competency targeting at quickly responsiveness to customers. Zhang JZ note that 4th generation port should be featured by differentiation, lean and agility with the SCM background. Three elements make up for the port agility: relevance, accommodation & responsiveness, and flexibility.

Relevancy competency states for the port ability of maintain focus on the changing needs of customers. Accommodation and Responsiveness reflect the port ability to respond to unique customer requests. Flexibility represents the port ability to adapt to unexpected circumstances. Paixão and Marlow (2003) define the 4th generation port and also suggest the paths for arriving 4th generation and agile port.

Competitive Advantages of Ports

Based on RBV, logistics capability is regarded as the source of competitive advantage, and the competitive advantages will finally become the determinants by which the customers choose their target call port or hub port. The determinants mainly include port charge and cost advantages, operation efficiency and service advantages, and market share advantages.

1. Charge and Cost advantages
   The Rates of port, including charge and price, serve as the means for competition among container ports. This is also the same case with cost that port saved for the customers. The combination of high efficiency in production and low cost in operation, together with great cost-cut for customer, enable the ports to utilize pricing tactics to attract more shipping lines and consigners.
2. Service advantages
   As a kind of productive services, port and its logistics rest the advantages on the service level, such as service quality, time-cutting, and availability of service. The indicators for quality of service mainly include precision ratio of ship lines, precision ratio of ships and container. The indicators for time-cutting dominance mainly focus on three time-related elements, namely, average time ships delay on port, average time container trucks delay on port, average time of clearance for cargoes, which reflect the degree of port congestion. The availability of port service covers the hinterland connection, feeding port connection, and stability of logistics service delivery.
3. Market share advantages
   The advantages of port can also be shown as market share dominance, such as shipping lines, cargo source of hinterland, transit quota of container transportation, and etc. Notteboom and Winkelmans regard the shipping lines of port play a critical role during port choice from user (Notteboom and Winkelmans 2001).

Basing on the research on container ports in Taiwan Straits area, Tai HH argues that cargo source of hinterland has the most significant influence on competitiveness advantages of container ports.

Port Performance

Port performance can be measured from the perspectives of productivity, finance, social and satisfactory. The productivity and financial performance are efficiency-oriented and financial-oriented respectively, considering from the port internally. The social and satisfactory performances are effectiveness-focused viewing from the stakeholders of ports, and they are becoming hot issues in the field of port logistics research recently, e.g. Bichou and Gray (2004), and Brooks (2006).

1. Productivity performance
   Productivity performance, which reflects the handling efficiency of ships and container, firstly and mainly makes up for the whole performance of container ports. It can be classified into the performance in ship/container handling and performance in utilization of berth resource.
2. Financial performance
   Financial performance always counts the top goals for profitable organization without exception in port industry. Financial performance is classified into total volumes, current profitable index, and ratio-like index standing for potential. The sub-items for total volumes are total assets of port, total operation income, total profit. The sub-items for profitable index are return on equity, return on total assets, operation profit ratio, and ratio of cost-profit. The ratio-like index includes operating income growth rate, total assets growth rate, and profit growth rate.
3. Social performance
   With the regionalization and fusion of ports into the community where they are located, container ports can advance development of economic, promotion of trade, improvement of employment, along with the influence they made for local transportation and environment. All of this can be assessed by social performance of container ports. Peter de Langer points out that a comprehensively and newly established performance index of port should not only satisfy the request from port authority, but also cater to the interests of stakeholders (Langen et al. 2007).
4. Satisfactory performance
   With background of service-oriented industry and enlightenment from service assess practice, satisfactory performance of port can be defined as the satisfactory perception of stakeholders, such as direct customers, partners along the service chain, other roles. It can be viewed as effectiveness-oriented performance index.

Reference from the design of scales on port performance by MR. Brooks in a special research project on port governance and performance in 2006 (Brooks 2006), this paper presents a comprehensive measurement framework of container port performance as followed Table 39.1.

Table 39.1 Definition and original of PLC, PCA and PP

Elements	Sub-elements	Origins of identification
PLC		
Positioning	Strategic element, mainly including: (1) strategy; (2) supply chain; (3) network; (4) organization	Bowersox et al. (1995), Robinson (2002), and Notteboom (2002)
Integration	Integrative element, mainly covers the integration of: (1) information and communication system; (2) multimodal;(3) supply chain	Bichou and Gray (2005), Robinson (2002), Song (2008), Rodrigue and Notteboom (2009)
Infrastructure	Hardware element, mainly covers: (1) berths; (2) material handling; (3) warehouse & yard	Estache et al. (2005)
Operation	Managerial element, mainly covers: (1) standardization; (2) measurement; (3) innovation; (4) value-added service	Bowersox et al. (1995), de Martino and. Morvillo (2009), and Notteboom (2002)
Agility	Time-related element, mainly cover: (1) relevancy; (2) accommodation & responsiveness; (3) flexibility	Bowersox et al. (1995) and Paixão and Marlow (2003)
PCA		
Charge, cost	(1) Charge; (2) price; (3) cost	Lirn et al. (2003)
Serve advantages	(1) Quality of service; (2) time-cutting; (3) availability	Kuang and Li (2009)
Market share	(1) Shipping line;(2) hinterland; (3) transit	Notteboom and Winkelmans (2001)
PP		
Productivity performance	Internal technical elements, cover: (1) material handling efficiency; (2) berth utilization	Bichou and Gray (2004) and Cullinane et al. (2002)
Financial performance	Internal & financial elements, cover: (1) total; (2) profit; (3) rates	Bichou and Gray (2004) and Talley (2006)
Social performance	External contribution or influence, cover: (1) GDP; (2) trade; (3) employment; (4) environmental	Bichou and Gray (2004) and Langen et al. (2007)
Satisfactory performance	External and micro elements, include the perception from: (1) Customer; (2) Partner; (3) Stakeholders	Lai et al. (2002) and Winkelmans (2008)

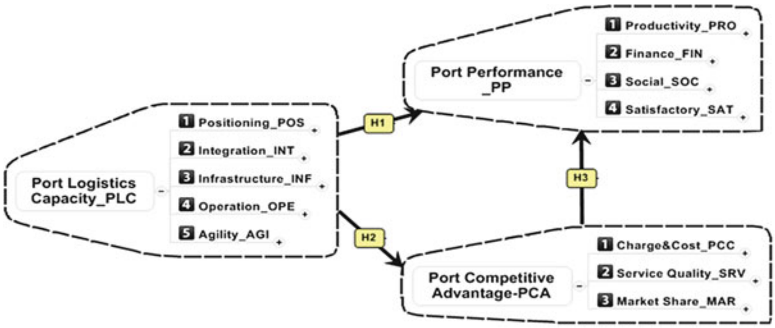


Fig. 39.1 Concept model about the relationship among *PLC*, *PP* and *PCA*

Model Construction and Hypotheses

Figure 39.1 describes the research framework conceptualized in this research. The framework proposes that port logistics capacity (PLC) will have impacts both on port performance (PP) and on port competitive advantage (PCA), which are labeled as H1 and H2 respectively. Port competitive advantage will also influence the port performance as noted as H3. Basing on the literature support, the upper relationship and hypotheses among the PLC, PP and PCA are discussed.

Methodology

During the pre-pilot study, the initial questionnaire was reviewed by six experts in port, logistics and firm performance through structured interviews. Based on the feedback, redundant and ambiguous items were either modified or eliminated. The revised questionnaire was composed of three independent topics, namely, establishing of port logistics capability (PLC), assessment of port competitive advantages (PCA) in logistics and shipping market and evaluation of port performance (PP) which were unfolded with 17, 9 and 12 sub-items respectively. The total 38 items were 5-point Likert scales.

The final questionnaire was sent to around 600 target respondents who are mainly the managers or with higher job title of each company spreading in the main 30 large and medium-sized ports which are engaging in container business and located coastally or inland in China. The survey was carried in two waves to ensure the response rate. 29 of the 181 returned questionnaires were discarded owe to the reason of data integrity or information missing. The response rate was therefore 25.3% (152/600), an acceptable value for logistics empirical research.

This study adopted the two-step SEM approach. Firstly, the validity of the measurement model, including unidimensionality, reliability, convergent validity, and discriminant validity, was assessed by using CFA. Secondly, the model validation by SEM software can be applied to estimate the structural model, which was followed by the explanation of the good-of-fit the model and the structural relationship between PLC, PCA and PP.

Empirical Analysis and Results

Results for the Measurement Model

Factor analysis was conducted for the loading values of the items belong to the sub-factors of the PLC, PCA and PP. All the item loadings are acceptable (>0.70), and they were statistically significant ($p < 0.05$), which indicates that the conceptualization and the decoding of PLC, PCA and PP are all acceptable for unidimensionality.

The construct reliabilities of PLC, PCA and PP are assessed by Cronbach's Alpha, composite reliability, and average variance extracted (AVE). Table 39.2 shows the means, standard deviations (SDs), AVE, correlations, and composite reliability values for each of constructs. The reliability values are above 0.70, which are acceptable.

In the paper, PLC, PCA and PP, are conceptualized as second-order constructs which are composed of five, three and four factors respectively. Beside the general first-order CFA analysis, SEM powered by AMOS software can also support fit statistics analysis for high-order factor model. Table 39.3 shows the fit statistics analysis of the first-order and second-order model. The RMSEA, CFI and NNFI values from the table indicate a reasonable model-data fit of the measurement of constructs and the existences of the high-order constructs PLC, PCA and PP.

Results for the Structural Model

As for the structural model conceptualized shown in Fig. 39.1, structural model results are obtained by applying AMOS to the samples and the results of path diagram are displayed in Fig. 39.2. The model fit indices are $\chi^2/df = 2.17$ (<3.0), $RMSEA = 0.065$ (<0.08), $CFI = 0.91$ (>0.90) and $NNFI = 0.92$ (>0.90), which indicate that the model adequately fits the data. The path coefficients between PLC, PCA and PP are, 0.58 ($t = 3.81$), 0.65 ($t = 4.12$) and 0.37 ($t = 2.18$), which are statistically at the level of 0.05. The data supports the formed claim that PLC has significant and positive, and direct impacts on PP, namely hypotheses H1. H2 and H3 are all confirmed.

Based on the standardized coefficients of hypotheses, indirect effects and total effects can be calculated, as shown in Table 39.4. The standardized coefficient of indirect effect of PLC on PP is 0.21, indicating that PLC can have a direct, positive

Table 39.2 Results of reliability assessment

Items	Mean	SD	1	2	3	4	5
PLC							
1.POS	3.70	0.73	0.86[a]				
(4[c])			0.79[b]				
2.INT	3.96	0.69	0.52*	0.86[a]			
(3[c])				0.79[b]			
3.INF	3.34	0.64	0.56*	0.39*	0.86[a]		
(3[c])					0.79[b]		
4.OPE	3.33	0.63	0.39	0.33	0.59*	0.86[a]	
(4[c])						0.79[b]	
5.AGI	3.24	0.88	0.18	0.12	0.08	0.15	0.86[a]
(3[c])							0.79[b]
PCA							
1.PCC	3.37	0.67	0.74[a]				
(4[c])			0.71[b]				
2.SRV	3.65	0.72	0.32*	0.82[a]			
(3[c])				0.76[b]			
3.MAR	3.84	0.82	0.42*	0.53*	0.87[a]		
(3[c])					0.83[b]		
PP							
1.PRO	3.74	0.85	0.85[a]				
(2[c])			0.71[b]				
2.FIN	3.69	0.81	0.68*	0.79[a]			
(3[c])				0.75[b]			
3.SOC	3.53	0.77	0.37*	0.21*	0.82[a]		
(4[c])					0.79[b]		
4.SAT	3.49	0.72	0.36	0.23	0.49*	0.88[a]	
(4[c])						0.76[b]	

Note: (1) *correlation is significant at the 0.05 level (two-tailed), (2) [a]composite reliability; [b]average variance extracted, (3) [c]number of sub-item

influence on PP as well as an indirect one through PCA. And the total effects value is 0.86, which is a considerable high path coefficient.

Conclusion and Limitations

The paper is engaged to justify the elements and structural relationships among port logistics capability, port competitive advantage and port performance in container transport. The empirical research also supports the recognitions of the inner leverage power of logistics capability on port performance and the outer means value of logistics capability for port competitive advantage. Firstly, during the construction of port logistics capability in the era of global logistics and SCM integration, more attentions should be paid to the intangible factors e.g. strategic positioning, integration, operation and agility besides the infrastructure.

Table 39.3 Results from CFA model for PLC, PCA, PP

items	χ^2	*Df*	χ^2/df	p	RMSEA	CFI	NNFI
PLC[a]	421.56	154	2.74		0.079	0.91	0.92
POS	7.19	5	1.438	0.207	0.040	0.99	0.99
INT	3.348	3	1.116	0.490	0.035	0.99	0.97
INF	3.855	3	1.285	0.112	0.062	0.99	0.99
OPE	7.24	5	1.447	0.146	0.069	0.97	0.98
AGI	5.17	3	1.724	0.231	0.053	0.99	0.99
PCA[a]	221.88	85	2.61		0.072	0.94	0.91
PCC	8.872	4	2.218	0.174	0.053	0.98	0.99
SRV	9.452	4	2.363	0.369	0.042	0.99	0.99
MAR	5.526	3	1.842	0.203	0.032	0.97	0.97
PP[a]	201.40	95	2.12		0.076	0.92	0.93
PRO	4.854	2	2.427	0.197	0.051	0.98	0.99
FIN	5.502	3	1.834	0.492	0.045	0.98	0.97
SOC	9.615	5	1.923	0.182	0.068	0.99	0.99
SAT	6.966	3	2.322	0.177	0.071	0.99	0.99

Note: (1) [a]First-order items, (2) *RMSEA* root mean square error of approximation, *CFI* comparative fit index, *NNFI* nonnormed fit index

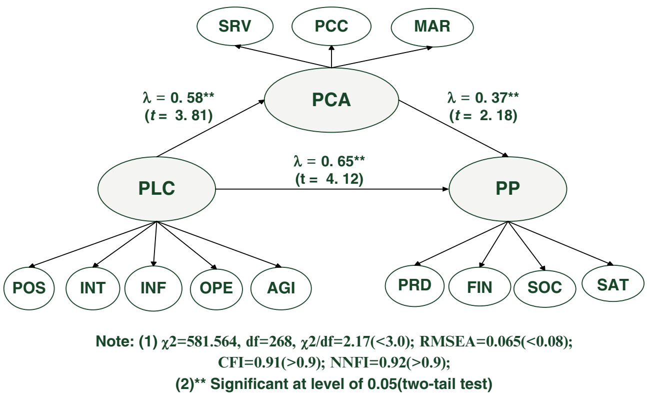


Fig. 39.2 Result of hypotheses test basing on SEM

Table 39.4 Statistics Results of structural equation model

H	Total effects	Direct effects	Indirect effects	Result
H1	0.86	0.65**(4.12)	$0.21 = 0.58 \times 0.37$	Support
H2	0.58**(3.81)	0.58**(3.81)		Support
H3	0.37**(2.18)	0.37**(2.18)		Support

Note: (1) $RMSR = 0.065$; $CFI = 0.91$; $NNFI = 0.92$; (2) **significant at $\alpha < 0.05$; (3) H1 for PLC → PCA, H2 for PLC → PCA and H3 for PCA → PP

Secondly, effectiveness-oriented performance counts for more in the all-around port performance evaluation which making breakthrough out of efficiency or financial-focus measurement limits. Thirdly, port competiveness advantage do has positive impacts on performance; whereas, port logistics capability can also convert the better perform in competitive market to the comprehensive promotions in production, finance, satisfactory perception and social performance.

Due to the limits in the samples and first-hand resource, there are some limitations in this research. (1) The absence of longitudinal and historical analysis basing on specific container port; (2) The lack of evaluation from the view of shipping lines, forwarders, consignee, and local community parties besides the angle of port itself. (3) Without the consideration of third-party for the investigation of service satisfactory. Further research in port logistics should be done to overcome the mentioned issues for more persuasive findings.

References

Bichou K, Gray R (2004) A logistics and supply chain management approach to port performance measurement. Marit Policy Manag 1(31):47–68

Bichou K, Gray R (2005) A critical review of conventional terminology for classifying seaports. Transport Res Part A Policy Pract 39(1):75–92

Brooks MR (2006) Chapter 25 Issues in measuring port devolution program performance: a managerial perspective. Res Transp Econ 17:599–629

Closs DJ, Goldsby TJ, Clinton SR (1997) Information technology influences on world class logistics capability. Int J Phys Distrib Logist Manag 27(1):4–17

Cullinane K, Song DW, Gray R (2002) A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures. Transport Res Part A Policy Pract 36(8):743–762

de Martino M, Morvillo A (2009) A new framework for port competitiveness: the network approach. Presented at the research in transport and logistics 2009 proceedings, Doğuş University, İstanbul

Estache A, Perelman S, Trujillo-Castellano L (2005) Infrastructure performance and reform in developing and transition economies: evidence from a survey of productivity measures. World Bank policy research working paper No. 3514

Gilmour P (1999) A strategic audit framework to improve supply chain performance. J Bus Ind Mark 14(5/6):355–366

Kuang HB, Li HZ (2009) Chinese port X-efficiency measurement (in Chinese). Syst Eng Theory Pract 29(2):1–9

Lai KH, Ngai EWT, Cheng TCE (2002) Measures for evaluating supply chain performance in transport logistics. Transport Res Part E Logist Transport Rev 38(6):439–456

Langen P, Nijdam M, Horst M (2007) New indicators to measure port performance. J Marit Res 4 (1):23–36

Lirn TC, Thanopoulou HA, Beresford AKC (2003) Transhipment port selection and decision-making behaviour: analysing the Taiwanese case. Int J Logist Res Appl 6(4):229–244

Bowersox et al (1995) The global logistics research team, world class logistics: the challenge of managing continuous change. Council of Logistics Management, Oak Brook, pp 418–423

Notteboom TE (2002) Consolidation and contestability in the European container handling industry. Marit Policy Manag 29(3):257–269

Notteboom TE, Winkelmans W (2001) Structural changes in logistics: how will port authorities face the challenge? Marit Policy Manag 28(1):71–89

Olavarrieta S, Ellinger EA (1997) Resource-based theory and strategic logistics research. Int J Phys Distrib Logist Manag 27(9/10):559–587

Paixão AC, Marlow PB (2003) Fourth generation ports: a question of agility? Int J Phys Distrib Logist Manag 33(4):355–376

Robinson R (2002) Ports as elements in value-driven chain systems: the new paradigm. Marit Policy Manag 29(3):241–255

Rodrigue JP, Notteboom TE (2009) The terminalization of supply chains: reassessing the role of terminals in port/hinterland logistical relationships. Marit Policy Manag 36(2):165–183

Song DW (2008) Global supply chain and port/terminal: integration and competitiveness. Marit Policy Manag 35(1):73–87

Talley WK (2006) Chapter 22 Port performance: an economics perspective. Res Transp Econ 17:499–516

Winkelmans W (2008) Port governance and stakeholder relations management. Presented at the current trends and practices in the organisation operation and management of ports and port terminals, Thessaloniki, Greece

Chapter 40
Socially Responsible Supply Chain Coordination from Brand Equity Perspective

Rong Wang and S.H. Ying

Abstract The issues in socially responsible supply chain coordination from brand equity perspective are discussed in the current study. Socially responsible supply chain coordination that integrates all efforts of CSR initiatives from brand distributors to upstream partner-suppliers shall be surely needed within the uncertainly globalizing and networklizing knowledge economy era. This paper develops a five-step CSR performance evaluation from brand equity perspective for modeling and analysis of socially responsible supply chain coordination and shows relevant optimal coordination strategies to improve and reconcile economic, social and environmental benefits of all partners in the socially responsible supply chain system.

Keywords CSR • Socially Responsible Supply Chain • Supply Chain Coordination • Brand Equity Perspective

Introduction

China has become the world's second largest economy, with Japan surrendering its 42-year-old ranking after its economy shrank in the final months of 2010. According to the primary accounting statistics issued by National Bureau of Statistics of China on February 22, 2012, China's annual GDP in 2011 is 47,156.4 billion yuan (7.3 trillion U.S. dollars), up by 9.2% over the previous year and more than 90-times bigger than the 1978 introduction of economic reforms with 364.5 billion yuan (216.4 billion U.S. dollars), exhibited in Fig. 40.1.

R. Wang (✉)
Department of Operations Management, Antai College of Economics and Management, Shanghai Jiao Tong University, Shanghai, P.R. China
e-mail: rwang@sjtu.edu.cn

S.H. Ying
SIPT Institute, SIPM Information Technology Corporation, Shanghai, P.R. China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_40,

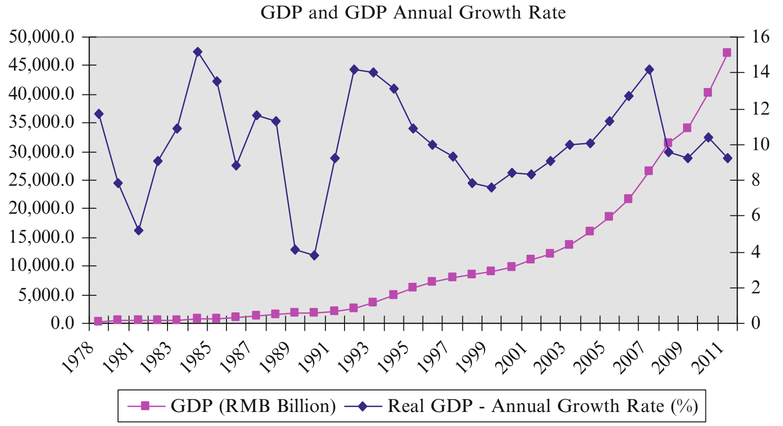


Fig. 40.1 China GDP and GDP Annual Growth Rate in 1978–2011 (Source: Created from Statistical Communiqué on the Annual National Economic and Social Development, National Bureau of Statistics of China, 1978–2011; China Statistical Yearbook 1978–2011)

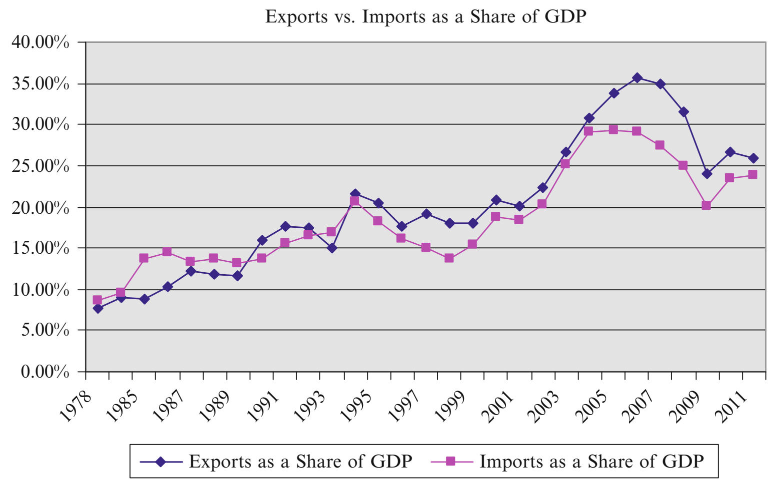


Fig. 40.2 China Exports and Imports as a Share of GDP in 1978–2011 (Source: Created from Statistical Communiqué on the Annual National Economic and Social Development, National Bureau of Statistics of China, 1978–2011; China Statistical Yearbook 1978–2011)

As illustrated in Fig. 40.2, China's annual total foreign trade in 2011 reaches 3.6421 trillion U.S. dollars, up by 22.5% over the previous year and more than 175-times bigger than the foreign trade volume 20.6 billion U.S. dollars in 1978. After more than 30 years of development since the launch of the reform and opening-up policy, China now is the world's biggest exporter and the world's second largest importer, with annual exports up 20.3% to $1.8986 trillion and annual imports up 24.9% to $1.7435 trillion in 2011. It is now well known that China is one of the three pillars of the global economy together with the United States and the European Union.

However, a serious urgent issue of global consequences as well as a major obstacle in the process of China's economic development is a lack of corporate social responsibility involving in consumer responsibility, transaction process responsibility, employee responsibility, community responsibility, environment responsibility, and so forth.

The issue of social responsibility is first presented by Bowen who sets forth an initial definition of the social responsibilities of businessmen: "It refers to the obligations of businessmen to pursue those policies, to make those decisions, or to follow those lines of action which are desirable in terms of the objectives and values of our society" (Bowen 1953). Carroll traced the evolution of the Corporate Social Responsibility (CSR) concept and proposed a universal four-part definition of CSR as following: "The social responsibility of business encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time" (Carroll 1979, 1991). Wartick and Coghran traced the evolution of the corporate social performance model by focusing on three challenges to the concept of CSR: economic responsibility, public responsibility, and social responsiveness (Wartick and Coghran 1985).

The green business guru Elkington convincingly argues that twenty first century business leaders should satisfy the triple bottom line that is economic, social and environmental sustainability (Elkington 1998). According to the standard definition of the European Commission which describes CSR as "a two-dimensional concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis" (Commission of the European Communities 2001).

Nowadays the general agreement on the new notion of "product" is defined not only embedding with goods and services, but also social and environmental behaviors and obligations. And the companies shall commit to social accountable conduct, full compliance to applicable national and international laws and respect for human rights in the spirit of internationally recognized social accountable standards, such as SA8000 (Larson and Cox 2003). The SAI's first social accountability system, SA8000, is a way for retailers, brand firms, suppliers and other organizations to maintain just and decent working conditions throughout the supply chain. Furthermore the SA8000 firms are required to apply these same standards to their own suppliers and to support this through monitoring social accountable practices.

CSR issues surrounding supply chains have only recently come to the fore, notably, in the context of conceptual and survey studies. Carter and Dresner examined environmental risks in supply management based on case studies that tapped the perspectives of purchasing managers and the managers in multiple, additional functional areas with whom they interacted when initiating environmental projects (Carter and Dresner 2001). Roberts concerned labor practices of ethical sourcing initiatives and effective approaches to managing sustainability issues in supply networks (Roberts 2003). Carter and Jennings empirically identified the dimensions of purchasing involvement in CSR and applied the label purchasing social responsibility (PSR) (Carter and Jennings 2004). Wang focused on social responsible supply coordinating relationship and strategies based on the social responsible "relational rent" (Wang 2005). Cruz considered the behaviors of various decision makers on the impact of corporate social responsibility in supply chain management and showed that social responsibility activities can potentially reduce transaction costs, risk and environmental impact (Cruz 2009).

Nevertheless, socially responsible supply chain coordination that integrates all efforts of CSR initiatives from brand distributors to upstream partner-suppliers shall be surely needed within the uncertainly globalizing and networklizing knowledge economy era. The current study develops a CSR performance evaluation from brand equity perspective for modeling and analysis of socially responsible supply chain coordination and shows relevant optimal coordination strategies to improve and reconcile the economic, social and environmental benefits of all partners in the socially responsible supply chain system.

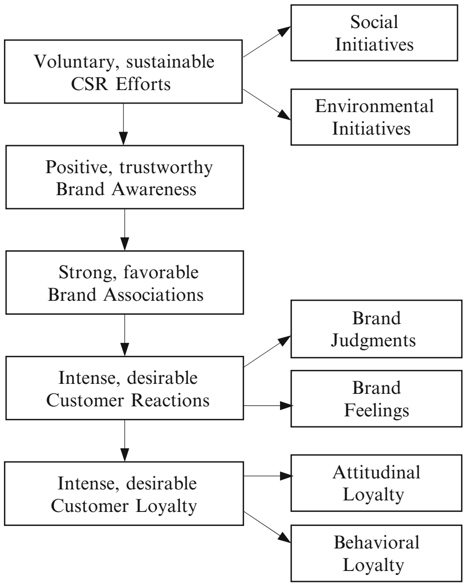
CSR Performance Evaluation from Brand Equity Perspective

Many management research literatures confirm that CSR has positive and distinct effects on financial value of brand equity (Sen and Bhattacharya 2001; Brammer and Pavelin 2004; Fombrun 2005; Tingfeng et al. 2007; Zhou and Zhang 2007; Chi-Shiun 2009; Haiqin 2010; Hoyer and Brown 1990). Keller defines customer-based brand equity as the differential effect of brand knowledge on consumer response to the marketing of the brand and conceptualizes that customer-based brand equity occurs when the consumer holds some strong, favorable, and unique brand associations in memory. As to how to build customer-based brand equity, Keller designed the classical Customer-Based Brand Equity (CBBE) model thought of four steps, where each step is contingent on successfully achieving the previous step (Keller 1993, 2001). According to the CBBE model, the first step is to establish the proper brand identity, that is, establish breadth and depth of brand awareness. The second step is to create the appropriate brand meaning through strong, favorable, and unique brand associations. The third step is to elicit positive, accessible brand responses. Furthermore, these brand responses can be distinguished according to brand judgments and brand feelings depending on whether they stem from the head or heart (Keller 2007). And the final step is to forging brand relationships with customers that are characterized by intense, active brand loyalty.

Chaudhur and Holbrook emphasized that the brand Loyalty can be broken down into two key dimensions: behavioral loyalty (as well as purchase loyalty) and attitudinal loyalty. The behavioral loyalty consists of repeated purchases of the brand, whereas the attitudinal loyalty includes a degree of dispositional commitment in terms of some unique value associated with the brand (Chaudhuri and Holbrook 2001). Both attitudinal loyalty and behavioral loyalty link to better corporate reputation (or corporate goodwill) with greater market share and premium in the marketplace.

Therefore, on the basis of the fore research literatures, especially, the standard CSR definition of the European Commission and the Keller's customer-based brand equity model (Commission of the European Communities 2001; Keller 2001, 2007), this paper proposes a five-step CSR performance evaluation from brand

Fig. 40.3 CSR performance evaluation from brand equity perspective



equity perspective in Fig. 40.3 for modeling and analysis of socially responsible supply chain coordination, which maps out component analysis and management of CSR brand equity.

The critical components and the key drivers of the five-step CSR performance evaluation from brand equity perspective are identified as follows: voluntary and sustainable CSR effort; positive and trustworthy brand awareness; strong and favorable brand associations; intense and desirable customer reactions; and intense and desirable customer loyalty.

Models and Assumptions

For analytical convenience, the modeling framework considering the socially responsible supply chain with two members: one brand firm and one upstream partner-supplier. Firstly, the notations and assumptions in the models developed will be stated in details as following:

It is clearly seen from Fig. 40.3, since the voluntary and sustainable CSR efforts are important in building CSR brand equity regarded as vital intangible assets to corporate equity, which is determined by better corporate reputation or corporate goodwill with greater market share and premium in the marketplace.

Suppose the brand firm and his partner-supplier can exert the total investment on CSR efforts e_m and e_s, respectively. Clearly it can generate the market demand functions about aggregate impact of both investment parameters $D(e_m, e_s)$ and can let $D(e_m, e_s)$ be continuously differentiable on $(e_m, e_s) \in (0, \infty) \times (0, \infty)$ and using right-hand derivatives at 0, strictly increasing in both parameters. And then we find the brand firm's expected market demand under the sort of goodwill is

$$D(e_m, e_s) = D_0 - {e_m}^{-\alpha} {e_s}^{-\beta} \tag{40.1}$$

where D_0, α and β are constants; α and β is the leverage rate of CSR efforts e_m and e_s, respectively, $\alpha \geq 0$, $\beta \geq 0$; D_0 is the potential market demand which is implemented relying on both CSR efforts e_m and e_s, that is, either e_m or e_s is 0, the actual market demand $D(e_m, e_s)$ shall turn to be disappeared due to the infinitely negative leverage rate of CSR efforts e_m or e_s.

Next consider the brand firm and his partner-supplier can gain the marginal revenue MR_m and MR_s, respectively, and suppose MR_m and MR_s are constants for analytical convenience. We now show that the brand firm's and his partner-supplier's expected revenue function under the sort of goodwill is as shown by express (40.2) and (40.3), respectively:

$$\begin{aligned} \pi_m(e_m, e_s) &= MR_m \cdot D(e_m, e_s) - e_m \\ &= MR_m \cdot (D_0 - {e_m}^{-\alpha} {e_s}^{-\beta}) - e_m \end{aligned} \tag{40.2}$$

$$\begin{aligned} \pi_s(e_m, e_s) &= MR_s \cdot D(e_m, e_s) - e_s \\ &= MR_s \cdot (D_0 - {e_m}^{-\alpha} {e_s}^{-\beta}) - e_s \end{aligned} \tag{40.3}$$

At first, from the view in non-cooperative static games, the two members choose strategies simultaneously and are thereafter committed to their chosen strategies, i.e., these are simultaneous move, one-shot games. So we have the following:

$$\begin{aligned} &\underset{r, e_s}{Max}\, \pi_m = \underset{r, e_s}{Max} \left[MR_m \cdot (D_0 - {e_m}^{-\alpha} {e_s}^{-\beta}) - e_m \right] \\ &s.t. 0 \leq r \leq 1, e_s \geq 0 \end{aligned} \tag{40.4}$$

$$\begin{aligned} &\underset{r, e_m}{Max}\, \pi_s = \underset{r, e_m}{Max} \left[MR_s \cdot (D_0 - {e_m}^{-\alpha} {e_s}^{-\beta}) - e_s \right] \\ &s.t. 0 \leq r \leq 1, e_m \geq 0 \end{aligned} \tag{40.5}$$

From differentiation,

$$\frac{\partial \pi_m}{\partial e_m} = MR_m \cdot \alpha {e_m}^{-\alpha - 1} {e_s}^{-\beta} - 1 = 0 \tag{40.6}$$

$$\frac{\partial \pi_s}{\partial e_s} = MR_s \cdot \beta {e_m}^{-\alpha} {e_s}^{-\beta - 1} - 1 = 0 \tag{40.7}$$

Thus the Nash equilibrium in non-cooperative static games is found

$$e_m{}^* = \left(\frac{1}{MR_m \cdot \alpha e_s{}^{-\beta}}\right)^{\frac{1}{-\alpha-1}} = \left[\frac{(\alpha \cdot MR_m)^{\beta+1}}{(\beta \cdot MR_s)^{\beta}}\right]^{\frac{1}{\alpha+\beta+1}} \tag{40.8}$$

$$e_s{}^* = \left(\frac{1-r}{MR_s \cdot \beta e_m{}^{-\alpha}}\right)^{\frac{1}{-\beta-1}} = \left[\frac{(\beta \cdot MR_s)^{\alpha+1}}{(\alpha \cdot MR_m)^{\alpha}}\right]^{\frac{1}{\alpha+\beta+1}} \tag{40.9}$$

As $\alpha \geq 0, \beta \geq 0$, observe the above express (40.9) that the optimal strategy $e_m{}^*$ and $e_s{}^*$ are positive relevant with the member's marginal revenue (i.e. MR_m, MR_s) and the leverage rate of CSR efforts (i.e. α, β) respectively, whereas negative relevant with the partner's marginal revenue (i.e. MR_s, MR_m) and the leverage rate of CSR efforts (i.e. β, α), respectively. In other words, no one of them has incentive to implement pareto optimal policy for socially responsible supply chain coordination in non-cooperative static games.

Cost Sharing Contract Coordination

Next considering in the case of socially responsible supply chain coordination strategy with cost sharing contract, the brand firm shall provide seriously a share rate of $r(0 \leq r \leq 1)$ of the total investment of partner-supplier's CSR efforts e_s, while the upstream supplier will be proposed a share of $1 - r$, $(0 \leq r \leq 1)$.

Consequently, as the Stackelberg follower, the supplier makes his own investment strategy of the CSR efforts is dependent upon the corresponding "share rate" of coordination strategy with cost sharing contract of his downstream partner-firm. For the brand firm may offer a "share rate" as the incentive for the supplier to increase CSR efforts and to be socially responsible partner integrated into the social responsible supply chain so as to improve his own aggregate goodwill. Thus it can be seen, as the Stackelberg leader, the brand firm must make the investment and "share rate" of coordination strategy with cost sharing contract first and then the partner-supplier observes this strategy and makes his own investment strategy choice.

Consider the above Stackelberg equilibrium policy, letting the brand firm first make investment level e_m on his own CSR efforts and "share rate" r of the investment of partner-supplier's CSR efforts.

In virtue of backwards induction, firstly, find the supplier's optimal CSR policy as a response to any strategies made by the Stackelberg leader:

$$\begin{aligned}\frac{\partial \pi_s}{\partial e_s} &= \frac{\partial[MR_s \cdot (D_0 - e_m{}^{-\alpha} e_s{}^{-\beta}) - (1-r)e_s]}{\partial e_s} \\ &= MR_s \cdot \beta e_m{}^{-\alpha} e_s{}^{-\beta-1} - (1-r) = 0\end{aligned} \tag{40.10}$$

Therefore, the investment of partner-supplier's CSR efforts generated is expressed as following

$$e_s^{**} = \left(\frac{\beta \cdot MR_s}{(1-r) \cdot e_m{}^{\alpha}}\right)^{\frac{1}{\beta+1}} \tag{40.11}$$

As $\alpha \geq 0, \beta \geq 0, 0 \leq r \leq 1$, then the following propositions may be given from the express (11),

Proposition 1. The optimal strategy e_s^{**} for partner-supplier is positive relevant with the "share rate" r, besides his marginal revenue (i.e. MR_s) and his leverage rate of CSR efforts (i.e. β);

Proposition 2. The optimal strategy e_s^{*} is negative relevant with his partner-firm exerting the total investment on CSR efforts e_m and leverage rate of CSR efforts $\boldsymbol{\alpha}$**.**

From these two propositions, it can be able to observe that, in addition to the marginal revenue MR_s and leverage rate of CSR efforts β, the partner-supplier only has incentive to increase his investment on CSR efforts as the brand firm increases the "share rate" r. Even if the brand firm solely increases investment level e_m and the leverage rate α on his own CSR efforts, his partner-supplier prefer to be a "free-rider" of partner's goodwill effect so as to have incentive to reduce the investment on CSR efforts instead.

Secondly, find the optimal CSR policy for the brand firm anticipating the response by his partner-supplier.

$$\begin{aligned} &\underset{r,e_s}{Max}\, \pi_m = \underset{r,e_s}{Max}\left[MR_m \cdot (D_0 - e_m{}^{-\alpha} e_s{}^{-\beta}) - e_m - re_s\right] \\ &s.t.\ 0 \leq r \leq 1, e_s \geq 0 \end{aligned} \tag{40.12}$$

Intuitively, the brand firm chooses the best possible point on his follower's best response function.

$$\begin{aligned} &\underset{r,e_s^{**}}{Max}\, \pi_m = \underset{r,e_s^{**}}{Max}\left\{MR_m \cdot [D_0 - e_m{}^{-\alpha}(e_s{}^{**})^{-\beta}] - e_m - r(e_s{}^{**})\right\} \\ &s.t.\ 0 \leq r \leq 1, e_s{}^{**} \geq 0 \end{aligned} \tag{40.13}$$

From differentiation,

$$\frac{\partial \pi_m}{\partial r} = \frac{\partial \{MR_m \cdot [D_0 - e_m{}^{-\alpha}(e_s{}^{**})^{-\beta}] - e_m - r(e_s{}^{**})\}}{\partial e_m} = 0 \tag{40.14}$$

Then,

$$r^{**} = \frac{\frac{MR_m}{MR_s} - (\beta + 1)}{\frac{MR_m}{MR_s} - \beta}, \frac{MR_m}{MR_s} \geq \beta + 1 \tag{40.15}$$

Considering $0 \le r \le 1$, only as $\frac{MR_m}{MR_s} \ge \beta + 1$, the brand firm shall provide the "share rate" $r(0 \le r \le 1)$ for partner-supplier's CSR efforts. And propositions is given below,

Proposition 3. The "share rate" r is positive relevant with firm's marginal revenue (i.e. MR_m);

Proposition 4. The "share rate" r is negative relevant with his partner-supplier's marginal revenue MR_s and his leverage rate of CSR efforts β.

In the same way from differentiation,

$$\frac{\partial \pi_m}{\partial e_m} = \frac{\partial \{MR_m \cdot [D_0 - e_m{}^{-\alpha}(e_s{}^{**})^{-\beta}] - e_m - r(e_s{}^{**})\}}{\partial e_m} = 0 \qquad (40.16)$$

Then we have the following Stackelberg equilibrium policy,

$$\begin{cases} e_m{}^{**} = \left[\alpha^{\beta+1}\left(\frac{1}{\beta}\right)^{\beta} \cdot (MR_m - \beta \cdot MR_s)\right]^{\frac{1}{\alpha+\beta+1}}, \\ \frac{MR_m}{MR_s} \ge \beta + 1 \end{cases} \qquad (40.17)$$

As $\alpha \ge 0$, $\beta \ge 0$ and $\frac{MR_m}{MR_s} \ge \beta + 1$, then the following propositions may be given,

Proposition 5. The firm's optimal strategy $e_m{}^{**}$ is positive relevant with his marginal revenue MR_m and leverage rate of CSR efforts α, whereas negative relevant with the partner's marginal revenue MR_s and the leverage rate of CSR efforts β.

Aggregating the Propositions (1) and (5), it can be reached the "share rate (r)" shall be the critical contract clause to coordinate the socially responsible supply chain to implement Pareto optimal policy with cost sharing contract.

Conclusion

The purpose of the current study is to develop a five-step CSR performance evaluation from brand equity perspective for modeling and analysis of socially responsible supply chain coordination and show relevant optimal coordination strategies to improve and reconcile economic, social and environmental benefits of all partners in the socially responsible supply chain system.

The critical components and the key drivers of the five-step CSR performance evaluation from brand equity perspective are identified as follows: voluntary and sustainable CSR effort; positive and trustworthy brand awareness; strong and favorable brand associations; intense and desirable customer reactions; and intense and desirable customer loyalty.

From all propositions in the socially responsible supply chain coordination strategy with cost sharing contract, it notes that the "share rate (r)" shall be the critical contract clause to coordinate the socially responsible supply chain to implement Pareto optimal policy in Stackelberg games to achieve the fully integrated social responsible supply chain performance, along with improving and reconciling economic, social and environmental benefits of all partners in the socially responsible supply chain system.

References

Bowen HR (1953) Social responsibilities of the businessman. Harpor & Row, New York, p 44
Brammer S, Pavelin S (2004) Building a good reputation. Eur Manag J 12:704–713
Carroll AB (1979) A three-dimensional conceptual performance. Acad Manag Rev 4(4):497–505
Carroll AB (1991) The pyramid of corporate social responsibility: toward the moral management of organizational stakeholders. Bus Horiz 34(4):39–42
Carter CR, Dresner M (2001) Environmental purchasing and supply management: crossfunctional development of grounded theory. J Supply Chain Manag 37(3):12–27
Carter CR, Jennings MM (2004) The role of purchasing in corporate social responsibility: a structural equation analysis. J Bus Logist 25(1):145–186
Chaudhuri A, Holbrook MB (2001) The chain of effects from brand trust and brand affect to brand performance: the role of brand loyalty. J Mark 65(4):81–93
Chi-Shiun (2009) The effects of corporate social responsibility on brand performance. J Bus Eth 87:71–89
Commission of the European Communities (2001) Promoting a European framework for corporate social responsibility. Green paper No. COM (2001) 366 final, Brussels
Cruz JM (2009) The impact of corporate social responsibility in supply chain management: multicriteria decision-making approach. Decis Support Syst 48:224–236
Elkington J (1998) Cannibals with forks: the triple bottom line of 21st century business. New Society Publishers, Gabriola Island
Fombrun CJ (2005) Building corporate reputation through CSR initiatives: evolving standards. Corp Reput Rev 8(1):7–11
Haiqin L (2010) An empirical study on the effects of corporate social responsibility on corporate reputation and customer loyalty. Nankai Bus Rev 13(1):90–98
Hoyer WD, Brown SP (1990) Effects of brand awareness on choice for a common, repeat-purchase product. J Consum Res 17(2):141–148
Keller KL (1993) Conceptualizing, measuring, and managing customer-based brand equity. J Mark 57(1):1–22
Keller KL (2001) Building customer-based brand equity. Mark Manag 10(2):14–19
Keller KL (2007) Strategic brand management: building, measuring, and managing brand equity, 3rd edn. Pearson Education, New York
Larson ER, Cox B (2003) Social accountability 8000: measuring workplace conditions worldwide. Qual Dig 18:26–29, CEPAA, New York, NY 10003
Roberts S (2003) Supply chain specific? Understanding the patchy success of ethical sourcing initiatives. J Bus Eth 44(2/3):159–170
Sen S, Bhattacharya CB (2001) Does doing good always lead to doing better? Consumer reactions to corporate social responsibility. J Mark Res 2(38):225–243
Tingfeng Z, Wenjian X, Guang H (2007) The review of corporate social responsibility based on the consumer's perspective. Consum Econ 23(4):95–97

Wang R (2005) Social responsible supply coordinating relationship and strategies under supply chain. In: Proceedings of the 12th international conference on management science and engineering, ICMSE'05, Inchon, South Korea, pp 685–689

Wartick SL, Coghran PL (1985) The evolution of the corporate social performance model. Acad Manag Rev 10(4):758–769

Zhou ZC, Zhang YJ (2007) The empirical study between the relative level of corporate social responsibility and purchase in-tention. China Ind Econ 9:111–118

Chapter 41
Prediction Analysis of Logistics Demand in ShanXi Province Based on Gray System Theory

Hai-lan Wang and Dao-zhi Zhao

Abstract With the resource-based economy transition in Shanxi Province, the demand of logistics and freight will be further increased in the future, it is necessary to analyze the history and estimate further logistics demand in Shanxi Province. This paper regards gray systematic theory as guidelines, based on the present situation of logistics demand and actual data in Shanxi province, establishes a gray forecast GM(1, 1) model, then forecasts the next 5 years logistics demand of Shanxi province, based on this, develops the logistics development plan from the government level and corporate level, according to some calculation, which could provide a quantitative base for government to plan the development of logistics.

Keywords Forecasting • GM(1, 1) • Logistics demand • Model

Introduction

Shanxi is an important energy resource province in China's Midwest junction, exploiting the accessibility of geographical advantages and energy chemical industry base of industrial advantages, a modern logistics center is actively building around the Bohai Sea, the Yellow River region, and logistics demand and freight volume are presenting increasing trend by degrees year after year. Meanwhile, with the resource-based economy transition in Shanxi Province, comprehensive reform pilot area is approved, it can foresee that the future of logistics and freight demand will further increase, logistics services of the road logistics industry will also be

H.-l. Wang (✉)
School of Management, Tianjin University, Tianjin, China

Department of Military Logistics, The Academy of Military Transportation, PLA, Tianjin, China
e-mail: wang_hailan@163.com

D.-z. Zhao
School of Management, Tianjin University, Tianjin, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_41,

further enhanced. Therefore, it is necessary to analyze the history of logistics demand in Shanxi Province to predict future demand for logistics.

There have been lots of logistics analysis and forecasting researches based on gray system theory, most of the scholars establish model then predict based on existing historical data. Xianbing Ping establishes a theoretical model based on gray system, then applies DPS9.50 standard edition to test the accuracy, which has a certain credibility and scientific (Xianbing Ping 2010). Fangbing Niu predicts the logistics demand in Shandong in the next 5 years according to GM(1, 1) model and actual data (Fangbing Niu 2011). As the founder of the gray system theory, Julong Deng analysis the gray system at the theoretical level deeply (Hassan and Gibreel 2000). Hassan Y puts forward the principle of consistency and safety evaluation on demand forecast (Murray and Mahmassani 2003). These research results provide a theoretical and methodological basis for this paper research.

The paper establishes a gray forecast GM(1, 1) model, then forecasts the next several years logistics demand of Shanxi province, according to some calculation. Different from the other papers, the paper is not limited by model data, but based on this, develops the logistics development plan from the government level and corporate level, according to the characteristics and trends of the logistics needs as well as the fair market analysis and research.

Construction of the Gray Predicting Model

Logistics system, much interfered by unpredictable factors, is a complex and uncertain system, it not only contains certain information but also contains unknown or uncertain information. Uncertain method is needed to forecast the logistics system, while gray system theory, which study and predict unknown information by known information, is providing a new way to solve the systematic problem of poor information. Based on the Gray system theory, this paper constructs a gray system theory Model of the planning of logistics industry in Shanxi Province, GM(Gray Model) can make global observation of the development and changement of the studying system, and also analyze and make long-term forecasts (Julong Deng 1998). It is the most common model with only one variable in first order differential equation prediction model, the base of the gray forecast. The model requires data with less simple in principle, calculate the amount of moderate, high precision results and many other advantages, and on this basis, make a scientific prediction of the logistics needs of Shanxi province.

Calculation Steps

First step: suppose the original sequence of number as

$$x^{(0)}(t) = (x^{(0)}(1), x^{(0)}(2), \ldots x^{(0)}(n))$$

Second step, make a accumulated generating operation to generate a new sequence of number as

$$x^{(1)}(t) = (x^{(1)}(1), x^{(1)}(2), \ldots x^{(1)}(n))$$

Among them:

$$x^{(1)}(t) = \sum_{k=1}^{t} x^{(0)}(k)$$

And $x^{(0)}(1) = x^{(1)}(1)$ $k = 1, 2, \ldots, n$
Third step: Construct matrix B and
vector Y_n

$$B = \begin{bmatrix} -(x^{(1)}(1) + x^{(1)}(2))/2 & 1 \\ -(x^{(1)}(2) + x^{(1)}(3))/2 & 1 \\ \vdots & \vdots \\ -(x^{(1)}(n-1) + x^{(1)}(n))/2 & 1 \end{bmatrix}$$

$$Y_n = (x^{(0)}(2), x^{(0)}(3), \ldots x^{(0)}(n))^T$$

Use least square method to get the coefficients a and b

$$P = \begin{pmatrix} a \\ b \end{pmatrix} = (B^T B)^{-1} B^T Y_n$$

Fourth step: get the GM(1, 1)model

$$\begin{cases} \hat{x}^{(1)}(k+1) = (x^{(0)}(1) - b/a)e^{-ak} + b/a & (41.1) \\ \hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) & (41.2) \end{cases}$$

Equations (41.1) and (41.2) are predictive equation of the GM(1, 1) model, $\hat{x}^{(0)}(k+1)$ is predicted value, $-a$ is development coefficient. b is gray action, $-a$ reflects the development trend of $\hat{x}^{(1)}$ and $\hat{x}^{(0)}$.

Accuracy Analysis

First step: to test the applicability of the GM(1, 1) model.
When $-a \leq 0.3$, GM(1, 1)can be used for long term forecasting; when $0.3 < -a \leq 0.5$, GM(1, 1) can be used for short-term forecasts and long-term forecast use with caution; when $0.5 < -a \leq 0.8$, GM(1, 1) for short-term forecasts should be

Table 41.1 Testing of the accuracy grade reference table

The grade of accuracy of critical value	Mean variance ratio C	Small error probability p
Good	≤ 0.35	≥ 0.95
Qualified	≤ 0.50	≥ 0.80
Unsatisfactory	≤ 0.65	≥ 0.70
Fail	>0.65	<0.70

very cautious, when $0.8 < -a \leq 1$, should use residual fixed GM(1, 1) model; when $-a > 1$, should not use the GM(1, 1) model (Hauser John and Don Clausing 1988; Cong Peng 2012).

Second step: using a posteriori residual to test precision of the GM(1, 1) model. The mean and variance of the original data:

$$\bar{x}_i^{(0)} = \frac{1}{n}\sum_{i=1}^{n} x_i^{(0)} \quad s_x{}^2 = \frac{1}{n}\sum_{i=1}^{n}\left(x_i^{(0)} - \bar{x}^{(0)}\right)^2 \quad s_x = \sqrt{\frac{s_x{}^2}{n-1}} \tag{41.3}$$

Residual mean and residual variance:

$$\bar{\varepsilon}^{(0)} = \frac{1}{n}\sum_{i=1}^{n} \varepsilon_i^{(0)} \quad s_\varepsilon{}^2 = \frac{1}{n}\sum_{i=1}^{n}\left(\varepsilon_i^{(0)} - \bar{\varepsilon}^{(0)}\right)^2 \quad s_\varepsilon = \sqrt{\frac{s_\varepsilon{}^2}{n-1}} \tag{41.4}$$

A posteriori residual ratio C and small error probability p:

$$C = s_\varepsilon / s_x$$

$$p = P\left\{\left|\varepsilon^i - \bar{\varepsilon}^{(0)}\right| < 0.6745 s_x\right\} \tag{41.5}$$

According to the value C or p, contrast with form of the gray prediction model's precision grade, to ascertain the precision of the model, as is shown in Table 41.1.

Construct and Test the Logistics Demand Prediction Model

Selection of Predictors

During the whole logistics process, transport is a fundamental activity. Although the demand for transport can not reflect all of the logistics needs, throughout the logistics activities, it is the key link to achieve the displacement in the logistics course, bond to contact the other logistics services, it can determine the amount of the logistics. According to statistics, the region's annual transportation costs

Table 41.2 The actual volume of Freight and Forecast Volume of Freight Statistics (2001–2010) million tons

Year	Actual volume	Forecasting volume	Offset value
2001	61,489	61,489	0
2002	65,098	64,364	734
2003	67,671	67,245	426
2004	72,621	72,223	398
2005	76,201	76,879	–678
2006	78,513	79,294	–781
2007	82,084	81,396	688
2008	66,709	67,973	−1,264
2009	54,786	53,545	1,241
2010	60,819	59,896	923

accounted for more than half of the total cost of logistics. Therefore, the amount of logistics needs is based on the traffic volume, and traffic is generally be measured based on volume of freight.

Data provided by the Shanxi Statistical Yearbook, volume of freight during 2001–2010 is used as reference quantity for model forecast to represent the actual logistics demands, based on this, the paper build a gray forecasting model, the specific data shown in Table 41.2.

Analysis of Model Data

First, set up the sequence of volume of freight as

$$x^{(0)}(t) = (61489, 65098, 67671, 72621, \ldots 54786, 60819)$$

Second, make a accumulated generating operation to generate a new sequence of number as

$$x^{(1)}(t) = (61489, 126587, 194258, 266879, \ldots 685991)$$

Cumulative matrix as:

$$B = \begin{bmatrix} -\frac{1}{2}(61489 + 126587) & 1 \\ -\frac{1}{2}(126587 + 194258) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(570386 + 625172) & 1 \\ -\frac{1}{2}(625172 + 685991) & 1 \end{bmatrix} Y = \begin{bmatrix} 65098 \\ 67671 \\ 72621 \\ \vdots \\ 54786 \\ 60819 \end{bmatrix}$$

$$P = \begin{pmatrix} a \\ b \end{pmatrix} = \left(B^T B\right)^{-1} B^T Y_n = \begin{pmatrix} -0.069003 \\ 52712.315 \end{pmatrix}$$

Then calculated, $-a = 0.069003 \leq 0.3$, therefore, here can use for long-term forecasting.

Calculated to get the Shanxi Province logistics needs GM(1, 1), as follows:

$$\begin{cases} \hat{x}^{(1)}(k+1) = 863377e^{0.069003k} - 763913 & (41.6) \\ \hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) & (41.7) \end{cases}$$

According to formula (41.7), then calculate the predicted value and relative error of the logistics needs of 2001–2010 shown as Table 41.2. Put the relevant data into (41.3), (41.4) and (41.5) and make a posteriori residual test, will get the result as:

$$C = 0.12431 < 0.35, \quad p = 0.96 > 0.95$$

Therefore, it is believed that the model can be applied with good accuracy (Tianshe Yang et al. 2005; Zhuwen et al. 2004; Yufeng et al. 2004).

Discussion

Through Gray theory model predictions, we can get that logistics demand of Shanxi in the year of 2011–2014 are 620.19 million tons, 641.19 million tons, 717.19 million tons, 867.37 million tons, showing increasing trend. These data largely provided decision-making basis for the relevant departments to develop appropriate logistics policies. In addition, from the data in Table 41.2, it can be seen that the freight volume in 2005–2007 are in good posture, increased from 762.01 million tons in 2005 to 820.84 million tons, due to the impact of financial crisis, the volume of cargo in 2008 reduced, reduced to 667.09 million tons, to a certain extent, indicating that the logistics industry was damaged. However, with the global economic recovery, internal and external trade will become more active, so demand for logistics will further increase (Ji-ying Zhang and Peng Xiao 2011; Ruo-bing Yu 2011; Bin 2011; Xian-zhen Guo et al. 2011; Ping-fan Liao et al. 2012).

With the implementation and promulgation of the "logistics industry restructuring and revitalization of planning", in order to promote modern logistics industry in Shanxi Province in transition leaps and bounds, scientifically and rationally plan and construct logistics service system, enable it to meet the further needs of economic development, to take a more refined, accurate and effective measures to accelerate industrial upgrading of the road logistics, continue to vigorously develop modern logistics industry is essential. Therefore, I recommend:

From the View of Government to Industry

First, accelerate the introduction of policies to encourage and support in the construction and operation of logistics parks or road freight hub, in the priority of the arrangement on land using, enjoy the policy of industrial land; allows for logistics enterprises implement the state-owned construction leaseholds years rent system. through the leasing of state-owned land tenancy, annual rent is to reduce the cost of inputs of the one-time land of enterprises.

The second is to establish and promote a modern logistics coordination mechanism, and drawn up regulations, implementing rules and detailed guidelines to lead the development of logistics industry.

The third is to perfect relevant industry standard to promote the intensification and scale of the industry.

Fourth, vigorously advocate, and promote socialized and professional logistics services, develop specialized, sophisticated and characteristic logistics services market.

Fifth, take financial discount or subsidy, to foster large-scale logistics enterprises, and guide the integration of logistics resources and transformation and upgrade traditional logistics.

Sixth, Promote regional logistics information platform construction, and improve the wide application of IT in the "Internet of Things", to play a better role of technological progress and informalization on the support and leading of development of the logistics industry.

View of the Development of Logistics Enterprises

First, actively integrate into the supply chain system, offer a comprehensive, high quality of integrated logistics services, that is to say specialized, informationized, refined, networked and "one-stop" logistics services to the core customers.

Second, integrate the advantage of scale network and node into the value of the product stream system, and actively establish business relationship with supply base as large enterprises and groups, customers, and maintain the stability of supply and cooperative relations.

The third is to strengthen optimization, integration with industry resources, and improve network coverage and intensification and scale.

Fourth, develop high access threshold, high value-added specialized, refined, characteristic logistics to avoid the homogenization of the low-end competition, to achieve differential development.

Fifth, speed up logistics informatization construction, form real-time tracking of the various links of the logistics, effective control and throughout management, improve logistics monitoring and response speed.

Sixth, accelerate the talent introduction and mechanism of long-term cultivation, draw up scientific goals and plans, develop multi-level education system and job training system, focus on the combination of short-term training and long-term introduction to improve logistics practitioners the ability to operate.

Conclusion

It plays an important role of analyzing the data model, which forecast the development trend of science, planning, coordination, and guide the health of the logistics industry in sustainable development, on the other hand, what the data model tells us will never be the answer at best only for our judgment to provide information. This requires that we develop appropriate logistics development plan according to the characteristics and trends of the logistics needs as well as the fair market analysis and research, government and enterprises move together to promote each other, to minimize total logistics costs and improve the efficiency of logistics, support and promote healthy and rapid development of economic in Shanxi promote transition across development.

Acknowledgment This paper obtains subsidy of conspicuous talents fund in The Academy of Military Transportation, PLA, as one of stage achievement for year 2012–2013.

References

Bin YE (2011) Prediction research on China's coal production based on grey theory. Sci Technol Eng 11(20):4947–4949
Cong Peng (2012) Applying multilevel grey evaluation in suppliers' strategic selection. J Chongqing Jiaotong Univ (Social Sciences Edition), JAU 12:60–63
Fangbing Niu (2011) Analysis and forecast of logistics demand in Shandong based on gray system theory. J Northwest A&F Univ 11(9):96–98 (in Chinese)
Hassan Y, Gibreel G (2000) Evaluations of highway consistency and safety: practical application. J Transport Eng 3:255–260
Hauser John R, Don Clausing (1988) The house of quality. Harvard Bus Rev 33:63–73
Ji-ying Zhang, Peng Xiao (2011) Gray relation analysis of growth of Gansu national economy. J Lanzhou Jiaotong Univ 30:111–113
Julong Deng (1998) Whitening definitions in grey system theory. J Grey Syst 7:81–86
Murray PM, Mahmassani HS (2003) Model of household trip chain sequencing in an emergency evacuation. Transport Res Board 34:137–141
Ping-fan Liao, Guo-song He, Ru-gang Zhong (2012) Forecast to the GDP of Xianning city based on gray system theory. Value Eng 3:96–97
Ruo-bing Yu (2011) A prediction of Xinjiang logistics demand based on GM(1,1). Logistics Eng Manag 33(203):37–41
Tianshe Yang, Jisheng Li, Yongxuan Huang (2005) Method of satellite fault diagnosis based on bayesian network. Eng Sci 3:52–57
Xianbing Ping (2010) Analysis of the logistics demand in Hunan province based on gray system theory. Logistics Eng Manag 32(189):17–19 (in Chinese)
Xian-zhen Guo, Xian-li Chen, Zhi-min Guan, Feng-man Shen (2011) Development and application of equipment malfunction prediction models for ironmaking process. J Northeastern Univ (Nat Sci) 32(9):29–32
Yufeng Gui, Jianfeng Tao (2004) The recognition and decomposition of mixed pixels in the remotely sensed images based on gray system theory. In: 2004 international symposium on distributed computing and applications to business; engineering and science proceedings, vol II
Zhuwen Wang, Jinghua Liu, Zhoubo Li, Chun Chang (2004) The identification of metamorphic lithologies based on the gray system theory. Expanded abstracts CPS/SEG 2004 international geophysical conference, vol II

Chapter 42
Digital Cultural Industry Value Chain Structure and Analysis of Its Influencing Factors

Qi Ma, Yang-feng Yang, Jing Gao, Lu Ren, and Wen-yu Zhang

Abstract In order to improve the traditional cultural industry and develop the emerging digital culture industry value chain, from the point of the value chain, firstly the digital culture industry on the value chain structure of horizontal and vertical linear and the existing problems were analyzed in this paper; then the output capacity, operational capacity, relationship of competition and cooperation of companies in the digital culture industry were discussed in this paper, from the angle of quantitative, the value chain efficiency was comprehensively evaluated by the use of cluster analysis. Finally, the influencing factors of achieving the digital cultural industry were put forward by analyzing the case of the Qujiang Culture Industry Investment Group.

Keywords Cluster analysis • Digital culture industry • Output efficiency • Value chain

Introduction

With the rapid development of information and communication technology, a blend of new industrial convergence of IT and cultural content – digital culture industry has been came into being and rapidly developed. Digital culture industry using digital high-tech means and the information technology to transform the different forms of cultural industry reconstruction, development and integration technology content and to improve the cultural and technology content and commercial value of high-tech cultural industry, include cultural industry, the information industry and the computer

Q. Ma (✉) • Y.-f. Yang
Xi'an Qujiang Cultural Industry Investment (Group) Co., Ltd., Xi'an, Shaanxi, China
e-mail: 276262840@qq.com

J. Gao • L. Ren • W.-y. Zhang
Xi'an University of Posts and Telecommunications, Xi'an, Shaanxi, China
e-mail: gaojing11987@qq.com; renlu87924@163.com; zwy888459@sina.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_42,

industry three basic blocks, involving a number of areas of mobile communications, the internet services, games, animation, audio, video, digital publishing and digital education training and other fields (Bin Wang Hong-bo Cai 2010).

The Structure of Digital Cultural Industry Value Chain

Horizontal Structure

It has a close relationship between the various industries of the digital culture industry. First of all, every industry has a certain cultural connotation, it will put the creative as the core of industrial development; Secondly, the various industries using digital technology to transform traditional cultural industry, industry digital trend is obvious. In addition, these industries are very value copyright, and to pay attention to the protection of intangible creative achievement, and as the key of the development of industry. Because of the relationship between the industry is growing, make the digital culture industry formed the related industrial division and cooperation of the transverse mesh industry value chain structure (Hai-jiao 2010). Digital network culture industry value chain is digital television, film, music, digital publishing, digital animation games, network media, digital culture derivatives such as production enterprise culture of infiltration and cross each other digital content industry value-added system (Amit and Zott 2001) (as shown in Fig. 42.1 below).

Vertical Structure

From the vertical division of industry function perspective, content creation, digital content, product production, product operation, copyright, trade and other key areas, formed the digital culture industry value chain of the longitudinal linear structure (Applegate 2001), and its value chain can use "smiling curve" to say (as shown in Fig. 42.2 below).

In the digital culture industry value chain longitudinal, each link has an integral internal logic relevance; content creation is the core value of the digital culture industry point. Research and application of digital technology, production and dissemination of digital cultural products, derivatives production and promotion, and such links is around to the content of the value-added activities, has the value added function (Dick Kaser 2008).

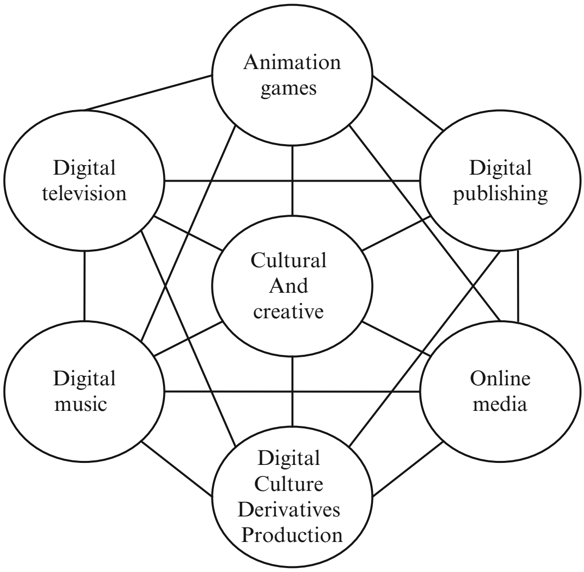


Fig. 42.1 Mesh value chain, the basic structure of the digital content industry

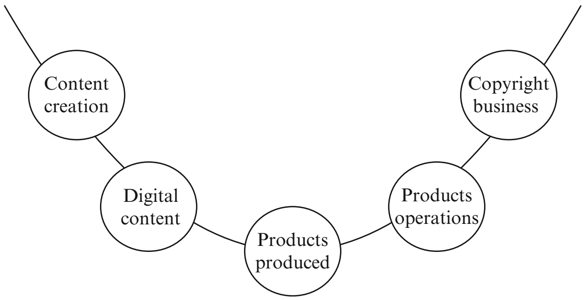


Fig. 42.2 "Smiling curve" of the vertical value chain of the digital content industry

The Operation of the Industry Value Chain Analysis of Digital Culture

Analysis of Output Capacity

The output capacities of the digital culture industry were of the creation ability of digital culture and digital culture products commercial development ability. Digital cultural product creation ability the specific performance of quantity of the creation of original works of digital cultural enterprises is the major value-added part. It in any case is to control the key link of the whole chain. Business development capability of the digital content product is embodied in the digital culture product design and production quantity. Such as quantity of the production cultural products to different forms of the CD-ROM package, web pages, video, DVD and other digital outputs.

Analysis of Operational Capability

Digital cultural products operations can be understood as digital content service providers to provide content of the integration of goods, through the digital content distribution platform to sell to the end user, and through the digital media digital content activities, in the digital culture industry of the basic value chain the middle reaches plays a connecting role (Zai-hua Hu 2006). Operational capabilities of digital cultural products can be reflected by the number of content distribution channel which digital content providers to provide and through the content to show and spread the revenue or cost margins.

Analysis of Competitive and Cooperative Relations

Cultural products production chain effect and associated effect makes the cultural enterprises often need to obtain a greater degree of the value added through partnership (You-ning Xie et al. 2010). However, because of the mutual cooperation between enterprises depend on the value creation processes and the value sharing involve the structure of respective interests, it makes competition and cooperation exist at the same time and linked together closely, which generated cooperative relations between competing enterprises. Competition and cooperation contains: improve the enterprise resource utilization efficiency reduce duplication of investment and resource waste to achieve the scale economy, reduce external transaction costs of corporate and internal organization costs, improve the flexibility of the corporate strategy and other features.

The Efficiency Evaluation of Digital Culture Industrial Value Chain

The Idea and Model of Cluster Analysis

Cluster analysis is a multivariate statistical analysis in quantitative study of the classification problem according to the characteristics of the thing itself, the basic ideological of which is that individuals have a greater similarity in the same class, individual big differences in the different classes, which identify the statistic that is able to measure the similarity between the samples (or variables), depending on multiple observations of the number of samples, and as a basis, a certain approach to all of the samples (or variables) were aggregated into different classes (Dong-jin Xiang et al. 2005). Similarity between objects can use two methods, both similarity coefficient and distance in the cluster analysis (Wang Dan 2010).

Similarity coefficient: The essence of the similarity coefficient is to express a formal language of the affinities between objects. If the similarity coefficient of two objects is 1, it means they are identical; if the similarity coefficient of two objects is 0, it means they are completely different; if the similarity coefficient of two objects is a value of 0–1, it means they are partially similar. A commonly used definition of the similarity coefficient is correlation coefficient.

$$R(X,Y) = \frac{\sum_i (x_i - \overline{x}) \cdot (y_i - \overline{y})}{\sqrt{\left(\sum_i (x_i - \overline{x})^2\right) \cdot \left(\sum_i (y_i - \overline{y})^2\right)}}$$

Distance: This concept used to describe the dissimilarity between the data. Independent property data into the d-dimensional linear space, and then combined with the spatial attributes to calculate the distance between the data, the greater distance means the greater the description of the differences between the data, and the smaller distance means the smaller the description of the differences between the data. Hamming distance is the common definition of the distance:

$$d(s_1, s_2) = count_i(s_{1i} \neq s_{2i})$$

Among them, the S_1, S_2, are two strings, S_{1i}, S_{2i}, i = 1, 2... is located in the members on the code word.

The Algorithm Steps of Cluster Analysis

The using methods of cluster analysis can be broadly divided into two categories: Hierarchical Clustering and Non-Hierarchical Clustering (Yuan-qi Wu and Rong-yang Feng 2002), this paper describes Hierarchical Clustering in major, comprising following steps:

The first step is to select the analytic index;

The second step, Standardization of data is used to eliminate the problem caused by different dimensionless in the variables or different units in the order of magnitude;

The third step is to select the distance or the formula of similarity coefficient, and calculated for distance or similarity coefficient of all samples (variable) between every two to generate the distance matrix or similarity matrix;

The fourth step is to select the clustering method, and merge the two most recent samples (or variables) into a class;

The fifth step, if number of the class is greater than 1, continuing to the third and fourth steps until all the samples classified as a class;
The sixth step is to output the maps of clustering results and system clustering;
The seventh step is to come to a conclusion of the final classification in accordance with the classification standards or principles of classification.

Case Analysis—Make Evaluation and Analysis to the Value Chain of Each Enterprise Efficiency in the Qujiang Culture Industry Investment Group

Following example to the Qujiang Culture Industry Investment Group (Cultural Group), and according to the output efficiency, the value chain of each enterprise about Culture Group is classified and evaluated. It must choose three indicators about grossrevenue, net profit and income margin at the same time be evaluation data to give an accurate and authoritative evaluate the whole operation effect about the value chain of digital culture industry in Culture Group.

By analyzing three indicators of digital cultural enterprises in Culture Group from January to October 2011 (slight the data here), Fig. 42.3 can be analyzed, the equity efficiency of both Xi'an Qujiang Cultural Tourism (Group) Co., Ltd. and Xi'an QUJIANG INTL. Conference & Exhibition Investment Holding Co., Ltd. is relatively better in 12 digital culture enterprises, Culture Group.

The Factors Affecting the Realization of Digital Culture Industrial Value Chain

The factors affecting the realization of digital culture industrial value chain can be concluded with government factors, resource factors, management factors and technical factors (Shi-gang Yan 2011). (1) The government factor means the government to promote, support and supervision. Both our government and the management department give great importance to the development of digital culture industry, and Introduced the relevant management approach, however, guide policy and legal systems of China's also slightly less needs to be improved. (2) Resource factors are talent, capital and technology elements. (3) Management factors mainly means strategic management, brand management and channel management, the internal management of enterprises directly affect the value of the digital content industry. (4) The technical factors are the protection of digitization of the cultural industries, including digital content processing technology and digital content protection technology, digital culture industry in technical standards and industry standards, public services, technology platform and copyright protection are still problems to be sound in China.

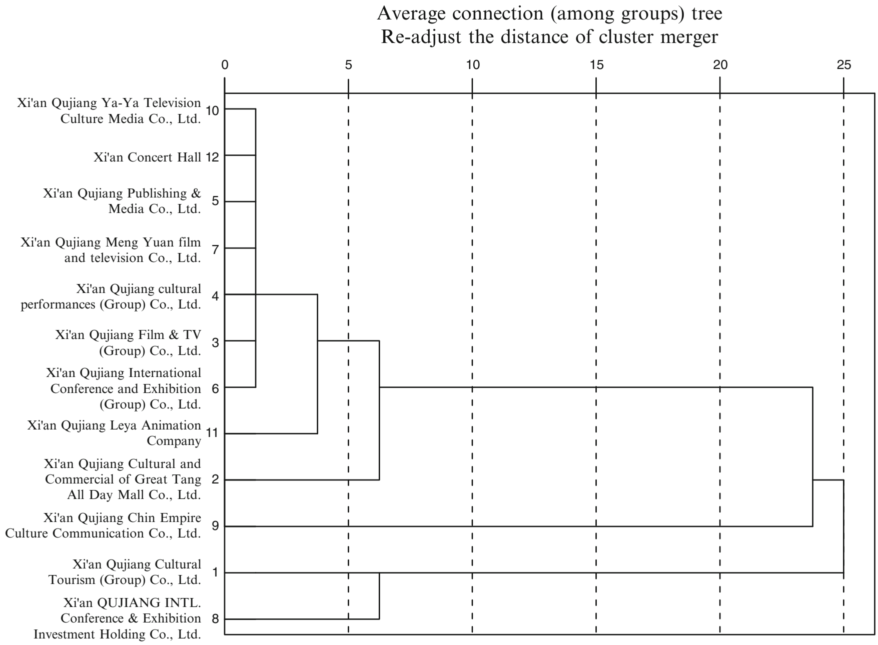


Fig. 42.3 Cluster diagram about the equity efficiency of digital cultural enterprises in Culture Group

Conclusion

This paper gave in-depth analysis about composition and influencing factors of the industry value chain in digital culture, explored the composition of the digital cultural industries, and analyzed the operation of the process respectively from the output capacity, operational capability, three aspects of the competitive and cooperative relations, used multivariate statistical analysis method of cluster analysis, introduced two commonly model of cluster analysis, studied the similarity between the objects of the digital culture industry, and demonstrated in depth a case of Xi'an Qujiang Culture Industry Investment Group. This study has a great significance to the development of cultural industries in China.

References

Amit R, Zott C (2001) Value creation in e-business [J]. Strateg Manag J 22(6/7):201–215

Applegate LM (2001) E-business models: making sense of the Internet business landscape [A]. In: Dickson G, Gary W, de Sanctis G (eds) Information technology and the future enterprise: new models for manager [C]. Prentice Hall, New York

Bin Wang Hong-bo Cai (2010) The connotation of the digital content industry, to define its international comparison [J]. Finance Trade Econ 2(2):110–116

Dick Kaser (2008) SIIA's Global Information Industry Summit: Content Industry Considers Business Models. Information Today [EB/OL], November, pp 52–53

Dong-jin Xiang, Hong-wei Li, Xiao-ya Liu (2005) Practical multivariate statistical analysis [M], vol 9. China University of Geosciences Press, Wuhan, pp 100–123

Hai-jiao Luo (2010) The development of the digital content industry is a national strategic decision-making [J]. Inf Ind China 3(3):25–28

Shi-gang Yan (2011) The digital content industry international development model compare and using for reference. Tech Econ Manag [J] 1:104–107

Wang Dan (2010) A cluster analysis method based on combination similarity and its application. In: Control and Decision Conference (CCDC), Northeastern University, Shenyang, China, 26–28 May 2010, pp 430–433

You-ning Xie, Hai-ping Yang, Xu-hong Jin (2010) Research on the development of digital content industry—discussion targeted on the evaluation standards for content industry. Intell Res [J] 54 (12):54–58, 73

Yuan-qi Wu, Rong-yang Feng (2002) Clustering analysis and calculation method of the theory and the results compared. Paper of Zhanjiang Ocean University 22(1):57–63

Zai-hua Hu (2006) Research on the digital content industry characteristics, the status and development strategy [D]. Central China Normal University, Wuhan, pp 142–147

Chapter 43
Storage Space Allocation Planning in the New Container Terminal

Pei-yu Li and Xiao-ming Sun

Abstract This paper develops a dynamic storage space allocation planning model with an objective to minimize the berthing time of container vessels. The study is based on the new container terminal which has a limitation on the number of the transport channels. A rolling horizon approach, considering the loading and unloading information of the containers, is used to solve the problem. The space allocation equality rate (SAER) is considered to assess the model balance. The learn model is solved by CPLEX solver 12.2. This study is valuable for improving the efficiency of actual new container handling system.

Keywords Storage yard • Allocation planning • Space allocation equality rate • Learn modal

Introduction

The container terminal plays a key role in the world trade and transportation industry. It is the link in the container transportation, and is also the container distribution center. Since the energy crisis, environmental protection and automation trends are increasing; the traditional container handling system urgently needs to be improved. Through a large number of studies on the modern container handling system over the world, Shanghai Zhenhua Port Machinery Company Limited (ZPMC) has proposed a new system, which has strong vitality, and is able to improve the core competition of the ports.

This research is sponsored by National Natural Science Foundation of China (project No. 2009AA043000).

P.-y. Li (✉) • X.-m. Sun
Department of Industrial Engineering & Logistics Management,
Shanghai Jiao Tong University, Shanghai, China
e-mail: lipeiyuhappy@sjtu.edu.cn; xmsun@sjtu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_43,

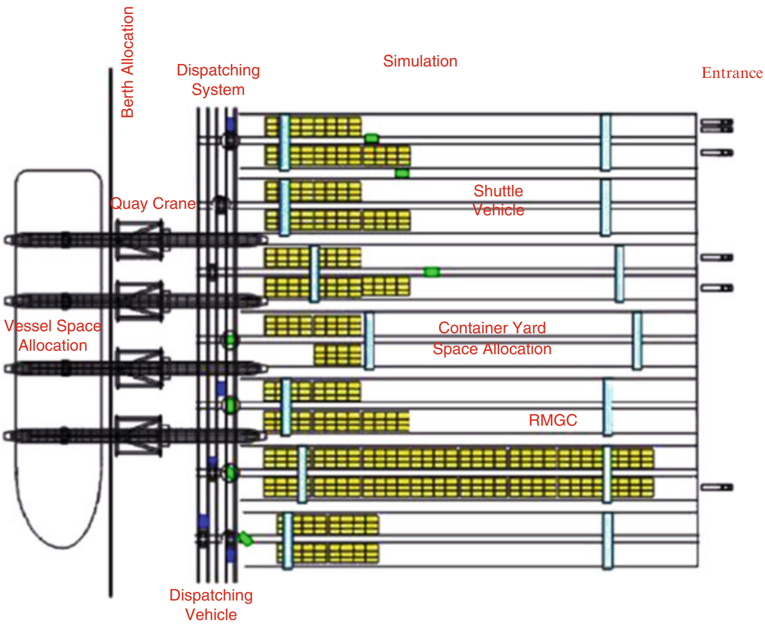


Fig. 43.1 A new container terminal

In the new container handling system, container yard is the logistic channel that lies between the sea side and the land side. The novel container storage space that connects the two sides is totally different from the scattered yards in the traditional container terminal. Instead of the operation of transport vehicles in the traditional terminal, a dispatching system similar to the inbound and outbound system of the automated stereoscopic warehouse is used.

The dispatching system consists of Dispatching Vehicle (DV) whose rail is parallel to quayside, Shuttle Vehicle (SV) whose rail is through the block and vertical to quayside, and Lifting Crane (LC) which is responsible for loading or unloading the containers before outbound and inbound. Since the handling equipment in the system are all running on the rail, they can move in a high speed and under a strong controllability. Then it is possible that the operations in the new container terminal can run automatically and more effectively (Fig. 43.1).

The storage space allocation problem (SSAP) has been first formulated by Zhang et al. (2003). They use a rolling horizon approach to solve the problem (Zhang et al. 2003). Then, an iterative improvement method proposed by Han et al. (2008) and a genetic algorithm put forward by Bazzazi et al. (2009) are used to resolve the storage space allocation problem, respectively, A hybrid algorithm, which applies heuristic rules and distributed genetic algorithm, is employed to resolve the space allocation model in the article published by Mi et al. (2009).

All the solutions mentioned in these papers are all focused on the traditional container terminal, and the relative approaches can provide some references to solve the problem in the new container terminal. However, there are essentially differences between the previous and the new container terminal operational strategies.

Problem Description

Based on the typical structure of the new container handling system, the processes of unloading containers from the vessels to the container storage space are: QC removes the container from the vessel that is berthing in the certain place to DV. Then with the container, DV which moves along the quayside to the point corresponds to the block of the storage space. LC is at this point to hold the container, and DV leaves for the next operation. Then LC puts down the held container on SV that is placed under the accepted point. SV turns the container 90°, puts the container in the direction that is correct for storage, then SV delivers the container to the point of the bay where it would be placed, and under RMGC. RMGC picks the container up and stacks it into a location in a bay of the block. The reverse flows of the above operations are the loading processes of the container.

According to the container handling processes described above, containers handled in the storage space can be assorted into four categories: Unloading Containers (ULC): Inbound containers that have not yet unloaded from the vessels or into the storage space; Loading Containers (LDC): Outbound containers that have arrived at the storage space waiting for shipment; Dispatching Containers (DPC): Inbound containers that have arrived at the storage space waiting for out; Receiving Containers (RVC): Outbound containers that have not yet brought into or stored in the storage space.

The number of containers can be adopted to judge the types of containers. The container flows in the terminal are caused by the arrival process of vessels. After being placed in the certain block, inbound ULC will convert to DPC, while RVC will change into LDC.

Since four types of containers will be operated at the same time, the loading and unloading containers must be mixed stored in one block. Based on the operation process principles, two LCs (i.e., LCd and LCl) have to use to realize the containers into and out of a block synchronously. So the restrictions on the number of LCs (the total number of LCds and LCls) are the focus in this article, and then it is the new space allocation problem under the limitation of transport channels.

There are many different performance indicators to evaluate the efficiency of the container terminal, such as QC operation time, RMGC operation time, the vessel berthing time, etc. (Kim et al. 2000; Preston and Kozan 2001; Stahlbock and Vob 2008; Steenken et al. 2004; Li et al. 2007). We choose a commonest one, minimize the average vessel berthing time, as the objective.

Problem Solving

The storage yard in the container terminal is a temporary storage space to place containers. It is a buffer to coordinate inbound and outbound containers.

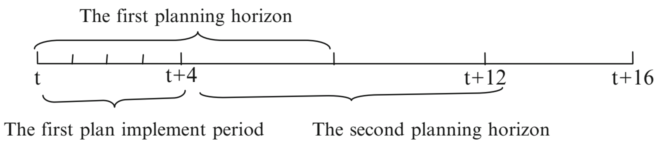


Fig. 43.2 The example of rolling horizon approach

From the perspective of improving the operating efficiency of the storage space, the leaving time has been known when the container arrived at the terminal. So, we use the planning time of containers arrive at the storage space to get the container storage space allocation plans through balancing the workload of RMGCs among different blocks. A fixed planning horizon is chosen. At each planning period, we use the newest information to formulate a plan for the nearest future and implement the schedule until the following planning note, then we re-enact and generate a new plan; this planning pattern is and repeated to satisfy the demand from the port. This planning method known as the rolling-horizon approach and an simple example is shown in Fig. 43.2 (Liu et al. 2010).

Notation

The data known at the beginning of the schedule are: B is the number of blocks in the storage space; T is the number of planning periods in one planning horizon; S_i is the storage capacity of block i; NLC is the total number of LCs; η is the allowable density for each block; V_{i0} is the initial inventory of block i; P_{it}^{0} is the initial number of DPC that are stored in block i and will be took out in period t; L_{it}^{0} is the initial number of LDC that are stored in block i and will be shipment in period t; G_{tk} is the number of RVC that arrive at the container terminal in period t and will shipment in period $t + k$; D_{tk} is the number of ULC that are loaded from vessels in period t and will be took out in period $t + k$.

The decision variables are: G_{itk} is the number of RVC stored in block i that reach the terminal in period t and will shipment in period $t + k$; D_{itk} is the number of ULC stored in block i that are loaded from vessels in period t and will be took out in period $t + k$; G_{it} is the number of RVC stored in block i that reach the container terminal in period t; D_{it} is the number of ULC stored in block i that are loaded from vessels during period t; L_{it} is the number of LDC that are stored in block i and will shipment in period t; P_{it} is the number of DPC that are stored in block i and will be took out in period t; V_{it} is the number of containers that are stored in block i at the end of period t; if LCd_{it} is 1, the LC located in block i in period t for descent move, 0 for otherwise; if LCl_{it} is 1, the LC located in block i in period t for ascent move, 0 for otherwise; $V_{\max}$, TPD_{it} and TPL_{it} are the temporary variables for calculation.

Modeling

The Objective Function

As mentioned above, we can balance the workload of RMGCs among different blocks to minimize the berthing time of vessels. Since the operations of RMGC are related to the both side of the container terminal: the seaside for loading or unloading containers from the vessels and the land side for picking up containers from blocks or sending containers to blocks. And we pay more attention on the containers that are related to vessels, thus, the objective is:

$$\min \sum_{t=1}^{T} \left\{ \begin{array}{l} \omega_1 \left[\max\limits_{i \in B}(D_{it} + L_{it}) - \min\limits_{i \in B}(D_{it} + L_{it}) \right] \\ +\omega_2 \left[\begin{array}{l} \max\limits_{i \in B}(D_{it} + L_{it} + G_{it} + P_{it}) \\ -\min\limits_{i \in B}(D_{it} + L_{it} + G_{it} + P_{it}) \end{array} \right] \end{array} \right\} \tag{43.1}$$

In this function (43.1), $(D_{it} + L_{it})$ is the number of loading and unloading containers that will be handled in block i during period t, and $(D_{it} + L_{it} + G_{it} + P_{it})$ is the number of containers that will be handled in block i during period t. Therefore (43.1) balances the containers that are related to vessels and the number of containers among blocks in each planning period. The weights of the two terms in function (43.1), ω_1 and ω_2, are tuned according to the actual situation in the container terminal. Both of them are strictly positive.

Constrains

In order to ensure the problem practical feasibility, there are following constraints:

$$D_{tk} = \sum_{i=1}^{B} D_{itk} \tag{43.2}$$

$$G_{tk} = \sum_{i=1}^{B} G_{itk} \tag{43.3}$$

$$D_{it} = \sum_{k=1}^{T-t} D_{itk} \tag{43.4}$$

$$G_{it} = \sum_{k=1}^{T-t} G_{itk} \tag{43.5}$$

$$L_{it} = L_{it}^{0} + \sum_{k=1}^{t-1} G_{i(t-k)k} \tag{43.6}$$

$$P_{it} = P_{it}^{0} + \sum_{k=1}^{t-1} D_{i(t-k)k} \tag{43.7}$$

$$V_{it} = V_{i(t-1)} + [(G_{it} + D_{it}) - (P_{it} + L_{it})] \tag{43.8}$$

$$V_{it} = \eta S_i \tag{43.9}$$

$$D_{it} \leq TPD_{it} \tag{43.10}$$

$$D_{it} \geq TPD_{it} - V_{\max}(1 - LCd_{it}) \tag{43.11}$$

$$D_{it} \leq V_{\max} LDd_{it} \tag{43.12}$$

$$L_{it} \leq TPL_{it} \tag{43.13}$$

$$L_{it} \geq TPL_{it} - V_{\max}(1 - LCl_{it}) \tag{43.14}$$

$$L_{it} \leq V_{\max} LDl_{it} \tag{43.15}$$

$$\sum_{i=1}^{B} (LCd_{it} + LCl_{it}) = NLC \tag{43.16}$$

Constraint (43.2) ensures the number of ULC waiting for distribution is the sum of the containers that are allocated to all the blocks. Constraint (43.3) implies similar constraint for RVC. Constraint (43.4) ensures that the number of ULC allocated to block i in period t is the sum of the containers assigned to block i that will shipment in period t. Constraint (43.5) implies similar constraint for RVC. Constraint (43.6) shows that the number of LDC containers handled in block i during period t, is the sum of the initial LDC that are stored in block i will shipment in period t in the current plan period and the containers that changed from RVC that are arrived in the current period. Constraint (43.7) implies similar constraint for DPC. Constraint (43.8) describes the container inventory updating. Constraint (43.9) ensures that in each planning period the number of container stored in each block will not exceed the actual available capacity Shen et al. (2007). Constraints (43.10), (43.11), (43.12), (43.13), (43.14), and (43.15) ensure the number of containers that are loading and unloading from the vessels is the sum of inbound and outbound containers in the container terminal. Constraint (43.16) ensures the number of LC is the sum of the number of LCds and LCls.

Conversion to a Linear Model

Because of the objective function, the above model is non-linear. Thus, it cannot be solved by the existing optimization tools. To convert it to a linear model, there are some definitions:

$$A_t = \max_{i \in B} (D_{it} + L_{it}) \tag{43.17}$$

$$B_t = \min_{i \in B} (D_{it} + L_{it}) \tag{43.18}$$

$$M_t = \max_{i \in B} (D_{it} + L_{it} + G_{it} + P_{it}) \tag{43.19}$$

$$N_t = \min_{i \in B} (D_{it} + L_{it} + G_{it} + P_{it}) \tag{43.20}$$

Then the model can be rewritten as the linear integer programming (LIP) model below.

$$\min \sum_{t=1}^{T} [\omega_1 (A_t - B_t) + \omega_2 (M_t - N_t)] \tag{43.21}$$

Modeling Evaluation

The space allocation equality rate (SAER) matrix $C = [C_1, C_2, \ldots, C_T]$ is used to evaluate the model. C_t is the SAER in period t. B_{it} is the number of containers that are allocated to block i in period t. When C_t is more closer to 1, the allocation in period t is more balanced. It means that when the elements in column matrix C are all closer to 1, the allocations in all periods are more balanced.

$$C_t = 1 - \frac{1}{B * B_{0t}} \sum_{i=1}^{B} (B_{0t} - B_{it}) \tag{43.22}$$

$$B_{0t} = \max_{i \in B} B_{it} \tag{43.23}$$

The ranges of the variables mentioned above are: $B, T, NLC \in N^+$, and $i = 1, 2, \ldots, B$, $t = 1, 2, \ldots, T$, $k = 0, 1, 2, \ldots, T - t$.

Model Application

CPLEX solver 12.2 is used to solve the LIP model in this paper. According to the actual operations in the container terminal, we take the 1 day duration in which containers remain in the terminal as an example. One day (24 h) is divided into 6 periods, and the planning horizon is 3 days, so the total number of planning periods in one planning period T is 18. Suppose there are 7 blocks (B = 7) with different storage capacities.

Since the loading and unloading of container mixture operation is used in the new container terminal, two LC are needed to realize containers into and out of a block synchronously. So we consider the impact on the space allocation when the number of handling containers is fixed and the number of transport channels can be changed. The quantity of the channels is determined by the number of LC (NLC).

The computational results are as shown in Tables 43.1 and 43.2. Due to the discreteness of the number of containers, the space allocation equality rate in every period will not equals 1. We can find that there is a very high SAER 0.9988. The results in Tables 43.1 and 43.2 show that even in different NLC, the allocation strategies are both optimal. The equilibrium allocation represents that the number of containers handled in different blocks, i.e., the workload among blocks are balanced.

The computational results demonstrate that a high SAER can be got in every period. That is to say, in all periods of the planning horizon we can maximize the operational capability of the equipment in the storage space.

Table 43.3 shows the distribution of LC when NLC is 12. It is observed from Table 43.3 that the model can be adopted to make the storage space allocation strategy under the limitation of transport channels.

Table 43.1 The allocation strategy in period 6 when NLC = 14

	Block						
Container type	1	2	3	4	5	6	7
ULC	60	34	50	60	39	54	34
LDC	1	27	11	2	22	7	27
RVC	61	41	47	61	45	46	35
DPC	1	21	15	0	16	16	27

The optimal value = 27, $C_6 = 0.9988$

Table 43.2 The allocation strategy in period 6 when NLC = 12

	Block						
Container type	1	2	3	4	5	6	7
ULC	27	46	61	16	61	59	61
LDC	34	15	0	45	0	3	0
RVC	62	8	62	19	62	61	62
DPC	0	54	0	42	0	0	0

The optimal value = 27, $C_6 = 0.9988$

Table 43.3 The distribution of LC (LCD, LCL) in period 6 when NLC = 12

	Period					
Block	1	2	3	4	5	6
1	(1,1)	(1,1)	(1,1)	(1,1)	(1,0)	(1,1)
2	(1,1)	(1,1)	(1,0)	(1,0)	(1,1)	(1,1)
3	(1,1)	(1,0)	(1,1)	(1,1)	(1,1)	(1,0)
4	(1,0)	(1,1)	(1,1)	(1,1)	(1,1)	(1,1)
5	(1,1)	(1,1)	(1,1)	(1,1)	(1,0)	(1,1)
6	(1,1)	(1,1)	(1,1)	(1,0)	(1,1)	(1,1)
7	(1,0)	(1,0)	(1,0)	(1,1)	(1,1)	(1,0)

Conclusion

Based on the characteristics of the new container handling system, we establish a non-linear optimization model to solve the space allocation problem when considering imitated transport channels of containers. Some definitions are introduced to linearize the model. Some mathematical solvers, e.g., CPLEX can be used to solve it. The method proposed in this paper can also provide an allocation strategy of the transport channels to the terminal. Therefore, the further promotion can provide some references to the operation of the automated stereoscopic warehouse with multilane.

References

Bazzazi M, Safaei N, Javadian N (2009) A genetic algorithm to solve the storage space allocation problem in a container terminal. Comput Ind Eng 56(1):44–52

Chuqian Zhang, Jiyin Liu, Yat-wah, Murty KG, Lim RJ (2003) Storage space allocation in container terminals. Transport Res B 37(10):883–903

Jianfeng Shen, Chun Jin, Peng Gao (2007) Research on knowledge-based planning of storage space allocation in container yards (in Chinese). Appl Res Comput 24(9):146–151

Jianzhong Li, Yizhong Ding, Bin Wang, (2007) Dynamic space deployment model of container storage yard (in Chinese). J Traffic Transport Eng 7(3):50–55

Kim KH, Park YM, Ryu KR (2000) Deriving decision rules to location export containers in container yards. Eur J Oper Res 124(1):89–101

Preston P, Kozan E (2001) An approach to determine storage location of containers at seaport terminals. Comput Oper Res 28(10):983–995

Stahlbock R, Vob S (2008) Operations research at container terminals: a literature update. OR Spectr 30:1–52

Steenken D, Vob S, Stahlbock R (2004) Container terminal operation and operations research – a classification and literature review. OR Spectr 26:3–49

Weijian Mi, Wei Yan, Junliang He, Daofang Chang (2009) An investigation into yard allocation for outbound containers. Int J Comput Math Electr Eng 28(6):1442–1457

Yan Liu, Haigui Kang, Pengfei Zhou (2010) Fuzzy optimization of storage space allocation in a container terminal. J Shanghai Jiao Tong Univ 15(6):730–735

Yongbin Han, Loo Hay Lee, EK Peng Chewa, Kok Choon Tan (2008) A yard storage strategy for minimizing traffic congestion in a marine container transshipment hub. OR Spectr 30:697–720

Chapter 44
An Optimal Jatropha Seed Warehouse Location Decision Using Myopic and Exchange Heuristics of P Median

S.P. Srinivasan and P. Malliga

Abstract *India has a vast cultivable land and* almost all seasons for production of all varieties of fruits and *vegetables*. However, India has also got a wide uncultivable waste lands. Jatropha seed is one of the highly suitable agricultural product for making an alternate fuel. As this seed can grow in any type of land it is necessary to focus on producing an alternate fuel with help of esterification process. Nearly 90% of the country's food and vegetable produce is handled by private organizations only. The goods cross at least five stages before reaching to the end customers. This leads to the hike in prices of the goods.

The Jatropha oil production process involves many stages of supply chain. In this paper an identification of optimal collection center for Jatropha seed which serves as the common point for the farmers (Producers) is focussed. This collection center facility may change significantly as per the policy of the government. The costs, production capacity, travel distance, mode of transport, time and other input variables of facility location models are highly uncertain. The p median algorithm is used to identify the optimal collection centers. Also it captures the various operational functions of the Jatropha supply chain uncertainty including distance, demand, graphical location etc., as the people have more flexibility to choose the collection center location, the facilities need to be modified in terms of farmers constraints. This paper assesses the field data and identified the optimal solution using Myopic and Exchange heuristics algorithms.

Keywords Jatropha • Supply chain median • Myopic • Exchange heuristics • Collection center

---

S.P. Srinivasan (✉)
Mechanical Engineering, Rajalakshmi Engineering College, Chennai, India
e-mail: spsrini@rediffmail.com

P. Malliga
Industrial Engineering, Anna University, Chennai, India
e-mail: mallipoo@annauniv.edu

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_44,

Introduction

The uncultivable wastelands (Hiromi Yamamotoa et al. 2001) are planned to utilize for cultivating Jatropha seed is the main focus in this research. The Jatropha total yield need to be collected and need to be sent to esterification. The identification of common collecting point is one of the most important factor for developing a supply chain of Jatropha seed. The effectiveness of identification of collection center affects the functional characteristics of supply chain network design.

Facility location issues locate a set of facilities to minimize the cost of fulfilling some sets of weight with respect to some sets of constraints. It is of strategic in nature (economic effects in long run). Locating common collection center must ensure two prime issues viz: comfort and farmers satisfaction in terms of logistics. The factors influencing location analysis are cost, availability of material, transportation, associated distances and number of facilities to be located. In modeling facility location problem, there are three main criteria;

1. minisum criterion
2. minimax criterion
3. maxmin criterion

In minisum criterion model the optimal location is determined so as to minimize weighted total distance to the demand points. In minimax criterion model the optimal location is determined so as to minimize the maximum distance between a new facility to be located and demand points. The maxmin facility location or obnoxious facility location problem seeks a location which maximizes the minimum distance to the sites. Minimax criterion model is chosen for our problem of concern.

Factors Influencing Jatropha Yield

The total yield of seed is influenced by many factors, which includes, climatic conditions, usage of fertilizers, soil type, altitude and processing (Trappey and Hsin-Ying Wu 2008; Srinivasan and Malliga 2009).

1. *Climatic conditions*: This plant will grow in any climatic conditions, but it gives better yield in warm climates. However the temperature and rainfall affects its growth.
2. *Fertilizers usage*: An organic fertilizer improves the yield of Jatropha. The fertilizers includes magnesium, potassium, Calcium etc., are added in the soil to increase its quality.
3. *Soil type and property*: There are different types of soils available in the Indian context. The soils like alluvial, arid, red etc., but it does not give a good result in the case of black soil.

4. *Altitude*: The altitude ranges are also affects the Jatropha yield. It gives poor results in case hill regions.
5. *Processing*: The maintenance of seeds plays a important role in getting the good yield. It should not be exposed to direct sun light. Hence it needs some amount of special care.

Methodology

The yield of Jatropha in any given location is influenced by the above factors. This yield affects the ware house location decision. In this paper p-median methodology has been used to solve ware house location problem. This methodology is also validated with its associated improvement algorithms like myopic and exchange algorithm.

The P Median Problem

The p-median problem is useful to solve the real world situations like location of public or industrial facilities to say collection center location in this case (Jacobs et al. 1996). It belongs to a class of formulation called minisum location models (Carson and Batta 1990). The problem can be stated as "Find the location of a fixed number of p facilities so as to minimize the weighted average distance of the system." The integer programming formulation of the p median problem is as follows:

$$\textit{Minimize}\left\{\mathrm{Z} = \sum\sum \mathrm{a}_i \mathrm{d}_{ij} \mathrm{x}_{ik}\right\} \tag{44.1}$$

Where i = 1, 2, ..., m
j = 1, 2, ..., n
Subject to,

$$\sum \mathrm{X}_{ij} = 1 \tag{44.2}$$

$$\mathrm{X_{ij}} \leqslant \mathrm{X_{jj}} \tag{44.3}$$

$$\sum \mathrm{X_{ij}} = p \tag{44.4}$$

$$\mathrm{X}_{ij} \in \{0, 1\} \tag{44.5}$$

Where,

I = index of demand points
m = total number o demand points in the space of interest
J = index of potential facility sites
n = total number of potential facility locations
a_i = weight associated to each demand point.
d_{ij} = distance between demand area i and potential facility at j.
x_{ik} = {1 if demand area i is assigned to a facility at j; 0 otherwise}

In the P median problem the distance matrix should be formed for the given network. Cost matrix is further formed by multiplying demand at the node i and distance between respective sites and the associated unit cost. The sites at which the columns summation is minimum is chosen as the first best sites that will have good accessibility with rest of the sites.

Data Interpretation and Analysis

The longitudinal and latitudinal data of 12 taluks (Zones) along with their yield data of Jatropha production is listed below,

Taluk number	Longitude	Latitude	Yield (tons)	Taluk name
1	10.983	77.033	165.12	Palladam
2	11.783	79.583	5,834.5	Panruti
3	12.35	77.5	55.04	Pennagaram
4	10.5	77.3	2,258.64	Nilakkotai
5	11.21	77.44	266.72	Erode
6	12.6	79.8	209.88	Uthiramerur
7	11.35	77.35	203.4	Uthangarai
8	12.533	78.266	1,555.952	Krishnagiri
9	13	79	606.32	Arcot
10	10.2	78.5	104.94	Usilampatti
11	11.28	78.1	208.375	Rasipuram
12	9.17	79.18	175.035	Rameswaram

Out of these 12 taluks 3 taluks need to be identified for a warehouse (collection center). Hence the objective of minimum transportation cost and the optimal selection of these three taluks are done with the help of P-median algorithm and it is analyzed with myopic, and exchange heuristics.

This paper is organized as follows in section "The P Median Problem" the p-median method is adopted to get the solution. And in section "Myopic Algorithm" and "Exchange Algorithms" the myopic and exchange algorithms are discussed respectively.

Computed cost matrix for the above data as follows: The selected site is swapped (For instance, if column X is selected it is compared for minimum cost with the column Y which being considered so this selected minimum cost is updated in the revised matrix until the entire column is done) with all other sites. The process is repeated till p facilities are selected. Node assignment is done based on the minimum distance between the selected nodes and its immediate succeeding node. If the succeeding node is one among the selected p facilities, then it should be considered for the assignment. Table 44.1 describes the detailed cost matrix of p-median problem. The total values of all 12 locations are summarized in the last row.

As per the p-median procedure, the facilities located are 2, 4 and 8 in the subsequent iterations (Table 44.2).

The p-median problem has been solved by heuristic methods, such as the variable neighborhood decomposition method (Hansen et al. 2001), by exact methods, such as the branch-and-cut approach (Briant and Naddef 2004). However, the latter represents the state of the art regarding exact solution methods to solve the p-median problem. In this paper the standard myopic algorithm and exchange heuristics of P-median has been formulated.

Myopic Algorithm

The myopic heuristic is a greedy type, which works in the following way. First, a facility is located in such a way as to minimize the total cost for all customers. Facilities are then added one by one until p is reached. For this heuristic, the location that gives the minimum cost is selected. The main problem with this approach is that once a facility is selected it stays in all subsequent solutions. Consequently, the final solution attained may be far from optimal. The procedure of this algorithm is same as that of the p median problem working procedure with a minor difference that objective value will be same for p number of facilities to be located (Table 44.3).

Exchange Algorithm

This algorithm was developed by Teitz and Bart (1934). It is an iterative algorithm used to find out the simple approximations. This is a finer version of minimax approximation algorithm. Its strategy tries each facility in the current solution, in turn, at every potential facility site not in the current solution. The shift offering the greatest reduction of the objective function for that facility is accepted- the old location is drooped from the current solution and the new location is added. Each facility in the current solution is treated in this way to complete one iteration of the algorithm. Additional iterations repeat the process until no further improvement is possible.

The Input data that is in desired form is fed in mostly as cost matrix. If p number of facilities to be located, then that number of facilities have to be arbitrarily selected and considered as initial set. The summation of minimum cost among

Table 44.1 Cost matrix iteration I

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	62,910.72	35,831.04	38,307.84	17,832.96	70,176	36,326.4	37,977.6	44,747.52	52,012.8	32,693.76	37,977.6
2	2,222,945	0	1,079,383	1,359,439	1,598,653	56,5946.5	1,079,383	1,219,411	816,830	2,112,089	1,079,383	89,2678.5
3	11,943.68	10,182.4	0	13,484.8	7,980.8	11,778.56	8,145.92	10,182.4	12,328.96	15,080.96	4,843.52	5,393.82
4	52,4004.5	52,6263.1	55,3366.8	0	35,2347.8	71,5988.9	15,3587.5	54,4332.2	59,8539.6	338,796	257,485	28,0071.4
5	28,805.76	73,081.28	38,674.4	41,608.32	0	85,350.4	14,936.32	38,140.96	33,340	68,280.32	24,004.8	32,539.84
6	89,199	20,358.36	44,914.32	66,531.96	67,161.6	0	54,358.92	44,914.32	47,223	99,693	51,420.6	44,914.32
7	44,748	37,679	30,103.2	13,831.2	11,390.4	52,680.6	0	36,001.8	39,663	49,833	10,576.8	11,390.4
8	357,869	325,194	287,851.1	374,984.4	222,501.1	332,973.7	275,403.5	0	54,458.32	490,124.9	202,273.8	196,050
9	164,312.7	84,884.8	135,815.7	160,674.8	75,790	136,422	118,232.4	21,221.2	0	275,875.6	104,287	101,861.8
10	33,056.1	37,988.28	28,753.56	15,741	26,864.64	49,846.5	25,710.3	33,056.1	47,747.7	0	27,074.52	28,333.8
11	41,258.25	38,549.38	18,337	23,754.75	18,753.75	51,051.88	10,835.5	27,088.75	35,840.5	53,760.75	0	6,668
12	40,258.05	26,780.36	17,153.43	21,704.34	21,354.27	37,457.49	9,801.96	22,054.41	29,405.88	47,259.45	5,601.12	0
Total	**3,558,400**	**1,243,872**	**2,270,183**	**2,130,062**	**2,420,630**	**2,109,673**	**1,786,721**	**2,034,380**	**1,760,124**	**3,602,806**	**1,799,643**	**1,637,879**

Table 44.2 Cost matrix iteration II

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	38,307.84	35,831.04	38,307.84	17,832.96	38,307.84	36,326.4	37,977.6	38,307.84	38,307.84	32,693.76	37,977.6
2	0	0	0	0	0	0	0	0	0	0	0	0
3	10,182.4	10,182.4	0	10,182.4	7,980.8	10,182.4	8,145.92	10,182.4	10,182.4	10,182.4	4,843.52	5,393.82
4	0	0	0	0	0	0	0	0	0	0	0	0
5	28,805.76	41,608.32	38,674.4	41,608.32	0	41,608.32	14,936.32	38,140.96	33,340	41,608.32	24,004.8	32,539.84
6	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36	0	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36
7	13,831.2	13,831.2	13,831.2	13,831.2	11,390.4	13,831.2	0	13,831.2	13,831.2	13,831.2	10,576.8	11,390.4
8	325,194	325,194	287,851.1	325,194	222,501.1	325,194	275,403.5	0	54,458.32	325,194	202,273.8	196,050
9	84,884.8	84,884.8	84,884.8	84,884.8	75,790	84,884.8	84,884.8	21,221.2	0	84,884.8	84,884.8	84,884.8
10	15,741	15,741	15,741	15,741	15,741	15,741	15,741	15,741	15,741	0	15,741	15,741
11	23,754.75	23,754.75	18,337	23,754.75	18,753.75	23,754.75	10,835.5	23,754.75	23,754.75	23,754.75	0	6,668
12	21,704.34	21,704.34	17,153.43	21,704.34	21,354.27	21,704.34	9,801.96	21,704.34	21,704.34	21,704.34	5,601.12	0
Total	**544,456.6**	**595,567**	**532,662.4**	**595,567**	**411,702.7**	**575,208.6**	**476,433.8**	**202,911.8**	**231,678.2**	**579,826**	**400,977.9**	**411,003.8**

Table 44.3 Resultant matrix of myopic algorithm

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	37,977.6	35,831.04	37,977.6	17,832.96	37,977.6	36,326.4	37,977.6	37,977.6	37,977.6	32,693.76	37,977.6
2	0	0	0	0	0	0	0	0	0	0	0	0
3	10,182.4	10,182.4	0	10,182.4	7,980.8	10,182.4	8,145.92	10,182.4	10,182.4	10,182.4	4,843.52	5,393.82
4	0	0	0	0	0	0	0	0	0	0	0	0
5	28,805.76	38,140.96	38,140.96	38,140.96	0	38,140.96	14,936.32	38,140.96	33,340	38,140.96	24,004.8	32,539.84
6	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36	0	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36	20,358.36
7	13,831.2	13,831.2	13,831.2	13,831.2	11,390.4	13,831.2	0	13,831.2	13,831.2	13,831.2	10,576.8	11,390.4
8	0	0	0	0	0	0	0	0	0	0	0	0
9	21,221.2	21,221.2	21,221.2	21,221.2	21,221.2	21,221.2	21,221.2	21,221.2	0	21,221.2	21,221.2	21,221.2
10	15,741	15,741	15,741	15,741	15,741	15,741	15,741	15,741	15,741	0	15,741	15,741
11	23,754.75	23,754.75	18,337	23,754.75	18,753.75	23,754.75	10,835.5	23,754.75	23,754.75	23,754.75	0	6,668
12	21,704.34	21,704.34	17,153.43	21,704.34	21,354.27	21,704.34	9,801.96	21,704.34	21,704.34	21,704.34	5,601.12	0
Total	**155,599**	**202,911.8**	**180,614.2**	**202,911.8**	**134,632.7**	**182,553.5**	**137,366.7**	**202,911.8**	**176,889.7**	**187,170.8**	**135,040.6**	**151,290.2**

Table 44.4 Solution set iteration I

Solution set	Solution
{1,2,3}	1,040,251.71
{1,2,4}	544,456.61
{1,4,3}	1,641,832.01
{4,2,3}	532,662.35

the sites in the initial set is taken as the initial solution. Any site which is not a part of the initial set is replaced one by one with all the sites in the initial set and respective cost summation are done as said above. If the minimum cost summation among the selected combinations from the previous step is less than the initial solution, then there is a possibility of improvement in the initial solution. That minimum cost summation is taken as the improved solution set. This process is repeated considering the improved solution set until there is no possibility of improvement.

Thus solution from previous statement is considered as the optimal solution. The set {1,2,3} is selected as the initial solution arbitrarily and the facilities other than in the initial set are swapped one by one respectively, to say {1,2,4};{1,4,3};{4,2,3} and the associated transportation costs are computed which is as shown in Table 44.4.

The transportation cost for {4,2,3} is less than that of the initial solution; we carry this as the next initial solution (Tables 44.5 and 44.6).

Since the transportation cost for the sets {4,2,6};{4,6,5};{6,2,5} are greater than that of the 3rd initial solution, we carry out the same initial solution for the following iteration. Hence the initial solution is carried out for further iterations. Thus the final solution obtained through exchange heuristics is 200,141.36 is shown in Table 44.7.

Results

The purpose of this paper is to justify the importance of facility location decisions (Owen and Daskin 1998) in an organization and even in public sector projects with the assistance of various methodologies and algorithms says genetic algorithms, a4 algorithm, kruskal's algorithm, dijkstra's algorithm and etc. can be taken to validate the decision. It's of kind of decision support system (DSS) that focus on effective placement of facilities, proper utilization of associated resources with an objective of total cost reduction also satisfying the demand of customers. This field has ample of real time applications like mega construction projects, city planning, meeting trade off in residential location decisions, in picture of industry flexible automation process, effective equipment utilization, also enhance the material handling system as it stress upon the distances and cost involved.

Table 44.5 Solution set iteration II

Solution set	Solution
{4,2,3}	532,662.35
{4,2,5}	411,702.676
{4,5,3}	1,503,042.746
{5,2,3}	762,575.766

Table 44.6 Solution set iteration III

Solution set	Solution
{4,2,5}	411,702.676
{4,2,6}	575,208.65
{4,6,5}	957,290.816
{6,2,5}	754,815.796

Table 44.7 Solution set final iteration

Solution set	Solution
{4,2,8}	202,911.81
{4,2,12}	**200,141.36**
{4,12,8}	1,395,256.68
{12,2,8}	443,954.38

Conclusions

Oil is essential for all sectors of the society. One of the objectives of this research is to identify a location of collection centre. The p-median algorithms have been used to solve the above problem. Finally, three taluks were chosen for locating the seed collection centre using p-median algorithm to meet the rural agriculture supply chain requirement.

References

Badri MA (1999) Combining the analytic hierarchy process and goal programming for global facility location-allocation problem. Int J Prod Econ 62(3):237–248

Bhattacharya U, Tiwari RN (1994) Imprecise weights in weber facility location problem. Fuzzy Set Syst 62(1):31–38

Briant and Naddef (2004). The Optimal Diversity Management Problem 52(4):515–526

Carson YM, Batta R (1990) Locating an ambulance on the Amherst campus of the State University of New York at Buffalo. INFORMS 20(5):43–49

Kahraman C, Ruan D, Dogan I (2003) Fuzzy group decision-making for facility location selection. Int J Info Sci Inform Comput Sci 157(1–2):135–153

Darzentas J (1987) A discrete location model with fuzzy accessibility measures. Fuzzy Set Syst 23 (1):149–154

Daskin MS (1982) Application of an expected covering location model to EMS design. Decis Sci 13(3):416–439

Pierre Hansen (2001) Variable neighborhood search: Principles and applications. 130(3):449–467

Hiromi Yamamotoa, Junichi Fujinob, Kenji Yamajic (2001) Evaluation of bioenergy potential with a multi-regional global-land-use-and-energy model. Biomass Bioenergy 21(3):185–203

Jacobs DA, Silan MN, Clemson BA (1996) An analysis of alternative locations and service areas of American Red Cross blood facilities. Interfaces 26:40–50

Owen SH, Daskin MS (1998) Strategic facility location: a review. Eur J Oper Res 111:423–447

Srinivasan SP, Malliga P (2009) Optimum utilization of cultivable wastelands using decision support system. Int J Eng Res Ind Appl 2(VII):43–56

Teitz and Bart (1934). Heuristic Methods for Estimating the Generulized verter median of a weighted Graph. 16(5):955–961

Trappey and Hsin-Ying Wu (2008) An evaluation of the time-varying extended logistic, simple logistic, and Gompertz models for forecasting short product lifecycles. Adv Eng Inform 22 (4):421–430

Yuri Levin, Adiben-Isreal (2004) A Heuristic method for large scale multifacility location problems. Comput Oper Res 31:257–272

Chapter 45
A Study on Influential Factors of the Elderly's Shopping Channel Selection for General Merchandise Retailers

Min-te Kao and Eric Min-yang Wang

Abstract Due to population aging, complete social welfare system and retirement plans, the elderly will become one of the mainstreams of consumer market. The purpose of this study is to identify the factors that may affect the elderly's shopping channel selection for general merchandise retailers. In-depth interview applied in this study to explore the elderly basic needs of the shopping process. Through actual interview with 13 senior citizens who must be over 65 years old. We extract 45 factors that may affect the elderly's shopping channel selection, and then classify each factor into specific dimension. Although this study belongs to consumer psychology, it's based on the concept of human factors engineering. If we want to explore all various factors in the process of consumption, only understand consumer demand truly, so that the enterprise may create friendly shopping environment for elderly consumer.

Keywords Elderly consumer • In-depth interview • Shopping channel selection • General merchandise retailers

Introduction

The trend of population aging will spread continuously in the world including Taiwan. According to official statistics the seniors proportion were more than 10% at the end of 2010, and the proportion will increase rapidly, Taiwan will become an aged society by 2014, when 14% of the country's people are seniors, and expected to reach 20% by 2025. The phenomenon of population structure changes will result in the transformation of Taiwan's consumer market. Due to complete

M.-t. Kao (✉) • E.M.-y. Wang
Department of Industrial Engineering and Engineering Management,
National Tsing Hua University, Hsinchu, Taiwan, ROC
e-mail: ujm2005716@yahoo.com.tw

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_45,

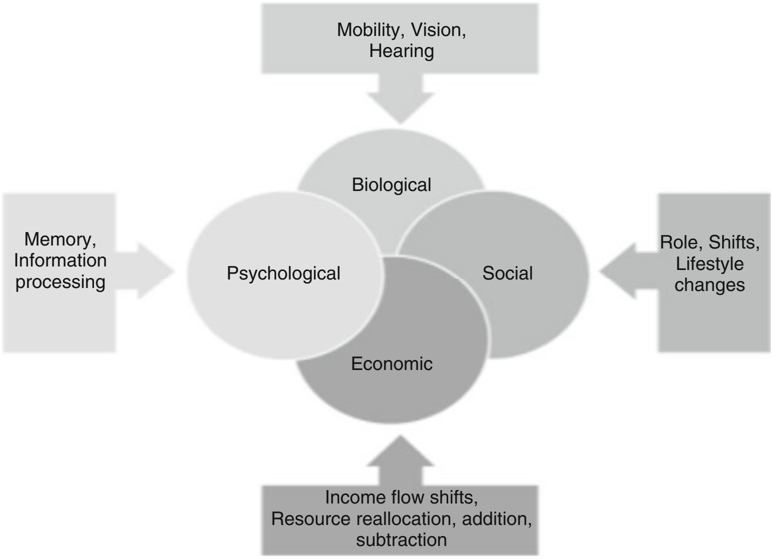


Fig. 45.1 Aging processes can transform consumers

social welfare system and retirement plans which provide more discretionary income (Oates et al. 1996), the elderly will become one of the mainstreams of consumer market.

Aging consumers face specific patterns of change along several dimensions (Pak and Kambil 2006). Pak and Kambil (2006) proposed a framework (Fig. 45.1) for thinking about the changes confronting senior consumers which builds on the biological, psychological, economic and social changes confronting elderly consumers. Therefore, there are really something difference between elderly consumers and other consumers.

When people faced the decision between many shopping channels, what reasons or motivation lead them to select a suitable one to consume. There are three influential dimensions most frequently mentioned by previous studies which include channel features, utilitarian value and hedonic value. Channel features such as operating time or product structure of specific stores. Utilitarian shopping value reflects the acquisition of products and/or information in an efficient manner and can be viewed as reflecting a more task-oriented, cognitive, and non-emotional outcome of shopping (Babin et al. 1994; Holbrook and Hirschman 1982), while hedonic value has been defined as perceived entertainment and emotional worth provided through shopping activities (Kim and Kim 2008). According to the above definitions, there are many factors may affect consumer's shopping channel selection based on these three influential dimensions.

Retail trends often mirror trends in a nation's overall economy (Berman and Evans 2009); hence retail development of the country is very important. The retail formats can be divided into many categories, this study focus on general merchandise

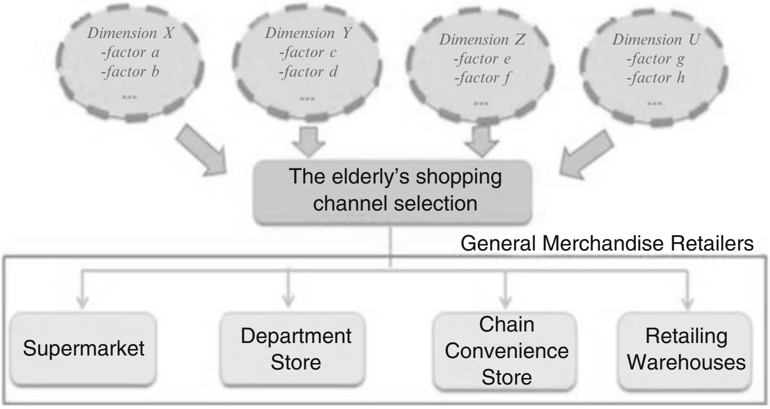


Fig. 45.2 Conceptual model

retailers, because it closely connected with our daily life. Moreover, the turnover of general merchandise retailer is a quarter of the retailer in Taiwan. The typical types of general merchandise retailers include: supermarket, convenience store, department store and retailing warehouse.

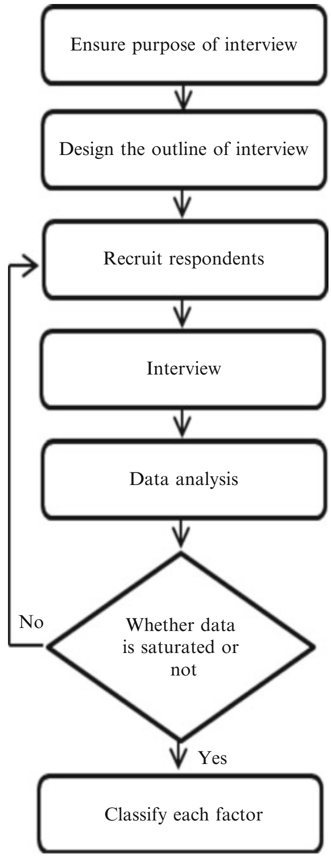
The purpose of this study is to identify the motivation and factors that may affect the elderly's (age over 65 years old) shopping channel selection for general merchandise retailers from elderly's shopping experience or cognitive toward different shopping channels, further classify each factor to specific dimension, and provide valuable reference for this research domain, the conceptual model presented in Fig. 45.2.

Methodology

Qualitative research method applied in this study, broadly defined, means "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (Strauss and Corbin 1990). As the flow chart shown in Fig. 45.3, due to the purpose of this research is to understand the motivation of elderly's shopping channel selection, therefore, through actual interview with elderly consumer, can truly reflect the elderly's cognitive toward different shopping channels. Use semi-structured interview to carry out the experiment, this kind of interview allows for the exploration of emergent themes and ideas rather than relying only on concepts and questions defined in advance of the interview, the basic questions in this study design based on literature review. However, the interviewer frequently has to formulate impromptu questions in order to follow up leads that emerge during the interview.

The majority of the respondents invited from different social organizations such as religious groups or health care groups. The decision of sample size is often

Fig. 45.3 Flow chart of experiment



justified on the basis of interviewing participants until "data saturation" (LoBiondo-Wood and Haber 2006) is reached. Without setting how many respondents need to invite, until the respondent can't extract or propose new or different point, then stop recruit respondents (Yun-Hee 2004).

The following basic steps proposed by Thomas (2006) could be used to analyze the content that respondents mentioned: (1) Preparation of raw data files, then (2) Close reading of text, the raw text is read in detail until the evaluator is familiar with its content and further identify the meaning unit in the content, and (3) Creation of categories, the evaluator identifies and defines categories or themes, categories are commonly created from actual phrases or meanings in specific text segments, (4) Overlapping coding and uncoded text, and (5) Continuing revision and refinement of category system (Thomas 2006).

In order to ensure the reliability of data analysis, we invited another analyst who has the relevant background and several experience about content analysis, and then randomly selected three data files to analysis. After that, we calculated the percent agreement statistic which reflects the number of agreements per total number of coding decisions, and following formula was used to compute the reliability coefficient proposed by Holsti (1969):

$$\text{Average interjudge agreement} = 2m/n_1 + n_2$$

Where
m = the number of coding decisions upon which the two coders agree
n_1 = number of coding decisions made by rater 1
n_2 = number of coding decisions made by rater 2

$$\text{Reliability coefficient} = N(\text{average interjudge agreement})/\{1 + [(N - 1)\,(\text{average interjudge agreement})]\}$$

Where
N = number of participants in data analysis

Results

Data collected from 13 senior citizens (8 female and 5 male), all the respondents must be over 65 years old. Their average age was 71 years (sd. = 4.6). Finally, we extract 45 meaning units that may affect the elderly's shopping channel selection, and then classify each factor into specific dimension. The reliability coefficient is about 0.84, it can be acceptable.

There are many factors may affect aging consumers choose supermarket to shopping. Especially, supermarket provides various types of merchandises; it can satisfy consumer's demands of one-stop shopping. More importantly, supermarket sold fresh food (fruits and vegetables) that attract the elderly consumer, and they also trusted the sources of fresh food, other factors such as cheaper product price or provide bargains information may also influence the elderly consumer, other influential factors presented in Table 45.1.

About department store, the respondents proposed that they are less to go to department stores; sometimes they go to department store with their family member or friends. Respondents consider product sold by department store are more valuable and suitable for gift giving, and they also proposed that feel the atmosphere is the main reason driving consumers to shopping. Therefore, hedonic shopping value is more important than utilitarian value for elderly consumer in these kinds of shopping channel, other results presented in Table 45.2.

Convenience stores provide service such as payment or photocopy that may attract senior citizens to consume. The store nearby home or open all day also the

Table 45.1 Factors affect elderly's choice of supermarket

Dimensions	Influential factors	Number mentioned
Merchandise selection	Various types	10
	Provide fresh food	10
Merchandise price	Cheaper product prices	8
Convenience	Flexible opening hours	5
	Satisfy consumer's demands of one-stop shopping	4
	Short distance	2
Merchandise quality	Reliable sources of fresh food	7
	Provide expiry date of fresh food	5
Information attainment	Provide information on a regular time	5
	Provide bargains information	4
Environment	Well-furnished merchandises	8
	Well-marked areas	2

Table 45.2 Factors affect elderly's choice of department store

Dimensions	Influential factors	Number mentioned
Merchandise selection	More valuable, refined	10
	Provide novel products	6
	Diversification	4
	Suitable for gift giving	4
Service	Good service and attitude	4
	Detail introduction	3
Environment	Clean and comfortable	10
	Special decoration	6
	Food street	5
Others	Shopping with the family	6
	Obtain popular information and new knowledge	4

Table 45.3 Factors affect elderly's choice of convenience store

Dimensions	Influential factors	Number mentioned
Merchandise selection	Provide service (ex: payment)	11
	Special product (ex: newspaper)	2
	Edible immediately meals	1
Service	Good service and attitude	3
Convenience	Nearby home	10
	24 opening hours	7
	Finish shopping process in shortest time	2

important factors for channel selection. It can satisfy consumer's immediate needs, other results presented in Table 45.3.

The respondents proposed many benefits about retailing warehouses such as cheaper price, quantity discount, better after-sales service and well planned parking space. Besides, the replacement and return mechanism of product is complete, it can be guaranteed to consumers, other results presented in Table 45.4.

Table 45.4 Factors affect elderly's choice of retailing warehouse

Dimensions	Influential factors	Number mentioned
Merchandise selection	Various types	12
	Diversification	2
Merchandise price	Cheaper product prices	13
	Quantity discount	4
	Zero interest rate by stages	3
Service	Clear guide	8
	Better after-sales service	6
	Detail introduction	3
	Provide personal service	3
Merchandise quality	Reliable sources	5
Environment	Wide space	7
	Well-planned parking space	7
Information attainment	Provide bargains information	5
	Provide information on a regular time	2
Others	Large quantities, can share with family and friends	5

Discussion

This study found that many influential factors may affect elderly's shopping channel selection, and some confirmed the points made by previous study. For example, merchandise prices, provide product information (Hoffman and Novak 1996), the atmosphere of shopping mall (Wakefield and Baker 1998), product decoration, convenient parking space, product category (Alba et al. 1997). The above points does not only affect the choice of the general consumer shopping channels, those more likely affect the elderly's shopping channel selection.

On the other hand, the research also found some difference points with previous study. For example, Putnam (2000) points out that elderly consumers like to mingle with other shoppers in the shopping process (Putnam 2000). Cox et al. (2005) consider that elderly consumers like to be pampered by servicer (Cox et al. 2005). The above two points have not been mentioned by respondents in the interview. My research supposed that national conditions and cultural differences will result in national consumer shopping motivations and habits are different. Therefore, consumers in different countries have their uniqueness and worthy of further study. In addition, this study also has new findings through actual interview. Elderly consumers will invite friends to join the purchase and take advantage of quantity discounts. Others points like personalized services and after-sales service are never mentioned before, but those of them really affect the elderly's shopping channel selection.

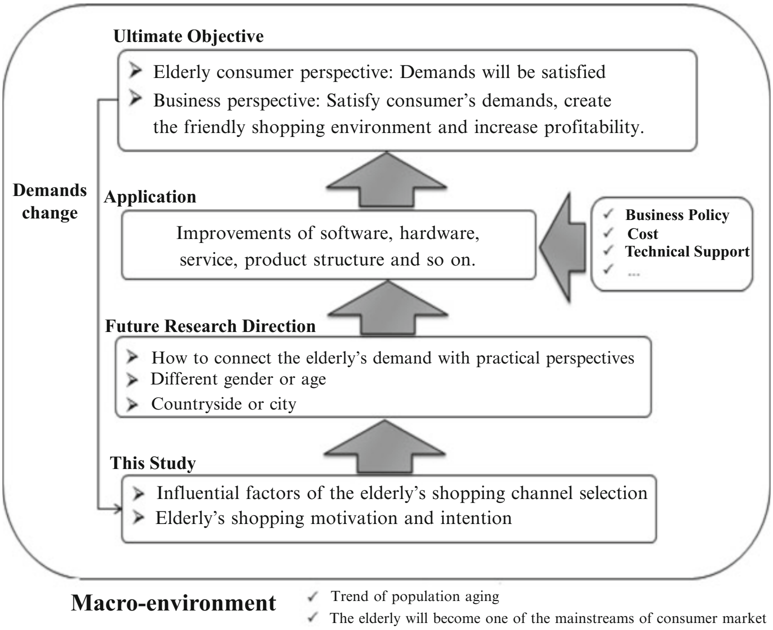


Fig. 45.4 Concept of future research directions

For general merchandise retailers, although different distributer have their specific commodity structure, this study found that product category provide by stores have a certain impact on the elderly through interview. Hence, each retailer need to rethink about the structure of product in stores before Taiwan become an aged society in order to predominate the mainstream consumer market in the future.

Conclusion

In conclusion, the research points out the elderly have both motivation and influencing factors to choose different shopping channels. Although this study belongs to consumer psychology, it's based on the concept of human factors engineering. If we want to explore all various factors in the process of consumption, only understand consumer demand truly, so that the enterprise may create friendly shopping environment for elderly consumer.

The future research directions are presented in Fig. 45.4. The proportion of elderly population is increasing in our environment today. This phenomenon caused population structure changed, and the elderly consumers will become one of the mainstreams of consumer markets. Therefore, this study uses in-depth interview to explore the elderly basic needs of the consume process in order to understand the impact factors of the elderly's shopping channel selection.

Future researches could explore how to combine these basic needs with shopping malls, and even explore the thought of the elderly of different gender and age on the shopping channel selection. The needs of the elderly consume process discussed above; we know that there are many research directions worth exploring. When these research areas become more complete in the future, distributors can base on research results to improve their hardware and software equipment, product structure or service. Of course, distributors need additional corporate support, such as corporate policies, costs, or technical support, in order to make research results applied to actual business organizations. Finally, the ultimate purpose of this research area can be divided into two aspects, for elderly consumer, all aspects of needs should be satisfied in the shopping process; for the enterprise, not only satisfy consumers demand but also create a friendly shopping environment for consumers, and thus enhance the profitability of the enterprise.

References

Alba J, Lynch J, Weitz B, Janiszewski C, Lutz R, Sawyer A, Wood S (1997) Interactive home shopping: consumer, retailer and manufacturer incentives to participate in electronic marketplaces. J Mark 61(3):38–53

Babin BJ, Darden RW, Griffin M (1994) Work and/or fun: measuring hedonic and utilitarian shopping value. J Consum Res 20(4):656–664

Berman B, Evans JR (2009) Retail management: a strategic approach, 8th edn. Prentice Hall, Upper Saddle River

Cox AD, Cox D, Ronald AD (2005) Reassessing the pleasures of store shopping. J Bus Res 58(3):250–259

Hoffman DL, Novak TP (1996) Marketing in hypermedia computer-mediated environments: conceptual foundations. J Mark 60:50–68

Holbrook MB, Hirschman EC (1982) The experiential aspects of consumption: consumer fantasies, feelings, and fun. J Consum Res 9:132–140

Holsti OR (1969) Content analysis for the social science and humanities. Addison-Westly Publishing Company, Menlo Park

Kim H-Y, Kim Y-K (2008) Shopping enjoyment and store shopping modes: the moderating influence of chronic time pressure. J Retail Consum Serv 15:410–419

LoBiondo-Wood G, Haber J (2006) Nursing research: methods and critical appraisal for evidence-based practice, 6th edn. Mosby, St. Louis

Oates B, Shufeldt L, Vaught B (1996) A psychographic study of the elderly and retail store attributes. J Consum Mark 13(6):14–27

Pak C, Kambil A (2006) Over 50 and ready to shop: serving the aging customer. J Bus Strategy 27(6):18–28

Putnam R (2000) Bowling alone: the collapse and revival of American community. Simon and Schuster, New York

Strauss A, Corbin J (1990) Basics of qualitative research: grounded theory procedures and techniques. Sage Publications, Inc., Newbury Park

Thomas DR (2006) A general inductive approach for analyzing qualitative evaluation data. Am J Eval 27:237–246

Wakefield K, Baker J (1998) Excitement at the mall: determinants and effects on shopping response. J Retail 74:515–532

Yun-Hee J (2004) The application of grounded theory and symbolic interactionism. Scand J Caring Sci 18:249–256

Chapter 46
Study on Private Capital in Supply of High-Speed Railway Projects

Gui-feng Qian

Abstract Importing the non-public capital participate in high speed railway supply is effective to expand the development fund of high speed railway, and important to promote the railway supply, to enhance the development of endogenous power and to increase efficiency. For the non-public capital participating in high speed railway, the necessity and possibility are analyzed in this paper. It is discussed the realization forms and the structure pattern about that, and brought forward that professional operation of special permission and DBFOM (DBFO) are new ideas. It is also stated that the non-public capital is important to intensify the reform and sustainable development in high speed railway.

Keywords Non-public capital • High speed railway • Project • Supply

Introduction

The economic system has undertaken great changes since the adoption of reform and opening policies in our country. As the non-public sector of the economy rapidly develops, it also has contributed a great deal to the economic development and improvement of living standards. The non-public sectors of the economy played an important role in energy, mining, telecommunications, roads and civil aviation industries. On the basis of the essence of state council relative documents, in July 2005, "the implementation proposals on how to encourage and guide the non-public economy to participate in the construction and operation of railways" is put forward by the Ministry of Railways for railway construction. That was the beginning of non-public capital's opening up to railway construction, passenger transportation, equipment and manufacturing of transportation and pluralistic

G.-f. Qian (✉)
Business School of Hehai University, Nanjing, China 210098
e-mail: qiangf2004@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_46,

operation. "The notice of continuing to open railway construction market" is proposed by the Ministry of Railways to expand the range of opening up in design, construction and supervision of the railway construction market in 2006. And the Ministry worked out "the investment and financing system reform plan" during National Eleventh Five-Year Plan to give scope to the basic role of the market in resource allocation, to build multi-structure of investment and the property right and the diversification of fund resources and financing pattern. In spite of the Ministry of Railways has a new set of laws to encourage external capital on railway construction in the past 6 years; however, external capitals were not positive to railway industry (Yang Ying 2008; Liu Xia 2007). During National Eleventh Five-Year Plan, the implementation of National Middle-long Term Construction of Railway Plans, China's high-speed railway has developed rapidly. Part of the high-speed railway had been set up and put into operation, the pressure of these railways' repayment has become increasing. Some of high-speed railways under construction in the key stage need more funds. At present, some high speed railway projects under construction have entered into the key period which starves for funds and is facing double pressure of both funds and operational efficiency. Therefore, high speed railways urgently need non-public economic entities' participation, but the system and model of such participation is not so complete that it needs to be further discussed and researched.

Necessary Analysis

Rational Division of Labor Among Investment Subject Are Needed in Market Economy

In the condition of market economy, the rational division of labor among investment subject can not only stimulate the initiative of the labor groups and a laborer form all ranks in various fields, but also fully play advantages in investment entities, to make the allocation of society resources more reasonable. The rational division of labor among investment subject is advantageous to rationalization of determinants of industrial structure and investment structure, is advantageous to making the ratio of the central government, the local government, enterprises and individuals in national income allocation process reasonable and benefits coordinated.

Government can change the condition of asset value less than issued debt to profitability by bringing some of the production (market) to a dynamic private enterprise. It not only increases government tax revenue, reduces government spending and debt, but also allows the public to get a higher quality of goods and services, improves people's living standards, reduces corruption and other undesirable phenomena, and extends the scope and depth for public support. The motivate for excellent performance of private enterprises not only can promote themselves to provide products and service of high quality unceasingly, to make up for the insufficiency of state-owned economy and to enrich the market, but also can obtain the profit that they are due to have, turn over to the state handsome tax, support the national finance, and can absorb the massive labor forces and address social issues such as employment and so on.

Railway Property System Is to Be Reformed in the Railway Reform Development

Since long ago, railway industry in our country exists as public-owned enterprises in the organization form. Public-owned enterprises have the following characteristics: firstly, they are owned by the country on the property right arrangement. Secondly, they have the powerful supplies exclusive right, and the characteristics which the government monopoly and the enterprise monopolize combine; finally they are under regulation of public square. Under the arrangement of such system, due to the internal opposition of business property, multiplicity of business goals, inadequacy of business constraints and incentive mechanism leads to inefficiencies. Therefore, the introduction of non-public capital to relieve pressure on the financial investment, improving operating efficiency, increasing the market supply and improving the quality of services should be the direction of reform.

In fact, the significance of allowing non-public capital to involve in the provision of high speed railway supply also goes beyond this. The market-oriented reforms in railway industry on the core of introduce competition, are to let different capital-owned enterprises contest. If the introduction manner of competition is basically to split and restructure the State-owned enterprises, the new market entrants are also essentially State-owned enterprises. It can’t create the main body of market competition which is based on clarification of property rights, and finally only is wasteful competition between State-owned enterprises under the soft constraint. As a result, it is likely to be both the effectiveness low shortcomings and advantage of the non-scale benefit. From another perspective, if only importing competition into a single State-owned or State-owned investment as a share in the ownership structure of the subject, all subjects of interest for competitors is only one, that is, state-owned (state-controlled) asset owners. In this way, any business in competition to be eliminated would be a great loss of state assets. For government departments, it cannot achieve the purpose to encourage real competition between the various operators, what can be formed only is non-monopoly but not real competitive situation. Therefore, the railway industry reform must carry on the railway property right system the reform firstly. Only to establish clear, standardized, diversified property rights relationship and perfect enterprise’s internal control structure, can produce a real market competition, and then form effective competition, and ultimately achieve the objective of increasing efficiency and improving service. This is what the fundamental necessity of the private enterprises to invest in railways is.

High Speed Railway Sustainable Development Needs the Non-public Capital

For the national long-term planning of rail network, the joint venture model provides a platform for promoting the high speed railway construction. For a specific project, The Ministry of Railways, the local government and social investors set up a high speed railway project company together, the corporate juridical person is responsible for the whole process of financing, project construction, production management, debt servicing and maintaining and increasing of the value of assets. At present, the main body of investment of the joint venture company is the state-owned enterprises, less the share of the non-public capital in the project investment structure, and their own loan scale is high. The project companies have the ownership of property of the high speed railway. They are responsible for the construction of the high iron system and vehicle purchase (or by the designated purchase). After the completion of the project, the Ministry of Railways entrusts railway administration to operate and maintain the vehicles and infrastructure. The project companies are responsible for repayment of the debt, paying entrust operation cost, overhauling infrastructure and rebuilding fund by the route fees they get. The Ministry of Railways formulates the entrust agreement for guidance, plans the train operation, determines the take and is responsible for internal accounting and supervise ticket prices. Under the current mode and settlement system, the risk of market demand, fares, completion, financing, cost of operation, maintenance and management of the railway administration is assumed by the high speed railway company. Even though the existing settlement system is further improved, and part of the risk is transferred from the high speed railway company to the railway administration, the situation that the public-operated departments assuming all the risk has not been changed yet, and the essence is still that the state assumed all the risks of high speed railway. To maintain a healthy and steady development of high speed railway, the funding sources should be expanded to protect the needs of the construction funds, and the profitability of the project should be improved as well to ease the burden of debt. The introduction of external capital, rational design of investment structure and ownership structure benefits to improve profitability of project and risk prevention ability, and benefits to the diversification of the investment subject and property right structure.

Feasibility Analysis

The Successful Practice in Foreign Countries Set an Example for Participating in Supply

Since the first high speed railway between Tokyo and Osaka, Japan, was built in 1964, the development of the world's high speed railway has undergone a nearly 50 year history. The technology of high speed railway as a safe, green and efficient transportation of passengers has also rapidly developed. Most countries have carried out the national middle-long term construction of high speed railway and transport plans. According to incomplete statistics, up to December 2010, the total length of high speed railways in operation in the world is above 20,000 km.

With the development of railway technology, the supply of high speed railway, that is investment construction and operation service, has also undergone a fundamental change from the national traditional monopoly or strict control to breaking the monopoly, de-regulation, and introducing competition. After 1980s, the United States, France, Germany, Japan and other developed countries have implemented reforms to the rail industry. In Japan, the market for railway was restructured and privatized, changing the ownership of the project. The European Union developed a uniform policy and the implementation of the separation between construction of rail and transport and competitive business model. Countries generally adopt the changes from the original direct government investment towards public-private mixed management In construction of the new line for high speed railway, making the private sector committed to part of the construction, operation and management, vehicle procurement and maintenance of business and market development in high speed rail system. Thus, the commissioned services mode and franchise mode has been successful practice in the implementation of high speed railway project. Through the reform of the supply mode in high speed railway, the operation efficiency is improved, the government's financial burden is lightened, railway public utilities have developed also, and the consumer gained more and better service at the same time, and the level of social welfare has been further improved.

China's Encouragement Policy to Participate in Supply Provides as a Guarantee

The Chinese Communist Party's Third Plenary Session of the Eleventh Central Committee made it clear that non-public ownership economy is a necessary addition of socialist economy. In 1993, the Third Plenary Session of the fourteenth Central Committee further pointed out that we must adhere to the basic economic system with public ownership as the mainstay and the common development of various economic sectors. In 1997, Congress comprehensively expounded the party's basic line and basic program of the primary stage of socialism, first proposed we must persist to follow the basic economic system to keep public ownership in a dominant position and have diverse forms of ownership develop side by side in China. In 2002, the Party's Sixteenth National Congress further specified that "according to the liberation and development of productive forces, upholding and improving the public ownership is dominant and diverse forms of ownership develop the basic economic system and must unswervingly consolidate and develop the public economy, must be unwavering encouragement, support and guide non-public economic development. In October 2003, the Party's Third Plenary Session of the Eleventh Central Committee announced that the Central Committee of Chinese Communist Party about Consummation Socialist market economy System Certain Question Decision to request, the relaxation market access, allowed the non-public capital to enter the infrastructure, the public utilities and other professions and the domain which the legal laws and regulations have not endured into. Non-public ownership enterprises in financing, taxation, land use and foreign trade, and so on, with other businesses enjoy the same treatment. The "Decision" has emphasized the importance of relaxing the monopoly market access and introducing competition mechanism. Qualified enterprises should actively promote diversity of investors with the necessary conditions, continue to advance and improve telecommunications, electric power, the civil aviation industry restructuring, accelerates railway, postal services and reform of urban public utilities such as water supply. Implement separating government administration from enterprise management, the political capital separates and the politics separates. The country's monopoly business needs effective supervision. The "Decision" marks that expanding market access and introducing competition in the natural monopoly industries becomes a national policy in China.

In 2005, the State Council promulgated the "regulations on encouraging, supporting and guiding the private and other non-public economic development in a number of opinions", which was the first systematic promotion of non-public economic development policy document. In March 2010, the State Council once again established policies and measures to encourage and guide the healthy development of private investment. In November the same year, the Central Economic Work Conference stressed the need to give full play to the market in allocating resources to the basic role, by promoting the reform to provide economic and social development with a powerful driving force and system security. Since reform and opening up, States file reflected the spirit of the CPC Central Committee on non-public ownership economy's increasing emphasis on the role and function of the degree, identified the significance of non-public enterprises allowed to enter the system reform of monopoly industries to promote economic significance.

Non-public Ownership Economy Development Situation Makes Their Participation in Supply Viable

The policy of reform and opening up in the early 1980s makes China's economy enter a period of rapid growth and makes private economies develop rapidly. The second economy of census data published in November 2009 and first economic census data released in 2006 show that from 2004 to 2008, the number of private enterprises in the national share of the number of national enterprises grew by 80%. Private enterprise's gross asset and the proportion also doubled during 4 years. In 2009, private holdings had invested more than 40% of the country's urban fixed-asset investment (Chen Yongjie 2010). Private investment had become an intrinsic vitality and power of the main sources of economic growth, and also had played an important role in optimizing the allocation of resources, increasing economic efficiency and the maintenance of supply and demand balance, expansion of employment, social stability. Under the national policy to encourage and guide electric power, telecommunications, roads, civil aviation and other traditional monopoly industries achieved results in the introduction of external capital. Long-term exploration and attempt shows that private enterprises access to natural monopoly industries in China, could contribute to the reform of monopoly industries. Firstly, the participation of private capital effectively makes up for the lack of government financial resources. Driven by the interests of private enterprises, there is a direct economic incentive to seek and engage in the construction of the user-pays, and at the same time willing to profit infrastructure in public to be able to pay the price level, provision of services to meet the needs of the community. In addition, infrastructure and long-term stable cash flow returns can better meet the needs of private capital investment. Secondly, it promotes government department's renewing and improving management level. Government public sector infrastructure mainly focuses on the end-user demand, leading to the initial investment, the high cost of doing business. The government tends to bear a heavier burden. The private enterprise embarking from the commercial operation angle is willing to expand the project scale gradually according to the project income situation and enables the project to achieve the anticipated economic efficiency. Project during introduction fund, also has brought the advanced management idea and the management system to the government. Thirdly, the promotion technology and the management innovation, has shared originally the risk which undertakes by the public department. Profit-oriented private sector, therefore, are more willing to use new technologies in the construction of the project, to focus on improving management efficiency helping shorten the development cycle, reduce costs, and control risk. Fourthly, as the private sector project funding provided by the use of more stringent controls can effectively prevent the government building in the project to generate rent-seeking and corruption.

Historical development of reform and opening up experience has shown that the further development of private economy, strongly encourage and guide the expansion of private investment, is to ensure steady economic growth of the objective requirements. As China's reform of the railway transportation known as the "last bastion of the planned economy", the demands for reform of "breaking the monopoly, increasing efficiency, improving service," are increasingly urgent (Qian Guifeng 2009). Therefore, the introduction of private enterprises enters the field of high speed railway and competes with the business, which is viable.

Research on Participation and Providing Mode

Modes of Realizing Involvement and Providing of Non-public Capital

The detailed step for the involvement and providing of non-public capital, it is prime important to solve the issue of using what mode. The characteristic of high speed rail operating and funds providing will determine the mode of realizing the non-public capital involvement and providing funds and franchise operating right for high speed rail. With the development of high speed rail, people pay much attention to the research on economic characteristic of high speed rails. On the basis of Natural monopoly theory, theory of externalities, public goods theory, as well as the railway project of distinction based on operational theory provides a basis for evaluation of high speed railway business and lays the foundation for establishment of Investment division of labor and analysis of the Realization form of Non-public capital into the high-speed rail. Firstly, profit-oriented infrastructure should give full play to the role of the market sector and fully attract private enterprises and non-public capital to undertake duties, such as the provisions of vehicle equipment and facilities and so on. Secondly, to the profit-making projects whose expectation of long-term economic benefit will be better, you can use a good system design, to increase the expected return on investment, and attract non-public capital. Thirdly, in order to maximize the introduction of non-public capital, for those pure public goods whose prices are difficult to form and significant externalities, the Public service infrastructure projects which must be funded by financial, can attract non-public capital participation by Imitation of commercial operation of the system design.

The supply of high speed railway project include high speed railway infrastructure provision and transportation service, supply chain include multiple processes and links of construction, maintenance, operation services and investment and financing. Along with technological innovation, especially the development of interconnection technology and business segmentation and the emergence of market capacity expansion and financial innovation, such as the operation of high speed railway service, maintenance of network infrastructure, lines and so on, and the design and construction of projects, which were originally considered as the natural monopolizing service or link, its barriers to entry and exit are gradually overcome, which fundamental create conditions for the non-public capital to enter in. The market-based instruments such as commission management, contract management, license services, which becomes realization form of the non-public capital to undertake the high speed railroad supplies responsibility.

Based on the above analysis, private capital can through three dimensions to participation in high speed railroad project. Firstly, it can take the form of capital access. For the Significant operating and profitable good project can open on investment subject to non-public capital. It takes the form of capital access and through joint-stock form to realize diversified investments. Secondly, it can take the form of competitive operating right. In the link which with network characteristics and natural monopoly characteristics, although the existence of structural and strategic barriers make the non-public capital through "competition in the market" to realize Participation more difficult, the non-public capital also can be ensured through "market-competitive form of power" to achieve Participation effectively, which through Institutional arrangements of franchised by the government, entrusted with the operation and contract management and so on. Thirdly, the mixture of capital and business right is adopted. That is, non-public enterprises operate under the principles of marketing, commercialization and participate in the process of undertaking the high speed railroad construction and maintenance part of the business and financing support.

Private and Public Capital Participates in Construction Mode of High Speed Railway

Mode of Commissioned Operation

In the aspects of high speed railway commissioned management, railway departments can opening to the outside in the aspect of high speed train transport operators, High speed train and the station building cleaning, station line facilities for routine maintenance and so on. Private enterprises can get the management business through competition or negotiation. Railway departments signed agreement with the winning companies on entrusted management to determine the number of service, quality standards and commissioning management cost. This model is characterized by attempts to reduce production cost to a minimum level and at the same time can purchase provided goods or service from it through financial purchases. Market can make the choice that government produce themselves or the chose to others. In this condition, private enterprises take full responsibility about the object of the contract operation and maintenance, but do not take on the capital risk. Time-limited agreement can promote the commissioned party to optimal management, promote advanced technology and improve product quality and services. The management models that introducing competition. On one side it will give users more opportunities for freedom of choice. On the other side it can bring more revenue and higher costs of public services. In this way productivity and service quality can be improved efficiency.

Mode of Contract

According to the economic characteristics of the contract, in the aspect of high-speed railway infrastructure construction, equipment vehicles purchase, government railway department or the project company (the owner) can be open to non-public economic agents. Through public bidding it makes the private sector get the project contract, opportunity of equipment vehicles, agreement price, clear contracting and contract rights and obligations of both parties to reduce costs and improve efficiency.

Mode of Equity Investment

Government railway department could set up High Speed Railway Company according to regional or trunk line, and carry out equity split by subjecting to the non-public economy and open society equity investment. Equity investors obtain economic benefits profits or dividends through the purchase of its shares or capital money, physical assets, intangible assets and other direct investments in shares of high speed rail projects. High speed rail could raise equity funds for high speed railway construction project within the scope of its business and new high-speed railway construction to expand its business scope. According to the different situation that investors controls the project, non-public capital investment in high speed rail could protect the investors' income accounting methods and oriented policy, based on the further innovation on the cost method or equity method of accounting for income.

Mode of Share Is Transferred

Government Railway Department can reorganize the stocks of the high railway joint-stock companies that have built and qualified, and remain a controlling stake in the form of state owned shares. Part of shares will be sold in the capital market. Non-public economic entities will form a defacto management rights through the purchase of shares in the capital market and the acquirement of share holder rights, and will bring into play the advantages of the private capital management, capital, technology, experience and the market power. The main advantage of state-owned share transferring mode in the field of high railway is that you can make an inventory of state-owned assets so that the government recovering part of the money could use into other projects, which will conducive to maintaining a high degree of coordination of rapid development, elimination contradiction between existing businesses and new enterprises, also conducive to rapid response of changes in demand of the end consumer in the high speed rail service.

Introducing Franchising into Non-public Capital

Franchising is applied to the infrastructure field, which has been successful practice. BOT (build-operate-transfer) is the most common and the typical form of the franchise, BOO (build-own-operate), LBO (lease-building-operation) is also common form. Theoretical Study of BOT franchise application in the railway field shows in the related literature (Qian Guifeng 2006; Yin Hongju 2010). Franchise model used in the field of high speed railway, the obvious advantage is quickly raising funds to ease the shortage of construction funds. By researching on the franchise model at home and abroad, we can take the following two potential innovative modes in China's high speed railway.

Commissioned Professional Franchise

The construction and operation of high speed railway project are awarded two separate professional firms by government railway department, coordinated by the both parties to complete the construction and operation. Infrastructure companies are Government Shareholding, attracting public and private co-investment investment identical to monetary, being responsible for the civil works and construction and maintenance of signal systems; the company is selected by comprehensive competition between the currently existing railway operating companies, the joint venture of state-owned rail operating companies and public and private investors, new combined of other public and private enterprises, the main elements of comprehensive competition are included the operating costs, service quality and so on. Vehicle purchase can be supplied by the infrastructure company, or operating companies. According to the contract scope of the commissioned franchise, we determine the costs of liquidation. There are similar cases with this model in underground Blue Line of Bangkok, Manila Light Rail Line 3 and other projects.

Advantages of this mode are in the following aspects. Firstly, it takes advantage of specialized division and improves efficiency of project incentive and risk management to improve project efficiency. Secondly, construction and operation are of relative independence. It will be not affected by the other changed. Thirdly, it helps draw up business datum and business expansion and helps private capital and other investors to enter. It also helps to improve the efficiency of project operations. Fourthly, government departments, infrastructure companies and operating companies are closer in link and the control. It will help the government improve the quality of supervision and services. Fifthly, with high flexibility, public department can keep the role of company of infrastructure or operating company. Of course, when taking the commissioned professional franchise, we also need to be concerned in the following three aspects: Firstly, the risk of construction company and operation company's co-ordination; Secondly, the complexity of project procurement and implementation. Thirdly, the market risking of infrastructure's transferring payments.

The DBFOM (DBFO) Franchise

DBFO franchise is included the design, the construction, financing and the way of operation in public and private approaches to cooperation, the government permits for the social the investor with the design, construction, financing and operation in high-speed railroad. The DBFOM franchise includes the design, the construction, financing and the operation, also includes the operation maintenance service. Compared with the corporation structure, DBFOM (DBFO) is more prominent in playing a role of society investor's function. This similar structure's case is The Channel Tunnel, British HS-1 (from The Channel Tunnel entrance to London) and so on.

Advantages of this mode are in the following aspects. Firstly, in term of the responsibility and the contact point, the government only faces the single object, namely the DBFO commissioned franchise operation. It is advantageous for the supervision and the control. Secondly, it has transparent and the relatively simple structure. Thirdly, it is advantageous for organizing the project purchase and the implementation. Fourthly, it is advantageous for reducing the procurement cost, reducing the design construction cost, integrating the system effectively, attracting to throw the financing organization the participation, reducing construction side coordinated cost and so on. The shortcoming lies in: firstly, it lacks the flexibility. It cannot solve the arrangement of the different special permission working plan, such as the civil engineering contractor possibly holds the short-term viewpoint, but the operator holds the long-term view, it is easy to have the conflicts of interest. Secondly, in the term of the organization, the project company's finance belongs to "project financing". It does not have shareholder's guarantee, and can only make the mortgage in the future income by the project, the risk is high, thus it causes the financing cost to be possibly more expensive. The DBFOM commissioned franchise and the DBFO commissioned franchise have the similar characteristic, as it has included the operation maintenance service, and then reduces the government's coordinated work, but is higher request to franchisor's synthesizing capacity.

Conclusion

The non-public capital's participating in high speed railway supplies, is the efficient way of the development of high speed railway construction funds channel and the security of high speed railway development with steady steps, is also the need of the deeply developing the railway industry reform. The country encouraging policy to the non-public economy development provides the support and the security of the non-public capital entering the high speed railway domain, the overseas high speed railway Anti-Monopoly's successful practice, the present situation of our country non-public economy development and other natural monopoly profession's reform practice has provided the experience which can be referenced. Under our country present system, the non-public capital participation in high speed railway can be the form of capital, the form of management right and the mix form of the capital and the right of management. The commissioned franchise operation and management, the project contractor, the stockholder's rights investment, and the stockholder's rights transfer pattern are the feasible pattern of public and private capital participating high speed railway supplies. The commissioned professional franchise, DBFOM (DBFO) franchise is the innovation pattern of high speed railway reform and development and introducing the non-public capital in our country.

References

Chen Yongjie (2010) The differences and changes between 36 non-public economy and the new 36 rules [N]. China Bus Times 5:18 (in Chinese)

Liu Xia (2007) Study on the barriers to entry of foreign capital in China's railway industry [D]. Fudan University, Shanghai, p 10 (in Chinese)

Qian Guifeng (2006) Research on the application in BOT project financing in the railway construction [J]. Railw Transp Econ 28(9):1–3 (in Chinese)

Qian Guifeng (2009) Study on evaluating the selling properties of railway facility projects and the management of classification investment [J]. Ind Econ Res 1(2):70–75 (in Chinese)

Yang Ying (2008) Study on public-private mixed financing in the railway capital construction projects. Railw Account 8:13–18 (in Chinese)

Yin Hongju (2010) Study on mode of China's railway project investment & financing [D]. Chang'an University, Xi'an, p 6 (in Chinese)

Chapter 47
Study on the Construction of Agricultural Product Logistics Public Information Platform

Dong Li, Xi-fu Wang, and Li Lei

Abstract Combining with the current situation of the circulation of agricultural products and the practical demands of informatization of agricultural logistics in China, the problems in the process of agricultural products circulation are put forward and the necessity of constructing a agricultural products logistics public information platform is analysed. It is divided into three layers, the base layer, the application service layer and the portal layer. The functional configuration and the operation mode of the platform are analysed as well.

Keywords Agricultural product • Logistics • Public information platform • Structure

Introduction

Informatization is the core of modern logistics development and an important symbol of modern logistics. That the application of information technology, communication and computer technology and other high-tech in logistics activities is a distinctive feature of modern logistics. At present, as one of the important national projects, the construction pace of logistics public information platform has been sped up in many fields (Abrahamsson et al. 2003). But which kind of public information platform to construct in the agricultural product logistics field? And what the structure and function are? The questions would be analysed and the answers would be given next.

D. Li (✉) • X.-f. Wang • L. Lei
School of Traffic and Transportation, Beijing Jiao Tong University, Beijing 100044, China
e-mail: arthurlee1121@yahoo.cn; wxfky@vip.sina.com; llei@bjtu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_47,

The Necessity Analysis

The construction of agricultural product logistics public information platform provides the precondition and foundation for efficient operation of agricultural logistics. It plays an important role in accelerating the modernization of agricultural logistics and protecting the interests of the farmers.

Agricultural Product Logistics Problems

At present, the phenomenon of “Peasant hurt by low price of vegetables” emerges in Jinan, Zhengzhou, Hubei and other places in China and that lead to bitter lessons. It brought great economic losses to local farmers, and the dull sales of agricultural products have brought a series of questions at the same time. Due to a lack of a unified information network platform the entire agricultural product logistics process is blocked, which lead to that the farm produce are divorced from marketing in the supply chain (Huan Zhou et al. 2005). The farmers are often in a passive position and assume greater risk.

The Necessity of the Construction

The agricultural product logistics public information platform is to use advanced information and communication technology to build a virtual and open logistics network platform. As a public and commercial platform, the agricultural public logistics public information platform is to provide service for farmers, enterprises, wholesale markets, supermarkets, consumers and relevant government departments. For providing real-time logistics information services and improving the efficiency of logistics operations it is very necessary to integrate and make full use of information resources on the current agricultural logistics operation mode (Li et al. 2011) shown in Fig. 47.1.

On the one hand the public information platform make farmers get more market information and take timely measures to reduce risk effectively. On the other hand, with the timeliness features of agricultural products, the participants in agricultural product logistics can keep abreast of agricultural logistics information via the public information platform so they may achieve fast transactions and enjoy timely logistics services. That promotes the circulation of agricultural products thus increases economic and social benefits.

The Goal

At present, the foreign logistics information platform construction is concentrated in three aspects, e-commerce site construction, portal construction and information systems development. With a view to the applications of agricultural product logistics

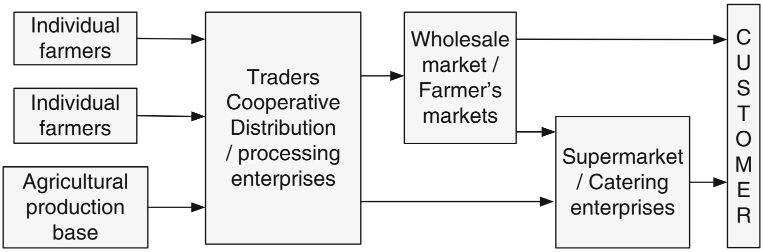


Fig. 47.1 Agricultural product logistics operation mode

information platform, the farmers, enterprises and government should be involved so the platform should have a more comprehensive functionality. It should base on the Internet and have website as the form, have logistics process as the backbone and have a variety of technology for support. It is an open platform that it provides information dissemination, exchange and information sharing and collaborative work environment for the participants.

Architecture and Function Design

Structural Design

The functionality of agricultural product logistics public information platform should meet the requirements of different participants in the logistics system. Therefore, from the systems engineering point and according to the whole circulation process of agricultural products it is divided into three layers, the base layer, the application service layer and the portal layer (Zhang and Huang 2007), as shown in Fig. 47.2.

1. Base layer. The base layer is the basic of the agricultural product logistics public information platform, which provides the hardware and software support for the platform running. It is the foundation of the platform (Fan Zhang and Feng Xiao 2009). The main components include the network infrastructure, agricultural product logistics information standard system, the public underlying database and etc. The public underlying database includes basic information database, agricultural supply/demand information database and agricultural product logistics integrated management database. The information on transportation, processing, products supply and demand, warehousing, vehicle scheduling as well as related legal information is stored in these databases. It can provide services for agricultural transportation, distribution, warehousing, planning and control, customer relationship management and statistical analysis at the same time.
2. Application service layer. Different application systems can be developed according to various needs of users, including agricultural product logistics

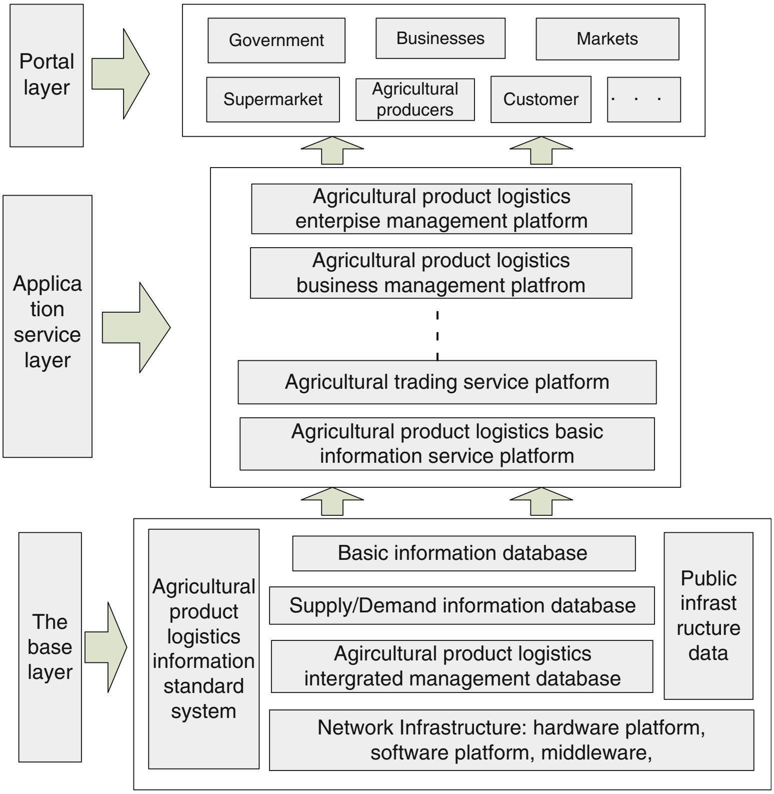


Fig. 47.2 Agricultural logistics public information platform architecture

basic information service platform, agricultural trading service platform, agricultural product logistics business management platform and agricultural product logistics enterprise information management platform. The basic information service platform provides the users with basic information services such as real-time status tracking and bill inquiries. According to the information displayed on the agricultural trading service platform, supply and demand sides can conduct online transactions conveniently (Chuan-jun Guo 2008). While the agricultural product logistics business management platform provides a variety of modern management tools for the logistics process of interrelated logistics enterprises and government departments. To the agricultural logistics enterprise information management platform it can help to improve enterprises' management and operational efficiency.

3. Portal layer. This platform contact the farmers, processing enterprises, logistics enterprises, supermarkets and farmer's markets as well as relevant government departments together. It provides access to a variety of information resources for those users so that they can get their information and services on this layer.

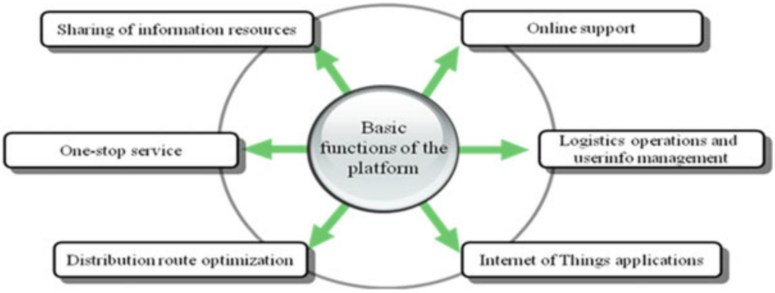


Fig. 47.3 Basic functions of agricultural product logistics public information platform

Functional Design

Different users' needs for information may be different so the platform should meet the needs of different users. The basic functions (Zi-yun Deng et al. 2011; Zi-yun Deng and You-sen Huang 2009) are shown in Fig. 47.3.

1. Sharing of information resources. To meet the information requirement of different users, the platform offers access to all departments including farmers, businesses, markets and government for information dissemination, retrieval, consultation and information issue.
2. Online transaction support. Online transaction processing of agricultural products are supported on the public information platform. That online trading, security certification, order management and tracking, contract management as well as tax and financial assisting services function are included.
3. One-stop service. That wealthy information resources as well as dynamic and standard integration mode on the platform enable it to provide integrated and comprehensive various individual service functions so one-stop and integrated ticketing system and a package of services are provided.
4. Logistics operations and userinfo management. By mastering logistics status of agricultural products different business units can achieve the informatization in logistics management including procurement, storage, distribution and tracking and etc. Meanwhile, it depends on the types of users that to assign the authority to achieve their browsing, reading, editing, general management and the notification function.
5. Distribution route optimization. Based on the capabilities of intelligent distribution management of the platform, the enterprises can take advantage of the data collected from RFID to establish a transportation optimization model for the distribution route. While, according to the location of the vehicles as well as transportation route information on the electronic map by GIS (Fang-ju Li and Jian Jiang 2011), the mathematical model is calculated and the best route would be located. That will help to improve the logistics efficiency and the quality of service and the logistics cost will be further reduced (Feng-lan Luo and Chao Luo 2011).

6. IOT applications. It is to construct the application platform of the IOT on the agricultural product logistics public information platform. Many consumers' concern of information on agricultural products is not only limited in logistics terminal, the original information as well as the information in the distribution process is also included. In the entire logistics system, the consumers can learn about the agricultural products in all process with the share of information. Especially the food, process tracing is an important guarantee of information traceability for the food safety.

Construction and Operation

The agricultural product logistics public information platform is a large and complex system so the construction cannot be achieved overnight and should be in stages. In accordance with the principle that the government push, the third party implementation and the market operation (Wang et al. 2006). An independent platform operator should be established in favor of the government departments and industry associations. According to market-based operation mode, the operator can provide high-quality logistics services through the public information platform. At the same time, the users should pay certain fees in return following the rule "who benefits, who pays" in order to support the long-term operation of the system. The government should play the supervisory role.

Conclusion

The construction of agricultural product logistics public information platform is an effective way to achieve agricultural product logistics informatization. It plays an important role in improving the operational efficiency of agricultural product logistics and in enhancing the competitiveness of distinctive agricultural products, besides, it is helpful to protect farmers' income. The structure and function of the platform are analysed in the paper and the operating strategy is proposed. The application will have a significant impact on agricultural product logistics thus contribute to the development of the entire logistics industry.

References

Abrahamsson M, Aldin N, Stahre F (2003) Logistics platform for improved strategic flexibility [J]. Int J Logist 6(3):85–106

Chuan-jun Guo (2008) Research and realization of logistic distribution public information platform [J]. Logist Sci Tech 4:120–121 (Chinese)

Fan Zhang, Feng Xiao (2009) Research on regional logistics public information platform construction [J]. Sci Mosaic 8:53–55 (Chinese)

Fang-ju Li, Jian Jiang (2011) Application of GIS in modern logistics information platform [J]. Mod Electron Tech 34(16):42–44 (Chinese)
Feng-Ian Luo, Chao Luo (2011) Research on logistics public information platform construction based on RFID [J]. Chin Electron Commer 6:42–43 (Chinese)
Huan Zhou, Li-ping Huang, Jin-chuan Zhan (2005) Construction of new agricultural product logistics information platform [J]. Jiangsu Rural Econ 6:28–29 (Chinese)
Li Hui-juan, Zhao Ting-ting, Zhang Mao (2011) Problems and countermeasures of agricultural product supply chain based on mode of connecting agriculture with supermarket [J]. Mod Agric Sci Technol 18:394–397 (Chinese)
Wang Xi-fu, Shen Jin-sheng, Guan Wei (2006) Research on the framework of regional modern logistics public information platform system [J]. Logist Technol 1:77–83 (Chinese)
Zhang Xiu-zhi, Huang Li-ping (2007) Study on the agricultural product logistics information platform based on the information portal [J]. J Agric Mech Res 5:5–7 (Chinese)
Zi-yun Deng, You-sen Huang (2009) Layer structure and analysis on the function about the logistics public information platform [J]. Logist Eng Manag 10:13–27 (Chinese)
Zi-yun Deng, You-sen Huang, Xiao-feng Yang (2011) Overall planning about human logistics public information platform [J]. Logist Sci Tech 4:106–108 (Chinese)

Part II
Assistive Technology of Industrial Engineering

Chapter 48
A Dynamic Method of the Representatives Apportionment

Qiong Zhang, Jin-ming Huang, and Xiao-mei Wang

Abstract All the federal unions, like the United States of America or the European Union face the issue of finding the right allocation of seats to their member states. There has been a lot of debates in the United States of America since two centuries in order to find the right mechanism to round off the number of representatives per state proportionally to their populations. This problem is now well documented. The existing methods of the representative apportionment actually are based on the max-utility rule, but they just satisfy one or two Fair Apportionment Axioms. To answer this question, we consider to present a dynamic apportionment method which satisfies the three axioms 1, 3 and 4. The calculable program is also presented.

Keywords Axiom • Dynamic method • Preference • Representatives apportionment

Introduction

Apportionment Problem (Cervone et al. 2001; Demange 2001; Feix et al. 2004; Felsenthal and Machover 2001; Galam 1990; Gehrlein 2002)

The well known apportionment problem (AP) can be formulated mathematically as follows:

Given states $s_1,\ldots,s_n$ with populations $P_1,\ldots,P_n$ and a positive integer h (think of h as the number of seats in the legislature), determine non-negative integers $a_1,\ldots,a_n$, where $a_1 + \ldots + a_n = h$.

Q. Zhang (✉) • J.-m. Huang • X.-m. Wang
Department of Foundation, Military Economics Academy, Wuhan, China
e-mail: zq0988@gmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_48,

The AP problem requires that each a_i be greater than or equal to 1, or more generally greater than or equal to b_i, where b_i is some positive integer.

Fair Apportionment Axioms (Lucas 1983)

One fairness idea is that each state should get either its lower quota or upper quota. A second approach to fairness is to look at pairwise equity between states. Huntington (Cervone et al. 2001) was a pioneer in using mathematical ideas to compare the different apportionment from a fairness point of view. Huntington realized that there were two major approaches to evaluating fairness:

1. Global optimization. This approach sets up a measure of fairness and for a given apportionment method sums up this measure for all the states. The goal is to select that method which minimizes the sum for the given measure over all the states.
2. Pairwise comparison for states. This approach involves making sure that switching a seat from one state to another does not diminish the fairness of the apportionment as given by some measure of fairness. He showed that each of the historic methods was best under at least one fairness measure.

M. L. Balinsky and H. P. Young (Demange 2001) constructed axiom system about AP, they argued five axioms of AP:

Axiom 1 (population monotone) For all i, when the population of state i is increased, but the population of other state is fixed, then state i should not get less seats.
Axiom 2 (unbias) An apportionment method used time after time should be fair to small or large states in a systematic way.
Axiom 3 (house monotone) The increasing in the size of the House of Representatives will not decrease any one state's seats.
Axiom 4 (quota) $\lfloor q_i \rfloor \leq a_i \leq \lceil q_i \rceil$.
Axiom 5 (fair quota) For $\forall 1 \leq i \neq j \leq m$, inequality $|a_i + 1 - q_i| < |a_i - q_i|$ or $|a_j - 1 - q_j| < |a_j - q_j|$ can not holds simultaneously.

A reasonable apportionment method should satisfy the five axioms. Balinsky and Young have shown "Impossibility Theorem" that there exists no apportionment method which embraces five axioms simultaneously.

Common Methods and Their Properties

Hamilton's Method (Bison 2004; Bobay 2001; Hosli and Machover 2002)

Hamilton's approach is a natural representative method. First, state i is allocated $[q_i]$ seats; Second, calculate

$$r = h - \sum_{i=1}^{n} \lfloor q_i \rfloor,$$

$$\Delta_k = q_k - \lfloor q_k \rfloor (k = 1, 2 \cdots, n),$$

and r states which have largest surplusk Δ_k will be allocated r seats.

The utility equilibrium theory of Hamilton's method: the utility of state i is defined as

$$u_i(a_i) = h\frac{P_i}{P} = (i = 1, 2, \cdots, n),$$

the state which has min-utility value is prior to getting next seat.

Hamilton's method does not satisfy the Axiom 3. For example, when $h = 20$, $(P_1,P_2,P_3) = (103,63,34)$, the apportionment is $(a_1,a_2,a_3) = (10,6,4)$. But if $h = 21$, the apportionment is $(a_1,a_2,a_3) = (11,7,3)$. The state 3 loses their oneseat!

Huntington's Method (Huntington 1928)

Huntington's can be summarized as following: First, each state is allocated one seat; Second, Calculate

$$Q_i = \frac{p_i^2}{a_i(a_i + 1)} (i = 1,\ 2, \cdots,\ m),$$

next seat will be allocated to the state which has the max-Q value. The utility equilibrium theory of Huntington's method: the utility of state i is defined as

$$u_i(a_i) = \frac{P_i}{\sqrt{a_i(a_i + 1)}} (i = 1,\ 2, \cdots,\ n),$$

the state which has min-utility value is prior to getting next seat.

Huntington's method is also called Q-method. This method does not satisfy Axiom 4. For example, $h = 100$, $(P_1,P_2,P_3,P_4) = (9599,135,134,132)$, the apportionment is $(a_1,a_2,a_3,a_4) = (97,1,1,1)$, where $a_1 = 97 > [q_1] = 96$.

Balinsky-Young's Method (Balinski and Young 2001)

Balinsky-Young's method is also called "Quotation Apportionment method", this is a recursion method. First, each state is allocated 0 seat; Second, supposing state i is allocated a_1 seats, s $= a_1 + a_2 + \ldots + a_n$, set E is defined as

$$E = \{i : a_i + 1 \leq (\mathrm{s} + 1)P_i/P\},$$

if $\frac{P_k}{a_k+1} = \max\limits_{i \in E} \{P_i/a_i + 1\},$ then state k is priority to be allocated next one seat.

The utility equilibrium theory of Balinsky-Young's method: the utility of state i is defined as

$$u_i(a_i) = -\frac{P_i}{a_i + 1}(i \in E),$$

the state which has minutility value is prior to getting next seat.

Balinsky-Young's method does not satisfy the Axiom 1. For example, $h = 6$, $(P_1,P_2,P_3,P_4,P_5) = (122,17,35,16,10)$, the apportionment is $(a_1,a_2,a_3,a_4,a_5) = (4,0,2,0,0)$. But if $(P_1,P_2,P_3,P_4,P_5) = (122,17,39,16,10)$, the apportionment is $(a_1,a_2,a_3,a_4,a_5) = (4,1,1,0,0)$. The state 3 loses their one seat!

Least Squares Method

According to the Least squares method, the seats every state should get are the solution to the following optimal problem:

$$J = \min_a \sum_{i=1}^{n} \left(\frac{P}{a_i} - \frac{P}{h}\right)^2$$

where $a = (a_1,\ldots, a_n)$ is an apportionment given h.

The utility equilibrium theory of Least squares method: the total utility of all states is defined as

$$u(a_1,\ a_2,\cdots,\ a_m) = \sum_{i=2}^{m} \left(\frac{p_i}{a_i} - \frac{p}{q}\right)^2,$$

the best apportionment is that one which can increase total utility of all states.

But the least squares method does not satisfy Axiom 4. For example, $h = 100$, $(P_1,P_2,P_3,P_4) = (9600,135,135,130)$, the apportionment is $(a_1,a_2,a_3,a_4) = (95,2,2,1)$, where $a_1 = 95 < \lfloor q_1 \rfloor = 96$.

By the knowledge of author, the existing methods satisfy at most two Axioms among 1, 3 and 4. We now propose a new method of apportionment which satisfies Axiom 1, 3, 4 simultaneously.

Dynamic Apportionment Method

$$\text{Let } u_i(a_i,\ q) = \frac{p_i/a_i - p/q}{p/q} = \frac{qp_i}{pa_i} - 1,$$

where $u_i(a_i,s)$ denotes the proportion of the number of its own citizens which one seat of state i represents exceeding the number of citizens one seat represents in the whole unions, a_i is the seats allocated to the state i, $s = a_1 + \cdots + a_n$ is the total seats has been apportioned.

Apportionment Method (Saari 2001)

The new dynamic apportionment method has four steps:

Step 1, every state is allocated one seat;
Step 2, arrange preference ranking among all states;
Step 3, the state which has the most preference ranking will be allocated next one seat;
Step 4, repeat the three steps until all seats are allocated.

We first introduce preference criteria. Without losing generality, we assume after the first step

$$u_i(a_i,\ q) \geq u_j(a_j,\ q)\ (\Leftrightarrow \mathrm{p_i}/a_i \geq \mathrm{p_j}/a_j)$$

1. When

$$u_i(a_i,\ q) = u_j(a_j,\ q)\ (\Leftrightarrow \mathrm{p_i}/a_i = \mathrm{p_j}/a_j)$$

if $u_i(a_i + 1,\, q + 1) \geq u_j(a_j + 1,\, q + 1)$

$$\left(\Leftrightarrow \frac{P_i}{a_i + 1} \geq \frac{P_j}{a_j + 1}\right),$$

state i is priority to be allocated next one seat.

2. When $u_i(a_i, s) > u_j(a_j,\ s)$

$$(\Leftrightarrow P_\mathrm{i}/a_i > P_\mathrm{j}/a_j)$$

if $u_i(a_i + 1,\, s + 1) \geq u_j(a_j,\ s + 1)$

$$\left(\Leftrightarrow \frac{P_i}{a_i+1} \geq \frac{P_j}{a_j}\right),$$

state i is priority to be allocated next one seat;
if $u_i(a_i+1,\, q+1) < u_j(a_j,\ q+1)$

$$\left(\Leftrightarrow \frac{p_i}{a_i+1} < \frac{p_j}{a_j}\right),$$

the preference criteria is the following:

2.1 When

$$u_i(a_i+1,\, s+1) \leq 0 < u_j(a_j+1,\, s+1)$$

$$\left(\Leftrightarrow \frac{P_i}{a_i+1} \leq \frac{P}{s+1} < \frac{P_j}{a_j+1}\right),$$

state j is priority to be allocated next one seat;
2.2 When

$$u_i(a_i+1,\, s+1) \leq 0 \geq u_j(a_j+1,\, s+1),$$

$$\left(\Leftrightarrow \frac{P_i}{a_i+1} \leq \frac{P}{s+1} \geq \frac{P_j}{a_j+1}\right)$$

state i is priority to be allocated next one seat;
2.3 When

$$u_i(a_i+1,\, q+1) > 0 \ \left(\Leftrightarrow \frac{p_i}{a_i+1} > \frac{p}{q+1}\right)$$

the following which has smaller weighted average is priority to be allocated next one seat:

$$\frac{P_i}{P_i+P_j} u_i(a_i+1,\ s+1) + \frac{P_j}{P_i+P_j} u_j(a_j,\ s+1)$$
$$\frac{P_i}{P_i+P_j} u_i(a_i,\ s+1) + \frac{P_j}{P_i+P_j} u_j(a_j+1,\ s+1)$$

In another words, the larger of

$$Q_k = \frac{P_k^2}{a_k(a_k+1)} \quad (k = i, j)$$

is priority to be allocated next one seat.

According to the preference criteria above, we can see that state i is prior to state j if and only if one of the following items holds:

(I) $\frac{P_i}{a_i} > \frac{P_j}{a_j}, \frac{P_i}{a_i+1} < \frac{P_j}{a_j},$

$$\frac{P_i}{a_i+1} \leq \frac{P}{s+1}, \frac{P_j}{a_j+1} \leq \frac{P}{s+1}$$

(II) $\frac{P_i}{a_i} \geq \frac{P_j}{a_j}, \frac{P_i}{a_i} > \frac{P_j}{a_j}$

$$\text{or} \frac{P_i}{a_i+1} < \frac{P_j}{a_j}, \frac{P_i}{a_i+1} \leq \frac{P}{s+1}, Q_i \geq Q_j$$

(III) $\frac{P_i}{a_i} < \frac{P_j}{a_j}, \frac{P_i}{a_i+1} > \frac{P}{s+1} \geq \frac{P_j}{a_j+1}$

(IV) $\frac{p_i}{a_i} < \frac{p_j}{a_j}, \frac{p_j}{a_j+1} > \frac{p}{s+1}, Q_i \geq Q_j$

Theorem 3.1. The method above of sorting prior order satisfies transitivity. Consequently, there exists the most prior state among n states in the process of comparing priority.

Proof. It is only need to be shown that if state 1 is prior to state 2 (i.e., for $(i, j) = (1, 2)$, one of the items (I)–(IV) holds), and state 2 is prior to state 3 (i.e., for $(i, j) = (2, 3)$, one of the items (I)–(IV) holds), then state 1 is prior to state 3 (i.e., for $(i, j) = (1, 3)$, one of the items (I)–(IV) holds).

There are 16 different cases in verifying state 1 is prior to state 3, we just consider one case, the left conditions can be shown in similar way.

Assuming that state 1 is prior to state 2 and condition (I) holds, i.e.,

$$\frac{P_1}{a_1} > \frac{P_2}{a_2}, \frac{P_1}{a_1+1} < \frac{P_2}{a_2},$$

$$\frac{P_1}{a_1+1} < \frac{P}{s+1}, \frac{P_2}{a_2+1} < \frac{P}{s+1}$$

1. State 2 is prior to state 3 and condition (I) holds, i.e.,

$$\frac{P_2}{a_2} > \frac{P_3}{a_3}, \frac{P_2}{a_2+1} < \frac{P_3}{a_3},$$

$$\frac{P_2}{a_2+1} < \frac{P}{s+1}, \frac{P_3}{a_3+1} < \frac{P}{s+1}$$

then

$$\frac{P_1}{a_1} > \frac{P_3}{a_3}, \frac{P_1}{a_1+1} < \frac{P}{s+1}, \frac{P_3}{a_3+1} < \frac{P}{s+1}$$

When $\frac{P_1}{a_1+1} < \frac{P_3}{a_3}$, condition (I) holds for $(i, j) = (1, 3)$, Otherwise, condition (II) holds for $(i, j) = (1, 3)$.

2. State 2 is prior to state 3 and condition (II) holds, i.e.,

$$\frac{P_2}{a_2} \geq \frac{P_3}{a_3}; \frac{P_2}{a_2} = \frac{P_3}{a_3} \text{ or } \frac{P_2}{a_2+1} \geq \frac{P_3}{a_3}$$

$$\text{or } \frac{P_2}{a_2+1} > \frac{P}{s+1}; Q_2 \geq Q_3,$$

then

$$\frac{P_1}{a_1} > \frac{P_3}{a_3}, \frac{P_1}{a_1+1} < \frac{P}{s+1}.$$

(2.1) If $\frac{P_2}{a_2} = \frac{P_3}{a_3}$, then

$$\frac{p_1}{a_1+1} < \frac{p_2}{a_2} = \frac{P_3}{a_3}; \frac{P_3}{a_3+1} \leq \frac{P_2}{a_2+1} \leq \frac{P}{s+1}$$

Since $Q_2 \geq Q_3$
Hereby, condition (I) holds for$(i, j) = (1, 3)$.

(2.2) If $\frac{P_2}{a_2} > \frac{P_3}{a_3}, \frac{P_2}{a_2+1} \geq \frac{P_3}{a_3}$, then

$$\frac{P_3}{a_3+1} \leq \frac{P}{q+1} \leq \frac{P}{s+1}$$

When $\frac{P_1}{a_1+1} < \frac{P_3}{a_3}$, condition (I) holds for (i, j) = (1, 3).
When $\frac{P_1}{a_1+1} \geq \frac{P_3}{a_3}$, it is easy to see that $Q_1 > Q_3$ consequently, condition (II) holds for $(i, j) = (1, 3)$.

(2.3) If $\frac{P_2}{a_2} > \frac{P_3}{a_3}$, $\frac{P_2}{a_2+1} < \frac{P_3}{a_3}$, $\frac{P_2}{a_2+1} > \frac{P}{s+1}$,
then it contradicts $\frac{P_2}{a_2+1} \leq \frac{P}{s+1}$.

3. State 2 is prior to state 3 and condition (III) holds, i.e.,

$$\frac{P_2}{a_2} < \frac{P_3}{a_3}, \frac{P_2}{a_2+1} > \frac{P}{s+1} \geq \frac{P_3}{a_3+1}$$

then it contradicts $\frac{P_2}{a_2+1} \leq \frac{P}{s+1}$

4. State 2 is prior to state 3 and condition (IV) holds, i.e.,

$$\frac{P_2}{a_2} < \frac{P_3}{a_3}, \frac{P_2}{a_2} > \frac{P_3}{a_3+1}, \frac{P_3}{a_3+1} > \frac{P}{s+1}, \; Q_2 \geq Q_3.$$

Since $\frac{P_2}{a_2} < \frac{P_3}{a_3}$, $Q_2 \geq Q_3$, then $\frac{P_2}{a_2+1} > \frac{P_3}{a_3+1} > \frac{P}{s+1}$.
then $\frac{P_2}{a_2+1} > \frac{P_3}{a_3+1} > \frac{P}{s+1}$.
It contradicts $\frac{P_2}{a_2+1} \leq \frac{P}{s+1}$

Theorem 3.2. If the total number of seats h satisfies the condition above, then the dynamic apportionment method satisfies Axiom 1, 3 and 4.

Proof.

(1) The dynamic apportionment method satisfies Axiom 3. This method allocates residual seats after step 1 in according to the priority of states, therefore,the increasing in total seats can not decrease seats every state has been allocated.

(2) The dynamic apportionment method satisfies Axiom 4. We frstly show that

$$a_i \leq \lceil q_i \rceil.$$

If there is a state, for instance, state 2 has been allocated $a_2 = \lceil q_2 \rceil$ seats, then there exists a state, for instance, state 1 of which the seats $a_1 \leq [q_1]$. If at this time the number of seats having been allocated is $s < h$, then

$$u_1(a_1, \; s) \geq 0 > u_2(a_2, \; s) \; , \; u_2(a_2+1, \; s+1) < 0$$

Consequently, $\frac{P_1}{a_1} > \frac{P_2}{a_2}$, $\frac{P_2}{a_2+1} < \frac{P}{s+1}$.
When $\frac{P_1}{a_1+1} < \frac{P}{s+1}$ and $\frac{P_1}{a_1+1} < \frac{P_2}{a_2}$,
for $(i, j) = (1, 2)$, the condition (I) holds; When

$$\frac{P_1}{a_1+1} > \frac{P}{s+1} \text{or} \; \frac{P_1}{a_1+1} \geq \frac{P_2}{a_2}, Q_1 > Q_2$$

for $(i, j) = (1, 2)$, the condition (II) holds. So state 1 is prior to state 2. Therefore we have $a_i \leq \lceil q_i \rceil$.

Next we show $a_i \geq \lfloor q_i \rfloor$. If there is a state, for instance, state 1 has been allocated $a_1 < \lfloor q_1 \rfloor$ seats, then there exists another state, for instance, state 2 of which theseats $a_2 \geq \lfloor q_2 \rfloor$. Meanwhile,

$$u_2(a_2+1, s+1) \leq 0 \leq u_1(a_1+1, q+1),$$

state 1 is prior to state 2 according to the arranging rank above. Accordingly, $a_i \geq [q_i]$.

(3) The dynamic apportionment method satisfies Axiom 1. It is easy to see that if state 1 is prior to the other, the increasing population in state 1 results in its priority.

Comments on the Dynamic Apportionment Method (Berg and Lepelley 1994; Coxeter 1935)

The dynamic apportionment method embraces three axioms of 1, 3 and 4. We can see that Axiom 1, 3 and 4 are more important than Axiom 5 and Axiom 5 is not enough reasonable because the axiom does not take into account the number of citizens one seat represents. For example, if state A has 100citizens, state B has 10 citizens, the surplus seats are 0.6 and 0.4 respectively. According to the Axiom 5, the one surplus seat should be allocated to state A. But in average state A will lose only 0.006 seat per capita, whereas state B will lose 0.04 seat per capita. The losing of state B is 0.04/0.06 = 20/3 times of state A!

The conditions that Axiom 5 is invalid. After the allocation using DAM, we can see from Axiom 4 that the allocated seats of arbitrary two states 1 and 2 satisfy$[q_i] \leq a_i \leq [q_i]+1$ $(i=1,\ 2)$. If $a_i = [q_i]+1$ or $a_i = [q_i]$ $(i=1,\ 2)$, the Axiom 5 holds;

If $a_1 = [q_1]+1,\ a_2 = [q_2]$, when the seat is enfeoffed from state 1 to state 2, the seats of state 1 and state 2 are $a'_1 = [q_1], a'_2 = [q_2]+1$, and if

$$|a'_1 - q_1| < |a_1 - q_1| \ ,\ |a'_2 - q_2| < |a_2 - q_2|$$

we have $q_1 - [q_1] < 0.5 < q_2 - [q_2]$

Consequently, only when $q_1 - [q_1] < 0.5 < q_2 - [q_2]$, the Axiom 5 is invalid.

Calculating Programme of DAM

The calculating programme of DAM is the following:

1. Allocate seats $a_i = [h\frac{p_i}{p}]$ $(i = 1, 2, \cdots, n)$ to state i, where h is the number of seats in the House of Representatives, P is the number of population in the Union. If $q = a_1 + a_2 + \cdots + a_n = h$, stop.

2. Else, sort ascending

$$t = \frac{P}{s+1},\ R_i = \frac{P_i}{a_i},\ r_i = \frac{P_i}{a_i + 1}\quad (i = 1,\ 2, \cdots,\ n),$$

the equalities are ranged in the same place.
3. Delete all the R's which are less or equal to the maximum $r = \max\{r_i, i = 1, \cdots, n\}$; delete all the r's which have the same suffxes with R's; delete all R's.
4. If $r > t$, then delete all r's which are less or equal to t.
5. If residual r's are all larger than t, these r's multiply R's which have the same suffxes with r's, allocate state which has the maximum product a seat, and it's seats plus 1. If there are residual seats, repeat step 2 until there is no residua. If residual r's are all less or equal to t, go to step 6.
6. Search the state which has the maximum R whose suffxes are the same to the residual r's, allocate one seat to the state, and it's seats plus 1. If there are residual seats, repeat step 2 until there is no residua.

References

Balinski ML, Young HP (2001) Fair representation, meeting the ideal of one person, one vote, 2nd edn. The Brookings Institution, Washington, DC

Berg S, Lepelley D (1994) On probability models in voting theory. Statistica Neerlandica 48(2):133–146

Bison F, Bonnet J, and Lepelley D (2004) La détermination du numbre des délégués au sein des structures intercommunales: une application de lindice de pouvoir de Banzhaf. Démocratie et Management local. Revue d'économie régionale et urbaine, pp 259–282

Bobay F (2001) La réforme du Conseil de l'Union Européenne 'a partir de lathéorie des jeux. Revue Française d'Économie 16:3–58

Cervone D, Gehrlein W, Zwicker W (2001) Which scoring rule maximizes Condorcet efficiency Under Zac. Theory Decis 145–185

Coxeter H (1935) The functions of Schläfli and Lobatschefsky. Quat J Math 6:13–29

Demange G (2001) Commentaire de l'article de F. Bobay. Revue Française d'Économie 16:63–71

Feix MR, Lepelley D, Merlin V, Rouet J-L (2004) The probability of conflicts in a U.S. presidential type election. Econ Theory 23(2):227–257

Felsenthal DS, Machover M (2001) The treaty of nice and qualified majority voting. Soc Choice Welf 18:431–465

Galam S (1990) Social paradoxes of majority rule voting and renormalization group. J Stat Phys 61:943–951

Gehrlein W (2002) Condorcet's paradox and the likelihood of its occurrence: different perspectives on balanced preferences. Theory Decis 52:171–199

Hosli MO, Machover M (2002) The nice treaty and voting rules in the council. A reply to moberg. Mimeo, Mannheim

Huntington EV (1928) The apportionment of representatives in congress. Trans Am Math Soc 30(1):85–110

Lucas WF (1983) Modules in applied mathematics, vol 2, Political and related models (M). Springer, New York

Saari DG (2001) Chaotic elections, a mathematician looks at voting. AMS, Providence

Chapter 49
Research on Equipment Inventory Based on the Analysis of Failure Rate

Qing Li, Guang-long Geng, Xiao-nan Ye, and Guang-xun Zhu

Abstract Scientific and rational equipment inventory is an important part of equipment optimization supply and management. Based on the analysis of usage failure rate, the quantitative research to determine the equipment inventory was presented. The usage failure rate of equipment and the main factors which affect the reliability of the usage of equipment were analyzed and determined. By determining the regression variables, regression coefficients, and estimating survival function and the use of failure rate, a ratio of failure rate regression model is established. A method to determine equipment inventory by using usage failure rate is proposed. The method provides the basis of decision making for the scientific management of equipment and apparatus. And it also offers the methods and means for the reasonable determination of inventory.

Keywords Inventory study • Optimization • Equipment management • Failure rate analysis

Introduction

In order to obtain the optimization supply of equipment and apparatus, the equipment consumption amount needs to be determined scientifically. In the process of determining, all of the various factors which lead to equipment consumption must be taken in account. The consumption of equipment depends not only on the part of equipment's failure, but also on the maintenance strategy, the equipment's use and management, the environment of equipment use, and the sensitivity of the damaged parts and many other factors. Following, the analysis method of failure rate is used to study the inventory of the equipment and apparatus quantitatively.

Q. Li (✉) • G.-l. Geng • X.-n. Ye • G.-x. Zhu
Air Force Logistics College, Xuzhou, China
e-mail: lqingx@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_49,

Determine the Failure Rate of Equipment and Apparatus

Analysis of Equipment Usage Failure Rate

The use experience and test results of a failure rate curve of a certain equipment show that, a lot of equipment failure rate is a function of time, the characteristic of which is that both sides are high and middle is low. The graphic is usually called the bathtub curve.

The composition of a certain equipment, some subsystems are consisted by a large number of components and parts, whose failure rate curve has early failure period, accidental failure period and depletion failure period, which is the typical failure rate curve—bathtub curve. However, not all of the devices have three failure periods. Many devices have only one or two fault periods. The accidental failure period of some devices which has poor quality is very short, and some of them even enter the depletion period directly followed by early failure period. Additionally, the failure rate of the same product also has a relationship with the date of manufacture. The failure rate of the first factory product is higher than the mass-produced products, and the failure rate of the initial products of mass production is higher than the latter part of the product.

The Factors Which Affect the Usage Reliability of the Certain Equipment

The reliability of a certain equipment system depends on three factors. The first is the technology level of design and development and produce, the second is the level of use and maintain, and the third is the work environment. The technology level of design, development and produce of the equipment has become the objective factors. They are not considered here.

Standards of use and maintenance are determined by the such factors as the determined maintenance cycle and life, the adopted working status, the technical level of the system operator, degree of perfection of the maintenance system and the actual degree of compliance, the quality of maintenance work, the technology state of maintenance staff, and the organization of labor management, etc.

Environment refers to external atmospheric conditions, such as atmospheric temperature, pressure, humidity, a variety of rays, the degree of air dust, salt dust degree and the role of aggressive chemicals, etc.

In the process of use and maintenance, the reasons for producing failures and disorders can be divided as fatigue cracks(deformation and damage produced by repeated effect load), wear and tear of active joints (threaded connections and riveting seam relaxation and other forms of mechanical loss), system equipment damage and deformation caused by the inappropriate and rude operation in maintenance and loading unloading work, deterioration in the performance of lubricants and specialty oil which is used to connect parts, accessories and systems, as well as the aging of the washers, cups, plastic parts which are made from organic materials, destruction of paint and other forms of protective layer, corrosion of the skin and multiply force component. They must be considered when determining the usage failure rate of equipment (Lawless 1997; Zhang Sheng et al. 2010; Zhang Weiguo 2007).

Regression Model of Proportional Failure Rate

In the study of the equipment's usage failure rate, it is usual to select equipment from different batches, different production and different supply manufacturers to do life tests. The equipment life data need to be unifiedly dealt with to make the results universal. Because the usage reliability of equipment is affected by many factors, the usual practice is to let the failure rate multiplied by a correction factor. Taking into account the distribution test methods commonly used lack of robustness, the proportional failure rate regression model from the survival analysis is introduced. And no-distribution method is applied to determine the usage failure rate of equipment (Chen Hongxia et al. 2005).

The advantage of the proportional failure rate regression model is that it does not require any distribution basically. The nature of the estimates does not depend on the selected life distribution, that means does not depend on $\lambda_0(t)$. In the analysis of the usage failure rate of equipment, the impact of the equipment, internal and external factors should not be ignored. The key question is how to consider these factors to determine the reasonable regression coefficients. COX proposed Conditional Likelihood Function, or called Partial Likelihood Function, which doesn't depend on β in $\lambda_0(t)$. The estimate of β is given under lacking the information about $\lambda_0(t)$. It has brought great convenience for the practical application of the proportional failure rate regression model (Sun Jinkang and Li Zhengneng 2001; Ragnhild Van Der Straeten et al. 2007).

The proportion of the failure rate model Cox proposed in 1972 is as (49.1).

$$\lambda(t|x) = \lambda_0(t)\exp(x\beta) \tag{49.1}$$

The model has two unknown part, the regression parameter β and the basic failure rate function $\lambda_0(t)$. Then the basic survival function can be considered as following.

$$S_0(t) = \exp(-\int_0^t \lambda_0(u)du) = \exp[-\Lambda_0(t)] \tag{49.2}$$

$\Lambda_0(t)$ is a cumulative failure rate function. Given x, the survival function of T can be written as

$$S(t|x) = \exp(-\int_0^t \lambda(u|x)du) = [S_0(t)]^{\exp(x\beta)} \tag{49.3}$$

We hope to use the censored data to estimate β and $\lambda_0(t)$, or $S_0(t)$. It is usually to maximize the likelihood function of observational data. However, due to the likelihood function depending on the unknown $\lambda_0(t)$, the estimate of β is hard to achieve. So the Conditional Likelihood Function or called Partial Likelihood Function presented by COX is adopted which does not depend on β of $\lambda_0(t)$. Lacking of the information of $\lambda_0(t)$, β's estimate is obtained. With β's estimate, the product limit can be used to estimate survival function $S_0(t)$ and the failure rate $\lambda_0(t)$.

Determine the Regression Variable x_{ti}

According to the analysis of failure rate of some equipment, equipment type x_{ti} is identified as a regression variable.

Equipment type is an important factor to determine the failure rate. Equipment can be divided into mechanical part, optical part, electronic part, rubber part, plastic part and other items. x_{ti} is defined as following.

$$x_{t1} = \begin{cases} 1 & \text{if the equipment type is mechanical part} \\ 0 & \text{if the equipment type is other items} \end{cases}$$

$$x_{t2} = \begin{cases} 1 & \text{if the equipment type is electronic part} \\ 0 & \text{if the equipment type is other items} \end{cases}$$

$$x_{t3} = \begin{cases} 1 & \text{if the equipment type is optical part} \\ 0 & \text{if the equipment type is other items} \end{cases}$$

$$x_{t4} = \begin{cases} 1 & \text{if the equipment type is plastic part} \\ 0 & \text{if the equipment type is other items} \end{cases}$$

Determine the Regression Coefficients

Suppose that there are n equipment to do life test, where there are k different observing life time and $n-k$ censored time. The k observing life time are denoted by $t(1)<\cdots\cdots(k)$. The risk set at the time $t(i)$ is denoted by $R_i = R(t_{(i)})$. That means a collection of equipment at normal working status and not censored at $t(i)$. Cox proposed the so-called Conditional Likelihood Function or Partial Likelihood Function as following.

$$L(\beta) = \prod_{i=1}^{k} \frac{\exp(x_{(i)}\beta)}{\sum\limits_{l\in R_i} \exp(x_l\beta)} \tag{49.4}$$

The β occurred in formula (49.1) is estimated by the Conditional Likelihood Function under lacking of $\lambda_0(t)$, where $x(i)$ is the regression variable of the equipment whose failure has been observed at $t(i)$. Equation 49.4 has nothing to do with $\lambda_0(t)$ and can be maximized to estimate $\hat{\beta}$. $L(\beta)$ is regarded as the likelihood, yet it is not the true likelihood function in usually sense. It can not be derived from the probability of occurrence of some observations in the described model.

Because of the collected data being censored and grouped, usually there are knots in them. If the quantity of knots is relatively less, Conditions Likelihood Function need to be adjusted in some way to open it. One approach is to use (49.5) instead of (49.4).

$$L(\beta) = \prod_{i=1}^{k} \frac{\exp(S_i\beta)}{\left(\sum\limits_{l\in R_i} \exp(x_l\beta)\right)^{d_i}} \tag{49.5}$$

Where d_i is the number of life time that equals to $t(i)$, S_i is sum of the regression variables of d_i equipment items. That is, if D_i represents the set of fault individuals at $t(i)$, then $d_i = |D_i|, S_i = \sum\limits_{l\in D_i} x_l$. If there is no knot, $d_i = 1$. Then (49.5) is degenerated to (49.4). The logarithm of the Likelihood Function of (49.5) is as the following.

$$\log L(\beta) = \sum_{i=1}^{k} S_i\beta - \sum_{i=1}^{k} d_i \log\Big(\sum_{l\in R_i} \exp(x_l\beta)\Big) \tag{49.6}$$

The first derivative of the $\log L$ is as the following.

$$\frac{\partial \log L}{\partial \beta_r} = \sum_{i=1}^{k} (S_{ir} - d_i \sum_{l\in R_i} x_{lr} \exp(x_l\beta)), r = 1, 2, \cdots, p \tag{49.7}$$

Where, S_{ir} is the r^{th} element in $S_i = (S_1, \cdots, S_{ip})$. The elements of matrix composed by the second-order partial derivatives of negative $\log L(\beta)$ are as following.

$$I_{rs}(\beta)=\frac{-\partial^2\log L}{\partial\beta_r\partial\beta_s}$$
$$=\sum_{i=1}^{k}d_i\left[\sum_{l\in R_i}\frac{x_{lr}x_{ls}\exp(x_l\beta)}{\sum\limits_{l\in R_i}\exp(x_l\beta)}-\frac{(\sum\limits_{l\in R_i}x_{lr}\exp(x_l\beta))(\sum\limits_{l\in R}x_{ls}\exp(x_l\beta))}{(\sum\limits_{l\in R_i}\exp(x_l\beta))^2}\right].r,s=1,\cdots\cdots,p \tag{49.8}$$

The maximum likelihood equation $\frac{\partial\log L(\beta)}{\partial\beta_r}=0(r=1,\cdots\cdots,p)$ generally can be solved by Newton–Raphson method.

Estimate the Survival Function and the Usage Failure Rate

Equations 49.2 and 49.3 show that the sample's survival function of covariant vector is $S(t|x)=[S_0(t)]^{\exp(x\beta)}$, where $S_0(t)$ is the basic survival function when $x=0$. Obviously, we are interested in estimating the $S_0(t)$. Because of using it, the estimate $S(t|x)$ and $\lambda(t|x)$ can be given to any x. Estimate $\hat{\beta}$ of conditional likelihood function first by approximate approach. Then estimate $S_0(t)$ by maximizing full-likelihood function (49.9), when β is equal to the Maximum Likelihood estimate value $\hat{\beta}$.

$$L[\beta,\lambda_0(t)]=\prod_{i=1}^{n}S_0(t_i)\exp(x_i\beta)\prod_{i\in D}\lambda_0(t_i)\exp(x_i\beta)$$
$$=\prod_{i\in D}\frac{\exp(x_i\beta)}{\sum\limits_{l\in D}\exp(x_l\beta)}\prod_{i\in D}(\lambda_0(t_i)\sum_{l\in R_i}\exp(x_l\beta))\prod_{t=1}^{n}S_0(t_i)^{\exp(x_i\beta)} \tag{49.9}$$

For simplicity, let $t(0)=0$, $t(k+1)=\infty$. Assume that $t(0)<\cdots\cdots(k)$ is the observed life time, and there are n_i samples at $t(i)$ being in the risk status, d_i samples in failure. Assume that there are λ_i censored time in $[t_{(i-1)},t_{(i)})$, denoted by $L_j^{(i)}(j=1,\cdots\cdots,\lambda_i)$. The observation likelihood function is as following.

$$L=\prod_{i=1}^{k}[(\prod_{j=1}^{\lambda_i}S(L_j^{(i)}|x_j^{(i)}))][S(t_{(i)}|x_{(i)})-S(t_{(i)}+0)]^{d_i}\times\prod_{j=1}^{\lambda_{k+1}}S(L_j^{(k+1)}|x_j^{(k+1)})$$

$x_j^{(i)}$ represents the regression variable of the censored sample at $L_j^{(i)}$. The aim is to maximize the L to $S_0(t)$, where $S(t|X)=[S_0(t)]^{\exp(x\beta)}$. Then $S_0(t)$ is continuous non-increasing function with β assumed known, because $S_0(t)$ is a survival function. So$\hat{S}_0(t)$ should be constant at other points except the observed life time $t(1), \cdots\cdots, t(k)$. Then

$$\hat{S}_0(t_{(1)}) = \hat{S}_0(L_j^{(1)}) = 1 \ (j = 1, \cdots\cdots, \lambda_1)$$

and

$$\hat{S}_0(t_{(1)} + 0) = \hat{S}_0(t_{(i+1)}) = \hat{S}_0(L_j^{(i+1)}) \quad (i = 1, \cdots\cdots, k; j = 1, \cdots\cdots, \lambda_{i+1})$$

Note that $S_0(t_{(i)} + 0) = P_i, (i = 1, \cdots\cdots, k)$. The following formula need to be maximized.

$$L_1 = \prod_{i=1}^{k} (\prod_{l \in D_i} (P_{i-1}^{\exp(x_l \beta)} - P_i^{\exp(x_l \beta)}) - \prod_{l \in C_i} P_{i-1}^{\exp(x_l \beta)}) \prod_{l \in C_{k+1}} P_k^{\exp(x_l \beta)}$$

Where D_i is the failure samples' collection at $t_{(i)}$, and C_i the sample collection at censored time $[t_{(i-1)}, t_{(i)})$. Assume that $\alpha_i = \frac{P_i}{P_{i-1}}$, $(i = 1, \cdots\cdots, k)$, then L_1 can be written as the following.

$$L_1 = \prod_{i=1}^{k} (\prod_{l \in D_i} (1 - \alpha_i^{\exp(x_l \beta)}) \prod_{l \in D_i - C_i} \alpha_i^{\exp(x_l \beta)}$$

Calculate the partial derivatives of $\log L_1$ to $\alpha_1, \cdots, \alpha_k$. And solve the equations and sort out

$$\sum_{l \in D_i} \frac{\exp(x_l \beta)}{1 - \alpha_i^{\exp(x_l \beta)}} = \sum_{l \in R_i} \exp(x_l \beta), (i = 1, \cdots\cdots, k) \tag{49.10}$$

If $d_i = |D_i| = 1$, the above equation has a solution as following.

$$\alpha^{\exp\left(x_{(i)} \beta\right)} = 1 - \frac{\exp(x_{(i)} \beta)}{\sum_{l \in R_i} \exp(x_l \beta)} \tag{49.11}$$

If $d_i > 1$, iterate by Eq. 49.10 to solve $\hat{\alpha}_i$. The initial value of $\hat{\alpha}_i$ can be obtained as following. When $\hat{\alpha}_i$ is close to 1, $\hat{\alpha}_i^{\exp(x_{(i)} \beta)} = 1 + (\log \alpha_i) \exp(x_l \beta)$. Substitute it into (49.10), there is the following formula.

$$\alpha_i = \exp\left(\frac{-d}{\sum\limits_{l \in R_i} \exp(x_l \beta)}\right) \tag{49.12}$$

Where, $d = \exp[(x_{(i)} - x_l)\beta)]$. The maximum likelihood estimate P_i is given by $\hat{p}_i = \hat{\alpha}_1 \cdots \hat{\alpha}_i$. Therefore, the method for estimating the basic survival function $S_0(t)$ is to determine $\hat{\beta}$ by the partial likelihood Eq. 49.4. Then estimate $S_0(t)$ by $\hat{\beta}$ instead of in (49.10). The estimate of $S_0(t)$ is as following.

$$\hat{S}_0(t) = \prod_{i:t_{(i)} < t} \hat{\alpha}_i \tag{49.13}$$

Then, the estimate of the individual survival function with covariant vector x is $\hat{S}(t|X) = [\hat{S}_0(t)]^{\exp(x\beta)}$. There is a very important limitation here. If the maximum observed value is the censored time L^* (that is $\lambda_{k+1}>0$), $\hat{S}_0(t)$ after L^* is not defined. Because L is unrelated with $S_0(t)$ when $t>L^*$, while $\hat{S}_0(t)>0$.

After determining the basic survival function $S_0(t)$ of the equipment, we can take use of the following formula $\tilde{\Lambda}(t) = -\ln[\hat{S}(t)]$ to estimate the accumulated experience of the failure rate function.

$$\tilde{\Lambda}_0(t) = -\ln[\hat{S}_0(t)] \tag{49.14}$$

$\hat{S}_0(t)$ and $\tilde{\Lambda}_0(t)$ relatively correspond to the product limit estimate of the basic survival function and cumulative experience failure function estimate.

Use Failure Rate to Determine the Equipment Inventory

Let N_t be the number of failures of the equipment at time t (That is the replaced times, the consumed quantity), as a random variable. Based on the actual statistical and theoretical analysis, we make the following assumptions.

•The expendable failure rate $\lambda(t)$ is a function of time t.

•The number of failures of equipment from time t to $t + s$ is unrelated with the number of failures before time t.

·•In a very short time interval h, the probability of consuming an equipment is approximately equal to the product of the failure rate $\lambda(t)$ at time t and time interval h of the consumption, the difference between them is a higher order infinitesimal $o(h)$.

·•Within a very short time interval h, the probability of consuming more than two equipments (include 2 equipments) is the higher order infinitesimals $o(h)$. That is, in a very short time interval h, it is a small probability event for consuming more than two equipments (include 2 equipments), and that does not occur in general.

According to the above assumptions, we can make the consumption number $\{N_t, t \geq 0\}$ of the expendable as a random count process $\{N_t, t \geq 0\}$, and call that $\{N_t, t \geq 0\}$ is the Poisson process of strength function $\lambda(t)$ with non-time homogeneous (Ouyang Xiaoxun 2010; Lou Shanzuo et al. 2010; Liu Yuewu 2011; Samul Karlin 1960).

According to the nature of Poisson process non-time homogeneous,

$$P\{N_t = k\} = \frac{1}{k!}[\Lambda(t)]^k \exp[-\Lambda(t)], k = 0, 1, \cdots\cdots \tag{49.15}$$

and

$$\Lambda(t)g = \int_o^t \lambda(u)du$$

We call it the cumulative failure rate (cumulative failure rate) function, assumed $\Lambda(\infty) = \infty$. And there is an equation as follows.

$$EN_t = \Lambda(t), t \geq 0 \tag{49.16}$$

According to the above analysis, we can get the expect consumption quota of expendable by following formula.

$$C_0 = Q \times N \times EN_t = Q \times N \times \Lambda(T_c) \tag{49.17}$$

Where

C_0—the expect consumption quota of expendable, the unit is the “piece”

Q—the number of safeguard weapons systems

N—the number of installation of the equipment of each set of the system

T_c—the working days of the equipment, usually 1 year (365 days), the unit is “day”

$\Lambda(T)$—the cumulative failure rate of equipment

The inventory should be k times of the expected consumption value. Then the equipment’s inventory is as following.

$$C = k * C_0 \tag{49.18}$$

k is the ratio of equipment inventory to the expected consumption value.

Conclusion

The reality that the complexity and difficulty of equipment supply and support is growing requires us to effectively optimize the equipment supply and support model. According to the failure rate analysis, in the paper, the methods of quantitative researching equipment inventory are studied. And a scientific basis for the scientific management of the equipment is provided. The benefit is remarkable.

References

Chen Hongxia, Guo Jin, Yang Yang (2005) Failure rate analysis of repairable system. Microcomput Dev 15(2):56–57, 75

Lawless JF (1997) Statistical models and methods in life data. (trans: Mao Shisong, Pu Xiaolong, Liu Zhong). China Statistics Press, Beijing, China

Liu Yuewu (2011) Study on the inventory decision-making model for the spare parts based on the information fusion. Value Eng 30(30):12–13

Lou Shanzuo, Wu Yaohua, Lv Wan (2010) Study on inventory control under autochastic disruptions. Acta Autom Sin 36(7):999–1006

Ouyang Xiaoxun (2010) Stochastic optimization of inventory control. Mathmatica Applicata 2 23:445–449

Ragnhild Van Der Straeten, Tom Mens, Viviane Jonckers (2007) A formal approach to model refactoring and model refinement. Softw Syst Model 6(2):139–162

Samul Karlin (1960) Dynamic inventory policy with varying stochastic demand. Manage Sci 6 (3):231–258

Sun Jinkang, Li Zhengneng (2001) Failure-rate analysis of repairable systems. J Beijing Univ Aeronaut Astronaut 27(5):578–581

Zhang Weiguo (2007) Fuzzy control theory and application. Xibei Industry University Publishing Company, Xi'an

Zhang Sheng, You Wei, Zhang Zenglei (2010) Research on the decision-making support application of maintenance material management based on multi-dimension analysis. Inf Technol Inf 4:67–70

Chapter 50
Business Model Innovation for Electric Vehicles in China

Yi-xi Xue, Jian-xin You, Yi Chen, and De-yang Kong

Abstract Greater market penetration of electric vehicles needs business model innovation. Business model innovation and industrialization is the focus of the development of electric vehicles during the "12th Five-Year Plan" period. So how to promote business model innovation is pivotal. However, now the theories about business model innovation for electric vehicles are not matching. The business mode for electric vehicles is a complex system and its innovation is in fact a transition of co-evolution process. Based on the discovery-driven approach and transition management theory, this paper analyzes the barriers and proposes some recommendations to business model innovation for electric vehicles in China.

Keywords Electric vehicles • Business model innovation • Transition management • Discovery-driven approach

Introduction

From the perspective of sustainability, many persistent problems are always associated with our current road transport system, including greenhouse gases (GHGs) emissions, climate change, congestion, noise, accidents, depletion of resources (Farla et al. 2010). Of all these problems, many are caused by the wide use of internal combustion vehicles (ICVs). Road transport is now one of the largest contributors to GHGs and transport is the sector with the highest growth rate of GHGs (Köhler et al. 2009). In this context, the dominant position of ICVs is being challenged by a number of radically innovative powertrains such as biofuels,

Y.-x. Xue (✉) • J.-x. You
School of Economics and Management, Tongji University, Shanghai, China
e-mail: nkxueyixi@yahoo.com.cn

Y. Chen • D.-y. Kong
School of Automotive Studies, Tongji University, Shanghai, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_50,

hydrogen, hybrid cars and etc., of which the pure battery electric vehicle (EV) is a prominent contender (Sierzchulaa et al. 2012).

China, as one of the major CO_2 emission countries, has taken many initiatives to promote market diffusion of EVs. However the industrialization of EVs has encountered many obstacles and the progress is very slow. According to the report *Economic Operation of China's Auto Industry In 2011* released by China Association of Automotive Manufactures, only 5,655 pure battery EVs and 2,731 hybrid electric vehicles (HEVs) are produced, and only 5,579 pure battery EVs and 2,580 HEVs are sold in 2011. This is far below the target set in the *Automobile Industry Restructuring and Revitalization Plan*. The key drivers to greater market penetration of EVs lie not only in technological breakthroughs, but also the business model innovation (BMI). Especially when the EV technology is not perfect and EVs have many disadvantages comparable with ICVs, the BMI matters most.

This paper aims to find approaches to stimulate BMI for EVs in China. Our contribution lies in connecting transition management (TM) with a discovery-driven approach to promote BMI for EVs. The rest of paper is organized as follows: section "Definition of EV Business Model" gives the definitions of the business model (BM) for EVs and BMI for EVs based on the literature about BMs. Section "Methodology" introduces the main ideas of TM and the discovery-driven approach which is an approach for BMI. In section "Barriers to EV Business Model Innovation in China" we analyze the barriers to BMI for EVs in China and propose some suggestions about how to promote BMI for EVs in China based on the discovery-driven approach and TM in section "Recommendations".

Definition of EV Business Model

The BM concept has already appeared and become prevalent since the advent of the Internet in the mid-1990s (Zott et al. 2010). However, the definition of BM hasn't got consistency and clarity among the study of scholars and business practitioners. Researchers adopt idiosyncratic definitions which fit their respective study purposes. Moreover, the BM is often studied without explicitly defining its concept. According to Zott et al. (2010), among the publications which take the BM as the main analysis objective from 1975 to 2009, 37% do not define the concept at all. The rate is even higher when we review the domestic publications about the BM for EVs. This will obstruct the cumulative research progress of the BM for EVs either in theory or in the practice. So a clear definition for EV BM is necessary.

At a general level, the BM has been referred to as a statement, a description, a representation, an architecture, etc. (Zott et al. 2010). Some most prevalent definitions of BM are as below. Timmers defined that the BM is an architecture of the product, service and information flows, including a description of the various business actors and their roles; a description of the potential benefits for the various business actors; a description of the sources of revenues (Timmers 1998). Amit and Zott argued that the BM depicts the content, structure and governance of transactions designed so as to create value through the exploitation of business opportunities (Amit and Zott 2001). Chesbrough and Rosenbloom defined the BM as "the heuristic logic that connects technical potential with the realization of economic value" (Chesbrough and Rosenbloom 2002). Teece defined that a BM articulates the logic, the data and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value (Teece 2010).

From the literature we can see previous BM studies mainly focus on the core company and take the BM as a business strategy for companies to get advantage over the rivals, although the definition of BMs goes far beyond the scope of a company. However, as for the EV BM, focusing on a company is not enough. Government, vehicle manufactures, parts manufactures especially the battery manufactures, energy supply utilities, charging infrastructure operators and customers are all vital for the innovative business models. Ignoring the complex interactions and relations among the stakeholders will result in the failure of BMI. So in this paper the BM for EVs does not focus on one company, but focus on a system and industry level and is virtually a complex system (Di Xu 2005). Based on this perspective and many definitions of BMs, we derived the following definition: the BM for EVs is a complex system including three levels of government, enterprises and end-users (Qiang Ye and He-wu Wang 2012). The BM fulfill the following functions: articulates the value proposition; identifies a market segment; describes various actors and their roles, positions in the whole value network; specifies the revenue generation mechanism for enterprises (Chesbrough and Rosenbloom 2002). Figure 50.1 gives the visualization of the BM system for EVs.

It involves many subsystems such as policies, technology, production, markets, culture, and infrastructure. Its innovation is a system innovation and is also referred to a sociotechnical transition, which can be defined as a gradual, continuous process of change where the structural character of a sociotechnical transforms (Rotmans et al. 2001). The transition is a co-evolution process involving technological changes, as well as changes in other elements. The developments in different levels interact with each other. An example of such a transition is from sailing boats to steamships.

Methodology

We have defined the BM for EVs as a complex sociotechnical system and BMI for EVs as a sociotechnical transition, so only considering conventional company-level BMI approaches is not enough. To well promote BMI for EVs in China, we should consider both sociotechnical system perspective and business model perspective. In this paper, we adopt TM and the discovery-driven approach as the basis for promoting BMI for EVs in China.

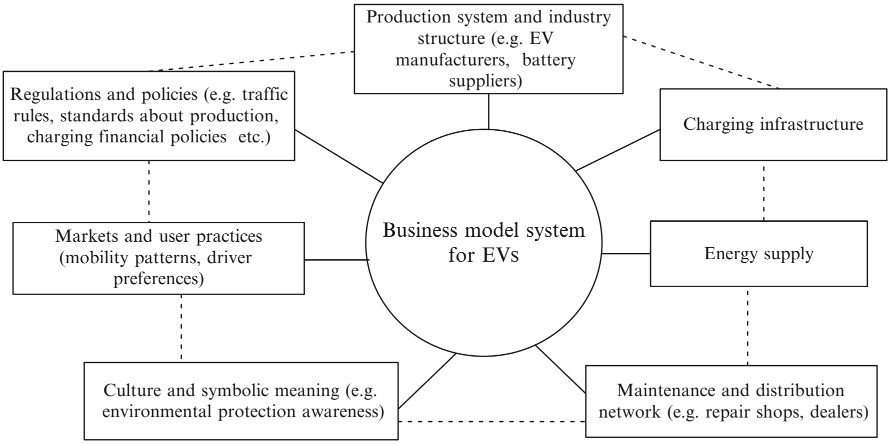


Fig. 50.1 Business model system for EVs

Transition Management

When sociotechnical transition is discussed, one important question is whether it can be managed. If the answer is yes, we need further ask how to manage it. The first study about societal transition management was the ICIS-MERIT study "Transitions and transition management" in the Netherlands and TM has become the theoretical basis of the Dutch environmental policy. More and more scholars are engaged in studying TM.

TM is a new steering concept that relies on darwinistic processes of variation and selection, with the aim for generating momentum for sustainability transition. The basic philosophy is that or goal-oriented modulation: the utilization of ongoing developments for societal goals. Characteristics of TM are: long-term thinking for framing short-term policy; multi-domain, multi-level, multi-actor, learning-by-doing and doing-by-learning; keeping a large number of options open (Émile Jean Louis Chappin 2011).

TM does not consist of a step plan but uses certain heuristics-of adaptive policies and portfolios, process management, learning by doing, problem structuring. In order to put TM ideas into practical ways so as to promote system transition, TM scholars developed a TM cycle as shown in Fig. 50.2 (Émile Jean Louis Chappin 2011). The starting point of the cycle is problem structuring (detailed description is in section "Recommendations").

The Discovery-Driven Approach

There are many approaches for BMI and one of the most prevalent is the discovery-driven approach. According to McGrath, BMI is not like conventional strategy development which emphasizes analysis. It must engage in significant

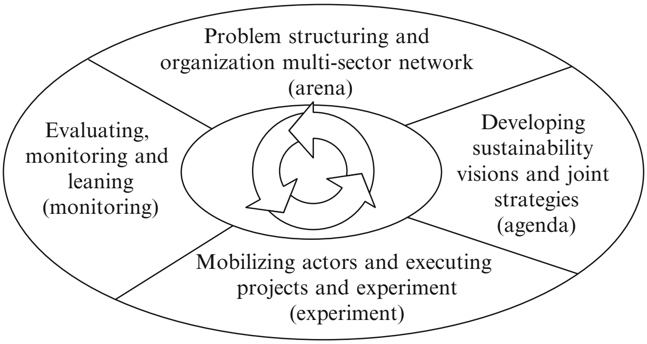


Fig. 50.2 Business model cycle

experimentation and learning-a discovery driven, rather than analytical approach (McGrath 2010). In conventional strategic planning, the measure of a plan's success is how close your projections came to what happened later on. However, in a fast-moving, complex and high uncertain environment, strategies are about insight, rapid experimentation and evolutionary learning as much as the traditional skills of planning and rock-ribbed execution. Given the uncertainty about future, it is more important to engage in experimentation and discovery than to try to assume the relevant information is all known, because many of the things that will turn out to be important may be no known at the time. Therefore BMI need produce massive amounts of experimentation, without any clear understanding at the outset of who the 'winners' will be. In the whole process of BMI, experimentation, failure and learning is through to the end.

Barriers to EV Business Model Innovation in China

The demonstration program "Ten Cities, Ten Thousand Vehicles" has been launched since 2010. One important aim of this program is to develop new BMs for EVs. Some progress has been achieved so far. However, a national BM has not got integrated and private purchasing of EVs is still limited. Many barriers still obstruct the further development of BMI for EVs in China.

Consumer Purchasing Barriers

The BM concept brings the customer in and value proposition (i.e., the value created for customers by an offering based on technology) is an essential element for the BM. Only by providing appropriate value proposition to customers, can the potential value in the new technology be achieved and companies gain profit.

However unlike other technology innovations having cost advantage or other advantages compared with conventional technology, EVs have many disadvantages compared with ICVs. These disadvantages include higher initial investment, long charging time, shorter driving range which all hinders the wider introduction of EVs. Furthermore customers have limited access to charging facilities due to limited numbers. The running costs of EVs are actually lower, but these advantages do not stand out sufficiently. What counts most in BMI is recognizing what final customers need and fulfilling these needs with the relevant offer. Especially when the technology is not perfect at the moment, a good BM must be able to find appropriate value proposition and realize the potential value in the new technology.

Standard Barriers

To achieve a smooth and quick BMI for EVs, the development, integration and adherence to of the standards is very important. The impacts of EVs in regards to public health and safety, environmental sustainability, as well as how quick this technology is adopted are greatly influenced by the standards to which the EV and related infrastructure are designed and the adherence to these standards by manufacturers, technicians, and other related professionals (Brown et al. 2010).

Up till now, standard barriers of EVs are still main obstacles to hinder the industrialization and BMI in China, although many standards have been made. Main problems about standards in China are that the standards are not complete and integrated, especially the latter. The core standards related to EVs include vehicle standards, charging standards, battery standards and energy supply standards. However, these standards are not integrated, and uniform national standards are very limited. This causes many serious consequences. For example, domestic EV manufacturers dare not invest too much in new production platform; related companies have to frequently change the mold and industrial processes to adapt different standards in different regions, which enhance the technology research and development costs; the process of building charging infrastructure is hindered and much investment may be later proved to be a waste, all of which greatly hamper the BMI for EVs.

Cognitive Barriers

In 1986 Prahalad and Bettis first introduced the concept of dominant logic, which relates to the main means used to make a profit. Negatively, dominant logic locks a company into thinking about making money in only one way. This narrowed approach can prevent a conducive environment for innovating and can stifle creativity. Dominant Logic is antipodal to the idea of using different methods for generating profit (Chesbrough 2010).

As to BMI for EVs in China, the cognitive barriers due to dominant logic are reflected in two aspects: the idea that BMI for EVs is only a product innovation and as long as the technology is improved, BMI can easily be achieved, ignoring that it is a complex system and involves innovation in and between multi levels, multi domains and multi actors; the fact that someone may follow the dominant logic too slavishly that may miss potentially valuable uses of the new technology, being locked in the conventional BM for ICVs, and far from clear about what the right business model ought to be.

Conflict Barriers

Conflict barriers to BMI for EVs in China refer to two aspects: conflict between BM already established for conventional ICVs and that which is required for EVs; interest conflict between different stakeholders especially between business companies.

The former conflict has already been identified in BMI literature like Amit and Zott (2001). As they argued, this conflict between established BM for ICVs and that for EVs disrupts incumbent firms for BMI. Typically, the gross margins for the emerging one are initially far below those of the established technology. The end customers may differ, as may the necessary distribution channels. As the incumbent companies such as vehicle manufactures allocate their capital, the EV technology may get much fewer resources than ICVs.

As to the latter conflict-interest conflict, it may be one of the most serious barriers for EV BMI in China. BMI for EVs means that some stakeholder (e.g. some part suppliers) in the established BM for ICVs may exist from the whole value network, some new stakeholders (e.g. energy suppliers) may enter the new value network and the dominant position of some stakeholders (e.g. vehicle manufactures) in the conventional value network may be displaced. So the game between different stakeholders will be more intense during the process of BMI. New BM for EVs won't be established unless each stakeholder in the new value network can get profit. An appropriate distribution method of profit is necessary.

Recommendations

The Ministry of Science and Technology issued "Electric Vehicle Technology Development '12th Five-Year' Special Plan "(summary)" in March 2012". According to this plan, the development of EVs in China has entered a critical period, and faces significant opportunities and serious challenges. One of the planning objectives is to achieve EV industrial upgrading. To achieve this objective, BMI is critical. In this section, we will give some approaches or proposals for Promoting BMI for EVs based on the BMI approach and TM.

Define and Structure the Problem

Problem definition, analysis and structuring are the starting point of the TM cycle, so is the BMI for EVs. As we have mentioned above, many publications study BM without explicitly knowing what the EV BM means and what the element are of EV BM. This will cause confusion and obstruct the BMI. So before starting BMI for EVs, it is necessary to define and structure it. BMI for EVs is in essence a systemic innovation and transition with the aim to construct the appropriate environment, explicitly define elements and actors in the whole value network, re-combine various options and find the appropriate combination (Di Xu 2005).

Establish Transition Arena

Interest conflict is a serious barrier for EV BMI. To solve this need all stakeholders communicate and cooperative with each other. Transition arena is such a systemic instrument. It is a virtual network or space for discussion and deliberation. Government has the responsibility to establish transition arena and organize stakeholders together for BMI. Stakeholders can gather and communicate in the transition arena, develop EV BMs, execute experiments and learn new experiences.

Develop Different Business Models

TM highlights that to achieve transition we need develop different transition visions and keep options open, especially at the beginning of transition. So is the case with BMI for EVs. Different BM options are like different transition visions in TM. Moreover the discovery-driven approach for BMI needs continuous experiments and this also needs to develop different BM options. The question is how we can find different BM options?

One promising approach is to construct maps of BMs to clarify the processes underlying them, which then allows them to become a source of experiments considering alternate combinations of the processes. One example of this mapping approach is Business Model Canvas coming from Osterwalder's work (Alexander Osterwalder 2004). It is a visual template preformatted with the nine elements of a BM (Fig. 50.3). It can be printed out on a large surface so groups of people can jointly start sketching and discussing business model elements. It is a hands-on tool that fosters understanding, discussion, creativity, and analysis. There are some other mapping approaches for BMI including business reference model, component business modeling.

Another promising approach to develop BMs is system innovation methods. One of the most used system innovation methods is General Morphological Analysis

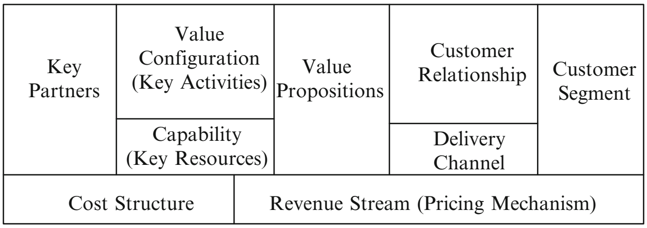
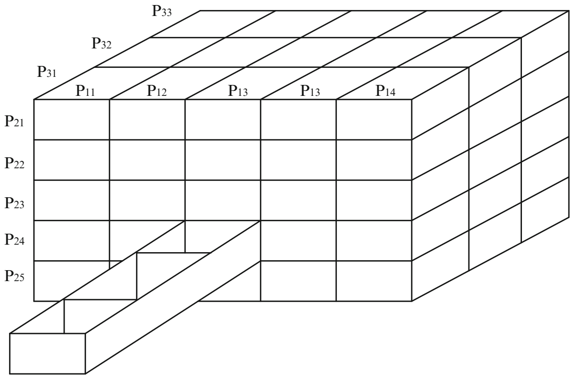


Fig. 50.3 Business model canvas



	Dimension 1	Dimension 2	Dimension 3
Values or Conditions of each dimension	P11	P21	P31
	P12	P22	P32
	P13	P23	P33
	P14	P24	
	P15	P25	

Fig. 50.4 A three-dimension morphological box

developed by Fritz Zwicky. This method is for exploring all the possible solutions to a multi-dimensional, non-quantified problem complex. It is an automatic method of combining parameters into new combinations for the later review of the problem solver. A selection of parameters or attributes is chosen and combinations explored. Five steps are included in this method: Clearly define the problem to be solved; properly define the dimensions of the problem complex to be investigated; assign each dimension a spectrum of values or conditions; use cross-consistency assessment for synthesized analysis and identify all the possible solutions; compare all the possible total solutions and choose appropriate ones. A morphological box is constructed by setting the parameters against each other in an n-dimensional matrix when using this method. Figure 50.4 shows a three-dimension morphological box, in which P_{ij} represents *j*th value or condition of *i*th dimension (Zwicky 1969).

Execute, Evaluate and Learn from Experiments

In TM cycle, transition experiments should be executed around the developed various transition visions. These societal experiments are with high risks and a high potential to contribute to a transition process. TM relies on iterative decision making and decisions are made on the basis of experiments, experiences and new insights.

The discovery-driven approach for BMI also puts emphasis on such a cycle: trial-and-error learning. The individual and group knowledge accumulated during the trial-and-error process must be integrated into the whole network. New, shared understandings and interpretations are developed and these collective understandings become crucial in formulating and implementing strategic choices based on more complex cognitive structures. Even if a viable business model has emerged, further trial-and-error learning is also vital because new external (or internal) triggers can still challenge its future viability (Sosna et al. 2010).

So in the process of BMI for EVs, we should execute experiments at different scales. The most important is that we should continuously evaluate these options and keep learning so as to know more about environment, markets, and user practices and promote continuous innovation.

Bring Customers and Government In

The BM for EVs is not just a product innovation, and it involves many actors including government, business companies and customers. To realize BMI, it is necessary and inevitable to bring customers and government in.

The value in any commodity can be realized only by exchange. A good BM must fulfill some needs of customers. Without this any BM is a failure. The value proposition is the first of the BM elements. It highlights the following questions: What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying? The companies or the whole industry cannot get profit if they couldn't find answers to the above questions. The market will eventually determine which BM is acceptable.

In a company, managers are responsible for BMI. But as to the BMI for EVs, it is beyond the scope of a company. The relationship between actors can stimulate, slow down or even block BMI, so government should play an important role during the process of BMI. According to TM, the role of government is different in each phase of the transition process. So is the case in BMI for EVs. In the preparation and early phase of innovation, government may play the catalyst and director, with the emphasis on maintaining a wide playing field and organizing and stimulating discussions among actors. Government is the builder of regulations and policies (e.g. standards) and should create a favorable environment for BMI. With the deepening of innovation, government should gradually give the task of resource allocation to the market and act as market supervisor.

Acknowledgement This study was supported by "*Shanghai Excellent Academic Leaders Plan (11XD1405100)*" of Science and Technology Commission of Shanghai Municipality and "National High-tech R&D (863) Program (*2011AA11AA87*)".

References

Amit R, Zott C (2001) Value creation in e-business. Strateg Manag J 22:493–520
Brown S, Pyke D, Steenhof P (2010) Electric vehicles: the role and importance of standards in an emerging market. Energy Policy 38:3797–3806
Chesbrough H (2010) Business model innovation: opportunities and barriers. Long Range Plann 43:354–363
Chesbrough H, Rosenbloom RS (2002) The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Ind Corp Change 11(3):529–555
Di Xu (2005) Business models innovation. Econ Manag Publ, Beijing, pp 60–80 (in Chinese)
Émile Jean Louis Chappin (2011) Simulating energy transitions. PhD dissertation, Delft University of Technology, Delft
Farla J, Alkemade F, Suurs RAA (2010) Analysis of barriers in the transition toward sustainable mobility in the Netherlands. Technol Forecast Soc Change 77:1260–1269
Köhler J et al (2009) A transitions model for sustainable mobility. Ecol Econ 68:2985–2995
McGrath RG (2010) Business models: a discovery driven approach. Long Range Plann 43:247–261
Osterwalder A (2004) The business model ontology-a proposition in a design science approach. PhD dissertation, L'Université de Lausanne, Switzerland
Qiang Ye, He-wu Wang (2012) The study on the business model system of electric vehicles. Forum Sci Technol China 1:44–48 (in Chinese)
Rotmans J, Kemp R, Van Asselt M (2001) More evolution than revolution: transition management in public policy. Foresight 3(1):15–31
Sierzchulaa William, Bakker Sjoerd, Maat Kees, van Wee Bert (2012) The competitive environment of electric vehicles: an analysis of prototype and production models. Environ Innov Soc Transit 2(2):49–65
Sosna M, Trevinyo-Rodrı´guez RN, Velamuri SR (2010) Business model innovation through trial-and-error learning: the Naturhouse case. Long Range Plann 43(43):383–407
Teece DJ (2010) Business models, business strategy and innovation. Long Range Plann 43 (3):172–194
Timmers P (1998) Business models for electronic markets. Electron Mark 8(2):3–8
Zott C, Amit R, Massa L (2010) The business model: theoretical roots, recent developments and future research. Working paper, pp 1–43
Zwicky F (1969) Discovery, invention, research-through the morphological approach. The Macmillan Company, Toronto, pp 30–50

Chapter 51
Research on Evaluation Problem of Culture Construction of Military Industrial Enterprises – Take Corporate A as an Illustration

Su-yang Zhang, Kang-hao Xiong, and Ke Shen

Abstract With the development of China's social and economic integration, Chinese military industrial enterprises are facing the external business environment which is profoundly changed. Faced the new opportunities and challenges, they must have supported and guided by the concept of the advanced enterprise value. Therefore, carrying out the construction of enterprise culture actively and effectively, focusing on the innovation of enterprise culture, are the objective requirements when building the advanced culture for military industrial enterprises. The thesis is based on the theory of enterprise culture, according to the characteristics of the military industrial enterprise, builds an evaluation system that is fit for the military industrial enterprise, and chooses corporate A as the evaluation object, using the methods of Delphi, AHP and Fuzzy Comprehensive Evaluation, analyzes the current situation of enterprise culture construction. The thesis is not only suitable for this corporation, but also having the significance for other similar corporations.

Keywords Culture construction • Evaluation • Military industrial enterprise • Suggestions

Introduction

The development process of Chinese military enterprises, has gone through from experience management to scientific management, and then to the stage of the cultural management. Facing the competitive environment and concept which are

S.-y. Zhang (✉) • K.-h. Xiong
School of Management and Economics, Beijing Institute of Technology, Beijing, China
e-mail: zsynestor@gmail.com

K. Shen
Chongqing Rural Commercial Bank, Chongqing, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_51,

changing nowadays, the military industrial enterprises have to build the enterprise culture, achieve the effective integration of the military enterprises' resources, and promote the fundamental shift in the idea of military enterprises management and style (Cuffs and Moore 2003). This is not only an urgent need, but also a problem to be solved for military enterprises currently.

With the deepening research of the corporate culture, many companies, including many military industrial enterprises are expected to establish a corporate culture management system which can give them a sustainable development support. Thus, how to evaluate the gap between the status quo of the corporate culture and corporate strategic target is quite significant. Also, analyze and evaluate the corporate culture is particularly important.

Evaluation Indexes and the Determination of Weights

The Determination of Evaluation Indexes

When determine the indexes of evaluation, we should follow these principles: first, objective and real, second, holistic and comprehensive, third, operational and independent (Macaleer and Shannon 2009; Flamholtz and Rangapiya 2005).

The thesis acquired the indexes system (first draft) of military industrial corporate culture evaluation by researching vast quantities of information and papers, then we visited three representative three military industrial enterprises, and found out some obvious characteristics of these enterprises, then modified 3 first-class indexes and 21 second-class indexes, and got the indexes system (second draft) of military industrial corporate culture evaluation. Finally, gave the second draft to 10 experts which are major in military industrial corporate culture evaluation, setting 10 points as the full marks for each index, and 8.5 points or more should be absorbed in the indexes system of military industrial corporate culture evaluation (Evans 2009). Then, using Delphi method to consult these ten experts with two rounds, and the opinions of experts be collected and calculated (Mintzberg 1998). Finally, according to the opinions of experts, we decided to use 4 first-class indexes and 16 second-class indexes in our indexes system of military industrial corporate culture evaluation. This can be seen in Table 51.1.

Selection of Evaluation Methods

Nowadays, many evaluation methods exist and have been utilized in studies and researches. By combining the actual situation of military industrial enterprises and the evaluation indexes as indicated above, we decided to use these three following methods, which include the methods of the Analytic Hierarchy Process (AHP), Delphi, and Fuzzy Comprehensive Evaluation. Based on these methods, too many

Table 51.1 Indexes system of military industrial corporate culture evaluation

Indexes of first-class	Indexes of second-class
Value system of military industrial enterprises X_1	Core values of military industrial enterprises X_{11}
	Cohesion of military industrial enterprises X_{12}
	Mental visage of military industrial enterprises X_{13}
Conveying and execute system of military industrial enterprises X_2	Visual identity of military industrial enterprises X_{21}
	Environmental construction of military industrial enterprises X_{22}
	Examples of military industrial enterprises X_{23}
	Institutional building of military industrial enterprises X_{24}
	Construction of characteristic culture of military industrial enterprises X_{25}
	Facilities and support of military industrial enterprises X_{26}
Organization and leadership system of military industrial enterprises X_3	Organizational system of culture of military industrial enterprises X_{31}
	Culture programming of military industrial enterprises X_{32}
	Culture training system of military industrial enterprises X_{33}
	Supervision and appraisal of culture construction of military industrial enterprises X_{34}
Effectiveness evaluation system of military industrial enterprises X_4	Competitiveness of military industrial enterprises X_{41}
	Production and operation of military industrial enterprises X_{42}
	Social reputation of military industrial enterprises X_{43}

factors of evaluation and weight distribution can be properly solved. Therefore, the rationality and accuracy of the evaluation results should be improved dramatically (Tepeci and Bart Bartlett 2002; Pearce and Robinson 2000).

The Evaluation Process of Culture Construction of Military Industrial Enterprises

In the first place, determine the weights by using the methods of Delphi and AHP. The qualitative and quantitative indexes of evaluating process are fully taken into consideration (Pitts and Lei 2002). Then process the data, and the experts should give them a respective score by analyzing. According to the experts' results, use AHP method to determine the weights of the indexes.

The final step is selecting the method of Fuzzy Comprehensive Evaluation, in order to make a proper description of the evaluation factors, analyze the evaluation objects, and obtain the quantized results (Quinn and Spreitzer 1991).

Evaluate the Culture Construction of Corporate *A*

The thesis chooses a representative military industrial enterprise-Corporate *A* as the evaluate object, uses the indexes system of military industrial corporate culture evaluation that we established in Chap. 2. By evaluating the culture construction of Corporate *A*, we can find out the situation of its culture construction (Robbins and Coulter 2005). At the same time, it plays an important role in supplement for the indexes system of military industrial corporate culture evaluation.

Weights of Indexes of Corporate A

We choose 406 staffs in Corporate A as our evaluation samples, then use the indexes system and methods which mentioned in Chap. 2 to calculate the weights of indexes, including indexes of first-class and second-class (Parise 2004). Finally we got the determination matrix *B* after normalization and the eigenvector *W*. Take the second index of first-class and its six indexes of second-class as an example. This can be seen in Table 51.2.

Next, we should calculate the consistency of determination matrix *B*. The largest eigenvalue meets:

$$\lambda \max = (1/n)[\sum_{i=1}^{n} (BW)_i / W_i],$$

Therefore, the index of consistency CI (Cameron and Quinn 1998):

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

And we seek that the average stochastic RI = 1.24, so the ratio of the consistency CR = 0.070/1.240 = 0.0560.

Because CR < 0.1, the result shows that the consistency is very well. It explains that the weight distribution of indexes is quite reasonable. By calculating, we got the weights of the second index of first-class:

$$\mathrm{W}_1 = 0.16; \mathrm{W}_2 = 0.18; \mathrm{W}_3 = 0.20 \ \mathrm{W}_4 = 0.05 \ \mathrm{W}_5 = 0.16 \ \mathrm{W}_6 = 0.25.$$

According to the comparison data of the evaluation indexes, repeat the calculating process above, we got the total weights which can be seen in Table 51.3.

Table 51.2 Determination matrix B after normalization and the eigenvector W

Determination matrix B after normalization								Eigenvector W
X_2	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	$\sum_{k=i}^{6} b'_{kj}$	$W_i = (1/6)(\sum_{k=i}^{6} b'_{kj})$
X_{21}	0.16	0.17	0.15	0.20	0.14	0.13	0.95	0.16
X_{22}	0.16	0.17	0.30	0.20	0.14	0.13	1.10	0.18
X_{23}	0.16	0.09	0.15	0.25	0.42	0.13	1.20	0.20
X_{24}	0.04	0.04	0.03	0.05	0.05	0.09	0.30	0.05
X_{25}	0.16	0.17	0.05	0.15	0.14	0.26	0.93	0.16
X_{26}	0.32	0.34	0.30	0.15	0.14	0.26	1.51	0.25

Table 51.3 Table of total weights

Indexes of first-class	Weights	Indexes of second-class	Weights
X1	0.562	X11	0.5396
		X12	0.2970
		X13	0.1634
X2	0.233	X21	0.160
		X22	0.180
		X23	0.200
		X24	0.050
		X25	0.160
		X26	0.250
X3	0.139	X31	0.3325
		X32	0.3325
		X33	0.1225
		X34	0.2125
X4	0.066	X41	0.163
		X42	0.540
		X43	0.297

The Evaluation Process of Culture Construction of Corporate A

First, we should build the evaluation set and the evaluation factors set. According to the indexes system of culture evaluation of Corporate A, we can build the factor set of fuzzy comprehensive evaluation. We should also build the subset of evaluation factors according to the indexes of second-class, denoted

$$X_i = \{X_{ij}\} \quad i = 1,2,3,4, \quad j = 1,2,\ldots,n$$
$$X_1 = \{X_{11}, X_{12}, X_{13}\}, \qquad X_2 = \{X_{21}, X_{22}, X_{23}, X_{24}, X_{25}, X_{26}\}$$
$$X_3 = \{X_{31}, X_{32}, X_{33}, X_{34}\}, X_4 = \{X_{41}, X_{42}, X_{43}\}$$

Second, we set a 5-level remark for each evaluation factor. Denote the evaluation set $V = \{v_1, v_2, v_3, v_4, v_5\} = \{\text{Very Good}, \text{Good}, \text{Normal}, \text{Bad}, \text{Very Bad}\}$, and each level corresponds a fuzzy subset (Hofstede 1994).

Third, the ten experts which are major in military industrial corporate culture evaluation will decide the level of each evaluation factor according to the evaluation standard and the situation of culture construction of Corporate *A*.

Forth, we should define the composition operator and the fuzzy relation matrix. According to the theory of fuzzy comprehensive evaluation, the composition operator Θ is a kind of the algorithm, which maps from the fuzzy relation matrix R to the set of evaluation V by the set of weights. In the thesis, we define the multiplication as the composition operator among the matrixes. That is to say, the result of the fuzzy comprehensive evaluation is S = WR. Similarly, we define the fuzzy relation matrixes as following:

$R = (RX_1, RX_2, RX_3, RX_4)$;
$RX_1 = (RX_{11}, RX_{12}, RX_{13})$;
$RX_2 = (RX_{21}, RX_{22}, RX_{23}, RX_{24}, RX_{25}, RX_{26})$;
$RX_3 = (RX_{31}, RX_{32}, RX_{33}, RX_{34})$;
$RX_4 = (RX_{41}, RX_{42}, RX_{43})$

Next, according to the opinions of ten experts, we take one of the indexes of second-class which called the Core Values of Military Industrial Enterprises X_{11} as an illustration and evaluate it (Denison 2004). The proportion of “Very Good” is 40%, “Good” is 30%, “Normal” is 20%, “Bad” is 10% and “Very Bad” is 0%. From above, we can obtain that: $RX_{11} = (0.4, 0.3, 0.2, 0.1, 0)$. By such analogy, we can get:

$RX_{12} = (0.3, 0.4, 0.2, 0.1, 0)$; $RX_{13} = (0.2, 0.5, 0.2, 0.1, 0)$;
$RX_{21} = (0.3, 0.3, 0.3, 0.1, 0)$; $RX_{22} = (0.1, 0.2, 0.5, 0.1, 0.1)$;
$RX_{23} = (0.3, 0.4, 0.2, 0.1, 0)$; $RX_{24} = (0.2, 0.2, 0.3, 0.2, 0.1)$;
$RX_{25} = (0.3, 0.4, 0.3, 0, 0)$; $RX_{26} = (0.2, 0.2, 0.3, 0.3, 0)$;
$RX_{31} = (0.2, 0.5, 0.2, 0.1, 0)$; $RX_{32} = (0.2, 0.4, 0.2, 0.1, 0.1)$;
$RX_{33} = (0.2, 0.3, 0.3, 0.2, 0)$; $RX_{34} = (0.1, 0.2, 0.3, 0.3, 0.1)$;
$RX_{41} = (0.3, 0.3, 0.2, 0.2, 0)$; $RX_{42} = (0.2, 0.2, 0.2, 0.3, 0.1)$;
$RX_{43} = (0.4, 0.3, 0.2, 0.1, 0)$

Then, according to the formula $R_{X_i} = W_{xi} \Theta R_{xii}$

We can calculate (RX_1, RX_2, RX_3, RX_4).

$RX_1 = (0.33762, 0.36238, 0.2, 0.1, 0)$;
$RX_2 = (0.234, 0.288, 0.316, 0.139, 0.023)$;
$RX_3 = (0.17875, 0.3785, 0.2335, 0.15475, 0.0545)$;
$RX_4 = (0.2757, 0.246, 0.2, 0.2243, 0.054)$

And we can calculate the final evaluation vector S

$S = (0.28731, 0.33961, 0.23168, 0.12490, 0.01649)$

Table 51.4 The Evaluation Results of Indexes of first-calss of corporate *A*

Indexes	Vectors of fuzzy relations					Evaluation results
X_1	RX_1					Good
	0.33762	0.36238	0.2	0.1	0	
X_2	RX_2					Normal
	0.234	0.288	0.316	0.139	0.023	
X_3	RX_3					Good
	0.17875	0.3785	0.2335	0.15475	0.0545	
X_4	RX_4					Very good
	0.2757	0.246	0.2	0.2243	0.054	

The Evaluation Results of Culture Construction of Corporate A

According to the principle of the maximal subordinate degree, we can get the evaluation of Corporate *A*. Take the result we calculated above for example, $S_2 = 0.33961$ is the maximum number in the 5 numbers and it corresponds V_2 in the evaluation set V. Therefore, for this index, the evaluation result is "Good". Similarly, we can acquire the results for other indexes. The results can be seen in Table 51.4.

Analysis and Suggestions

Analysis of the Evaluation Results of Corporate A

From the evaluation results of Corporate *A*, we know that generally, the culture construction of Corporate *A* is good. It means that in the culture construction of military industrial enterprises, Corporate *A*'s advantages far outweigh its disadvantages, but it also means that there exists a few of shortcomings in Corporate *A*.

The evaluation result "Good" represents that: first, the culture content system of Corporate *A* is perfect, with distinct cultural characteristics of military industrial enterprises. Second, the culture which has established by Corporate *A* has been widely acknowledged by staffs and the general public. Besides, it has a good social reputation, and the staff usually has a sense of belonging.

Furthermore, it boosts the productive efficiency of the military industrial enterprises, as well as Corporate *A*. Last but not least, it promotes the development of the military industrial enterprises

In general, we find out a culture construction program which has a strong applicability by evaluating the culture construction of Corporate *A*.

Suggestions for Corporate A *and Other Similar Military Industrial Enterprises*

In order to reinforce the culture construction of military industrial enterprises, several suggestions should be followed in the future work.

First of all, we should not only establish the culture evaluation system but also the evaluation standard of military industrial enterprises, so that we could find out the problems which exist in enterprises quickly;

Moreover, strengthen the culture construction of organization and leading, including these following works:

Strengthen the leading of evaluation, the experts should play a role adequately in the culture construction of military industrial enterprises (Carroll and Harrison 1998).

Finally, establish the incentive mechanism and the commitment mechanism of the evaluation as soon as possible, because it can help the military industrial enterprises arouse the enthusiasm, so that it can promote the productive efficiency.

Conclusion

In the thesis, we mainly discuss the problem of culture construction of military industrial enterprises, and besides, we do some research on the culture evaluation system of military industrial enterprises.

First, use Delphi method in order to select the indexes of culture construction, and based on these indexes, establish a culture evaluation system of military industrial enterprises;

Second, take a typical military industrial enterprise which called Corporate *A* as an illustration. We got the culture evaluation results of Corporate *A* by using the methods of the Analytic Hierarchy Process (AHP), Delphi, and Fuzzy Comprehensive Evaluation.

Third, the rationality of the indexes system has been tested in practice by analyzing the situation of Corporate *A*.

Finally, several reasonable and useful suggestions which are concerning the culture construction of military industrial enterprises have been put forward.

Acknowledgment Supported by National Natural Science Foundation of China (Fund No. 91024019).

References

Cameron KS, Quinn RE (1998) Diagnosing and change organization culture based on the competing values. Addition-Wesley Press, New York, pp 507–521 (Book style)

Carroll GR, Harrison JR (1998) Organizational demography and culture: insights from a formal model. Adm Sci Q 43:637 (Periodical style)

Cuffs A, Moore C (2003) Assessing information culture – an exploratory model. Int J Inf Manag 23:91–110, Chapter 4 (thesis or dissertation style)

Denison DR (2004) Corporate culture and organizational effectiveness: is Asia different from the rest of the world? Org Dyn 33:98–109 (Periodical style)

Evans M (2009) Bernard Forgues renewing strength: corporate culture revisited. Management 2 (4):63–87 (Periodical style)

Flamholtz E, Kannan-Narasimhan R (2005) Differential impact of cultural elements on financial performance. Eur Manag J 23(1):50–64 (Periodical style)

Hofstede G (1994) Management scientist are human. Manag Sci 40(1):15–17 (Periodical style)

Macaleer B, Shannon J (2009) Does HR planning improve business performance. Ind Manage 8 (2):1421–1429 (Periodical style)

Mintzberg H (1998) Strategy Safari: a guided tour through the wilds of strategic management. The Free Press, New York, pp 205–210 (Book style)

Parise G (2004) Dept. system management strategy to monitor insulated power cables. In: Industry applications conference, 2004. 39th IAS annual meeting, conference record of the 2004 IEEE, La Sapienza University, Rome, vol 3, pp 1755–1759 (Published Conference Proceedings style)

Pearce J, Robinson R (2000) Formulation, implementation, and control of competitive strategy. McGraw·Hill Companies, New York, pp 1009–1010 (Book style)

Pitts RA, Lei D (2002) Strategic management: building and sustaining competitive advantage, 2nd edn. South-Western College Publishing, Cincinnati, pp 125–129 (Book style)

Quinn RE, Spreitzer GM (1991) The psychometrics of the competing values culture instrument and an analysis of the impact of organizational culture on quality of life. Res Org Changes Dev 5:115–142 (Periodical style)

Robbins SP, Coulter M (2005) Management, 8th edn. Tsinghua University Press, Beijing, p 98

Tepeci M, Bart Bartlett AL (2002) The hospitality industry culture profile: a measure of individual values, organizational culture, and person – organization fit as predictors of job satisfaction and behavioral intentions. Hosp Manage 21:151–170 (Periodical style)

Chapter 52
The New Method to Define Ideality on Triz

Qing-hui Dai and Xi-kun Ma

Abstract Contradictory matrix and Ideality are the very important concepts of TRIZ-Theory. Generally, Ideality is defined as the ratio of useful function and harmful function. But, how to define "function", and how to differentiate the useful function and harmful function, has not confirmed yet. This thesis uses 48 parameters to redefine function, and then provides the formula of the Ideality of technology system. Furthermore, it puts forward a guess of the curve based on the increment of Ideality, which could provide the reference value for the evaluation of the new technology.

Keywords Ideality • TRIZ • Engineering parameters • The increment curve of Ideality

Introduction

Now the market environment is facing the situation of global highly compete, and innovation has felt more and more pressure, so TRIZ has become a new way to promote innovation. Ideality is one of the four basic theories of TRIZ (Mann 2001), and plays an important part in evolution theory of technical systems. The advance of ideality was from the theory of the technical system evolution, which comes out in two sides. First if the main performance index declines, the technical systems will be knocked out by the society; Second, if the system costs more because of adding useless new parts, it will die out as well (Guang Chen et al. 2011). In consequence, ideality is using for judging the adaptive degree of the social needs during evolutionary process of technical system.

Q.-h. Dai (✉) • X.-k. Ma
School of Energy Power and Mechanical Engineering, Department of Mechanical Engineering, North China Electric Power University, Baoding, China
e-mail: dqh6789@126.com; claudia1987@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_52,

The definition of ideality in TRIZ is deferent, but most scholars definite ideality as a measurement of the comprehensive benefits between useful function and harmful function (including cost and waste) (Soderlin 2003). However, there are no papers giving the way to definite how many functions in ideality are and what is the function really is. As well, there are some problems on the formula of ideality: first, the units of numerator and denominator are different; second, elevation of ideality sometimes can be confused with the compromise form of the change of numerator and denominator. So, how to definite function in ideality, and how can ideality be made to be an effective tool for quantizing and analyzing the product design? Both of them deserve to study.

Now, ideality basically has these main applications. First, it clearly shows the direction of innovation, and makes sure the technological innovation go through the direction of getting to the IFR (Ideal Final Result). Thereby, it avoids the defect of lacking target on traditional innovative methods, and promotes efficiency of innovation. Secondly, it is the very important tool for ARIZ, and be used to statement to construct and analyze the original issue. Thirdly, technical system improves itself by overcoming the contradiction and increasing ideality, so ideality is also used for judging the evolution level of the technical system.

Analysis of the Way on Defining Ideality

The Definition of Function

How to definite "function" in ideality? Some scholars directly think about it in the view of technical system functions. They classify the functions of technical system into three times: useful function (UF), harmful function (HF) and neutral function (NF) (Savransky 2000).

Useful function includes major function, auxiliary function and additional function. Major function is used for satisfying the needs of the system's major elements; auxiliary function is used for improving performance of major elements, in order to provide the integrity of system; additional function means the other useful function of the technical system except the major function and auxiliary function (Zlotin 2008). Harmful function means all the cost on the designated elements, including several kinds of bad effect such as sharp edge, noise and coloboma and some parameters that don't be needed (weight, measurement, etc.). Neutral function means the function which has relations with time. It will increase benefit for the enterprise, improve the performance of the major function, and provide extraneous earnings at a certain period. At the same time it will bring some indivisible harmful functions. Typical neutral function includes redundant and repeated functions, unnecessary intensity, precision and fixing devices. Sometimes the elements executing for the useful function can change into the wrong side along with the modification of the system. They all can be called neutral function (Guizhi Lv and Gongchang Ren 2009).

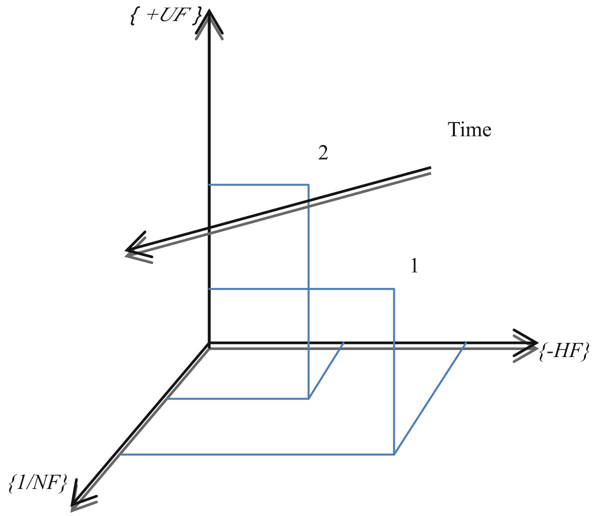


Fig. 52.1 Definition of ideality based on classification of technical system function

The Issue on Way of Defining Ideality

According to the definition of ideality and combing the classification method of technical system function, there comes a very simple formula (Savransky 2000):

$$Ideality = \sum UF \Big/ \sum HF \tag{52.1}$$

Where *UF* is useful function, *HF* is harmful function.

However, the formula is too rough; Savrasky put forward a concept of neutral function, and also brought up a new method of defining ideality of adding neutral function. Then he constructed a coordinate graphics which composed by useful function, harmful function, neutral function and time, in order to describe ideality directly. It presented in this pater is shown in Fig. 52.1 (Guizhi Lv and Gongchang Ren 2009).

Where, $\{+UF\}$ represents the positive direction of useful function, which means the set of quantity and quality of useful function in technical system. $\{-HF\}$ represents the positive direction of harmful function, which means the set of quantity and quality of positizing harmful function in technical system. $\{1/NF\}$ represents the positive direction of neutral function, which means the quantity set of neutral function in technical system. $\{+UF, -HF, 1/NF, t\}$ is ideality of technical system on t time.

When it is satisfied by this formula (52.2), it means the ideality of the technical system on time t_2 is higher than that on time t_1.

$$\begin{aligned}&\{UF_1\}>\{UF_2\}\ and/or\{-HF_2\}>\{HF_1\}and/or\\&\{1/NF_2\}>\{1/NF_1\}\end{aligned} \tag{52.2}$$

This kind definition of ideality is somehow directly; however it's complicated for operating. For this reason, Domb (1997), Savransky (2000), Slocum et al. (2003), and Helsinki (2003) provided a more simple formula of ideality to define ideality.

$$I = \frac{\sum UF}{\sum C + \sum HF} \tag{52.3}$$

Where, C is the cost of system.

Obviously, this way for defining is simply enough; however, there are three drawbacks. First, the unit of numerator and denominator is different, so it's not convenient to calculate. Second, the harmful function of any system is so much that can't be spread out all, and the summation of harmful function is closed to infinity, so it's hard to weather the ideality raises. The last, the technical system evolves by the way of overcoming the contradictions in order to raise ideality (Domb 2000). But it's hard now to explain the relationship between contradictions solving and ideality rising, and then, it's also hard to exactly analysis the complex relationship between the evolution of technical systems and ideality.

The New Way for Defining Ideality

The Function Definition Based on Engineering Parameters

Altshuller analyzed a large number of documentation literatures, and summarized 39 engineering parameters in order to solve practical problems effectively. These engineering parameters specialized describe the parameter attributes of the issues of technical system. Also they make specific issue generalized expression realizable. First of all TRIZ was brought into Europe and America and Asia, but then it seemed that all over the world are interested in studying and applying TRIZ. At present, some scholars have add the number of engineering parameters into 48, and made some adjustment of coding.

According to the change of the system's improving, engineering parameter can devices into two parts: positive parameters and negative parameters. Positive parameters are the engineering parameters whose characteristics rise when the system improves. When the parameters improve, system's performance turns to the positive side. On the opposite, the others are negative parameters.

In the same way, the engineering parameters which are used in technical contradiction matrix can also be used for defining functions in ideality. And the concrete steps are as followed:

1. Analysis the technical system, and make sure the major function of the technical system;
2. Detailed break down the technical system, make off the level of the system. Make a list of basic part and additional function for the super system, system, and subsystem.
3. Evaluate each function by the 48 engineering parameters. Then use AHP method, Delphi technique method or fuzzy comprehensive evaluation method to make sure the weight of the engineering parameters for the function. Here is the formula to help to get the value of the function:

$$F = -\sum_{i=1}^{48} \omega_i n_i + \sum_{j=1}^{48} \omega_{48+j}\, p_j \tag{52.4}$$

Where, ω is the weight of the engineering parameters, and meet the condition of $0 \leq \omega_i \leq 1$, and $\sum_{i=1}^{48} \omega_i = 1$. n is negative parameter, and p is positive parameters.

The engineering parameters mostly are summarized for the patent of invention. However, sometimes they are not all necessary for the specific function; the engineering parameters can be classified into two parts: be used for evaluating the function and not be used. Thereby, n and p should satisfy the conditions below:

$$n = \begin{cases} 1 & n \ \ is \ \ necessary \\ 0 & n \ \ is \ \ unnecessary \end{cases} \tag{52.5}$$

$$p = \begin{cases} 1 & p \ \ is \ \ necessary \\ 0 & p \ \ is \ \ unnecessary \end{cases} \tag{52.6}$$

Use formula (52.4), calculate the value of the function, and judge its character by the following formula:

$$\begin{cases} F>0 & useful \ \ function \\ F<0 & harmful \ \ function \end{cases} \tag{52.7}$$

Calculation of Ideality

On the definition of the function before, useful function set and harmful function set has been conformed:

$$UF = \{u_1, u_2, \cdots u_s\} \tag{52.8}$$

$$HF = \{h_1, h_2, \cdots h_n\} \tag{52.9}$$

Each function has its own contribution on the technical system, so we should confirm the weighting coefficient when judging the importance of each parameter. Sometimes, the subjective opinions of the designer can confuse the judgment of the weighting coefficient. So some method to confirm the weighing coefficient should be chose. Now the thesis is studying on the technical system, which has the character of highly technical and professional. So there comes Delphi technique method to confirm the weighing coefficient:

$$K = (\kappa_1, \kappa_2, \cdots, \kappa_s, \kappa_{s+1}, \cdots, \kappa_{s+m}) \tag{52.10}$$

Where, $0 \le \kappa_i \le 1$, and $\sum_{i=1}^{s+m} \kappa_i = 1$.

There comes the formula of the calculation of ideality:

$$I = \frac{\sum_{i=1}^{s} \kappa_i u_i}{\mu \sum C + \sum_{j=1}^{m} \kappa_{s+j} |h_j|} \tag{52.11}$$

Where, κ_i is the weighting coefficient of the i function. s is the number of useful function. μ is the weighting of cost, the level of cost in evaluation system is different for different technological innovation, most times it concerns prospective return. C is the cost of the innovation. m is the number of harmful function. u_i is the useful function of innovation, and h_j is the harmful function of innovation. The value of the h_j is negative, so the absolute value is used when calculating the ideality.

Ideality I is used for judging innovation capability. If $I > 1$, it means the innovation is effective after technical innovation, and the innovation is worth to develop and invest. If $I = 1$, it means the innovation can't help the product to get better, so it is invalid. If $I < 1$, it means the harmful function' number is larger than the useful function's, or it cost too much. So the innovation is harmful, and should be stopped right now.

This new way for defining ideality improves two sides for the once:

1. It uses engineering parameter to evaluate the technical system's function. In this way, the mistakes of defining function by subjectivism can be avoided. This new method uses divers engineering parameters to evaluate the function from different sides, and make sure the value of function at last.
2. Technical system improves itself by constant overcoming contradictions and improving ideality. In this way, it effective explains the relationship between contradiction settlement and ideality improvement, and precise analysis the complicated relation between technical system evolution and ideality.

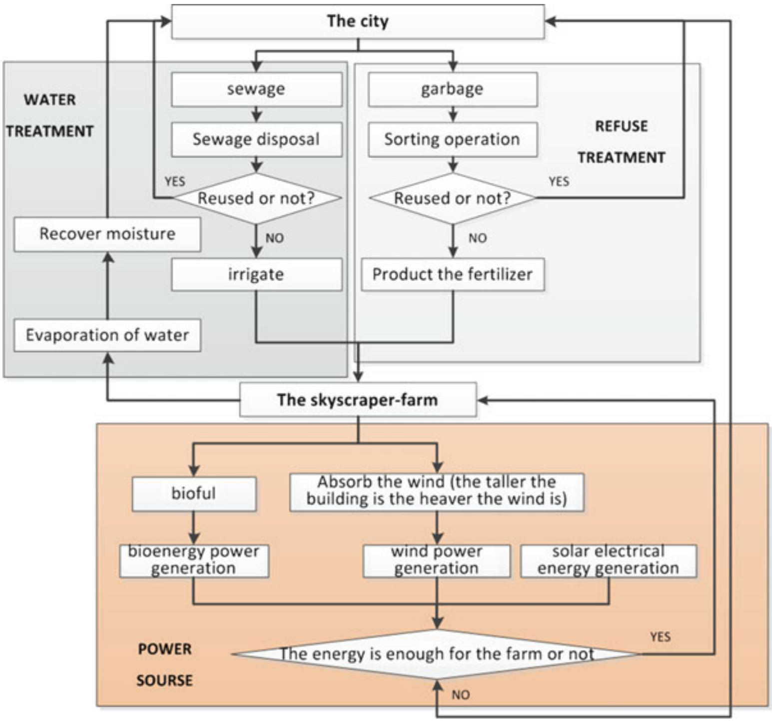


Fig. 52.2 The tread theory between the city and the skyscraper-farm

Example

1. Description (Xianbi Yang 2007)

   The development of the city makes more and more arable land and forest be taken up and the ecological environment is seriously destroyed. So many environmental experts discuss the way of developing green city. There comes a new idea of building a vertical farm in down-town, which builds a farm on the skyscraper. And the farm provides food and oxygen for the inhabitants of the city, on the other side; it also can absorb carbon dioxide and cool the earth. Finally, it makes the wish of greening the city come true.

   This skyscraper-farm has 30 floors and each floor is 5 m which can give the tall fruit trees enough place to grow up. And it can also be divided into several floors to grow the short corps in order to save the place. A skyscraper-farm like this can feed 50,000 people a year. It can not only supply foods for the city, but also can recover garbage and sewage from the city, and sometimes provides electricity for the city. The process is presented below (Fig. 52.2):
2. Solution procedure

   ① Generalize the main function of the innovative design: a. Grow the corps F_1; b. Decrease the floor area of the arable land F_2.

Table 52.1 Weight values of function parameters

Function		Parameter	Weighted value
F_1	Negative	31 Harmful factor from the object	0.12
		45 Complexity of the system	0.03
		46 Difficulty degree of monitoring and testing	0.23
	Positive	34 Maneuverability	0.22
		44 Production efficiency	0.4
F_2	Negative	45 Complexity of the system	0.07
		46 Difficulty degree of monitoring and testing	0.28
	Positive	6 The area of stationary objects	0.48
		32 Applicability and versatility	0.23
		43 Degree of automation	0.17
F_3	Negative	34 Maneuverability	0.3
	Positive	21 Structural stability	0.23
		39 Aesthetic property	0.47
F_4	Negative	30 Proliferation of harm	0.22
		32 Applicability and versatility	0.11
		34 Maneuverability	0.14
		45 Complexity of the system	0.24
	Positive	24 Operating efficiency	0.2
		27 Energy loss	0.1
		35 Reliability	0.01
F_5	Negative	34 Maneuverability	0.16
		45 Complexity of the system	0.45
	Positive	25 Material damage	0.33
		31 Harmful factor from the object	0.06

② Generalize the miscellaneous function of the innovative design: a. Improve the urban environment F_3; b. Product energy F_4; c. Recycle the garbage and sewage F_5.

In view of the complexity of the example, there only enumerate representative main function and miscellaneous function.

③ Evaluate the function F_1, F_2, F_3, F_4, F_5 based on 48 general engineering parameters, and obtain the value of each function. The positive parameter, negative parameter and weighted value of them are presented as the follow Table 52.1:

For F_1, which is substituted in formula (52.4), then there comes to the value of F_1:

$$F_1 = \omega_{31} n_{31} - \omega_{45} n_{45} - \omega_{46} p_{46} + \omega_{82} p_{82} + \omega_{92} p_{92} = 0.24$$

Similarly;

$$F_2 = -\omega_{45} n_{45} - \omega_{46} n_{46} + \omega_{54} p_{54} + \omega_{80} p_{80} + \omega_{91} p_{91} = 0.53$$

$$F_3 = -\omega_{34} n_{34} + \omega_{69} p_{69} + \omega_{87} p_{87} = 0.4$$

$$F_4 = -\omega_{30}n_{30} - \omega_{32}n_{32} - \omega_{34}n_{34} - \omega_{45}n_{45} + \omega_{72}p_{72} + \omega_{75}p_{75} + \omega_{83}p_{83} = -0.4$$

$$F_5 = -\omega_{34}n_{34} - \omega_{45}n_{45} + \omega_{73}p_{73} + \omega_{79}p_{49} = -0.22$$

So there comes the result that: F_1, F_2, F_3 are useful functions, and F_4, F_5 are harmful functions. So, $u_1 = 0.24$, $u_2 = 0.53$, $u_3 = 0.4$, $h_1 = -0.4$, $h_2 = -0.22$.

Then use Delphi method again, and confirm κ_i and μ.

Where, $\kappa_1 = 0.35$, $\kappa_2 = 0.4$, $\kappa_3 = 0.13$, $\kappa_4 = 0.08$, $\kappa_5 = 0.04$. The pro-cost of the innovative design is 200 million dollars. Considering about the profit of the environment, and the requirement of the global, confirm $\mu C = 0.21$. So the ideality of the innovation comes bellow based on the formula (52.11):

$$I = \frac{\kappa_1 u_1 + \kappa_2 u_2 + \kappa_3 u_3}{\mu C + \kappa_4 |h_1| + \kappa_5 |h_2|} = 1.38$$

Finally, the ideality of the technical innovation is $I = 1.38$, $I > 1$,which means the technical innovation has some effect. But the value of the ideality is not very big, mostly because it costs too much and the system is so complex that so hard to be brought out perfectly.

The Curve Based on the Increment of Ideality

Technical system innovation is the course of realizing each element of the function working from low level to high, from inefficiency to high efficiency, and system function evolving from single to aggregation. This improving course is the technical system evolution course. Altshuller found technical system evolved regular as the S curve based on analyzing mounts of patent for invention. S curve is using for forecast the degree of normality of the technical system, which is divided into infancy, growing, maturity and recession four parts.

In the same way, ideality has the same function as S curve. Also, increment of ideality has a curve to judge the development of the technical system, which has four parts too as the Fig. 52.3 shows:

The curve has four parts in the same way as S curve, which is also infancy, growing, maturity and recession. In infancy, it's the initial stage of the technical system. There are some risks like inefficiency, poor reliability, and some unresolved problems which may slow down the raises of ideality, even stop the raises of that. In growing, the technical system develops fast, and the problems are effective solved, efficiency and reliability of the product increase fast, so the increment of ideality is fast. In maturity, each function of technical system is reaching the best. And all what needed to is improve part of the system. The increment of ideality is the largest, and begins to decrease. In recession, the increment of ideality is tending

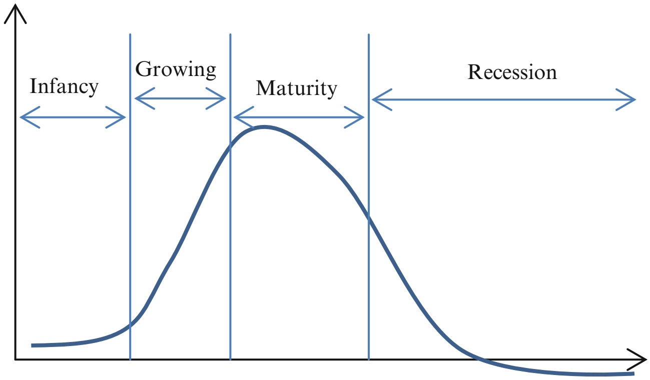


Fig. 52.3 The curve based on the increment of ideality

to small, even to negative value. So, before the system comes into recession, there should be a new technical system to replace, in order to raise the ideality, and bring the new life of the system.

Conclusion

Ideality is an important concept of TRIZ theory. The method of raising ideality is the basic method of technical system evolved. This thesis lists the major judgment method for ideality all over the world, then analysis them, and finds that there are some issues to be solved. So it uses engineering parameters to redefine functions, and give the new idea of calculating ideality. Besides, this method calculates the function of technical system, also the parameters that have summarized can help to solve the contradictory matrix.

Now the generation is the innovative generation. When to import the new technology, what kind technology should we import is meaningful for the technical system. This thesis comes out the curve based on increment of ideality, which hoping to give the judgment of new technology.

References

Domb E (1997) The ideal final result: tutorial [EB/OL]. TRIZ J 2(2). http://www.triz-journal.com/archives/1997/02/a/index.html, 25 Aug 2008

Domb E (2000) Strategic TRIZ and tactical TRIZ: using the technology evolution tools [J/OL]. TRIZ J 1(1). http://www.triz-journal.com/archives/2000/01/e/index.htm, 25 Aug 2008

Guang Chen, Bolu Wang, Lili Zhao (2011) Innovative thinking and methods: theory and application of TRIZ [M]. Science Press, Beijing

Guizhi Lv, Gongchang Ren (2009) Modeling of IFR in TRIZ base on functional analysis [J]. Mach Des Manuf 4(4):41–43

Helsinki (2003) Thoughts on value and ideality is the concept of ideality – is the concept of ideality “Scientific”? [J]. TRIZ J 5(5):51–56

Mann DL (2001) An introduction to TRIZ: the theory of inventive problem solving [J]. Creat Innov Manage 10(2):123–125

Savransky SD (2000) Engineering of creativity-introduction to TRIZ methodology of inventive problem solving [M]. CRC Press LLC, Boca Raton, pp 47, 71–72, 98–101

Slocum M, Lundberg C, Walter K (2003) Reangularity, semangularity, and ideality [EB/OL]. TRIZ J 6(6):1–27. http://www.triz-journal.com/archives/2003/06/a/01.pdf

Soderlin P (2003) Thoughts on value and ideality, is the concept of ideality “scientific”? [J]. TRIZ J 5:51–56

Xianbi Yang (2007) Turn the tower of the city into green farm [J]. Invent Innov 11:17

Zlotin B, Zusman A (2008) Instruments for designing consummate systems [J]. TRIZ J 2. http://www.triz-journal.com/archives/2008/04/03

Chapter 53
Integration of Agent-Based Logistic Operation for Container Terminal

Yan-qing Yuan, Xin-hai Xia, and Jun Cheng

Abstract After analyzing operational process for container terminal, the design employs a role Agent for each operation that coordinates with neighbouring role Agent. The structure of logistic operational integrated system based on Multi-Agent for container terminal is established via computation Agent, and the working process of operational role Agent is demonstrated. The computation Agent coordination model is designed. Based on the analysis of conflict of logistic operation for container terminal, integration mechanisms for adjacent operation role via the combination of game theory and Q-learning are proposed. Numerical experiment in container terminal about the adjacent operation integration between yard trailer and quay-crane testifies the validity of the integration. It helps improve the system's reliability.

Keywords Multi-Agent • Integration • Port container terminal • Logistic

Introduction

Professor Hamer proposed the concept of "business process reengineering" in 1990. It refers to the fundamental thinking and thorough reconstruction for the process and aims to make significant improvements in cost, quality, service and speed. Integrated optimization of processes is an important means to achieve process reengineering. In recent years, more and more attention has been paid to the related work about the research of integrated optimization of logistic operation for container terminal at home and abroad. The current study contains the field of container terminal logistic system (Jing-lei 2003), berth allocation problem (Kia et al. 2002), bridge crane allocation and scheduling jobs (Bish 2003), and the trailer path and scheduling of terminal (Ng and Mak 2005).

Y.-q. Yuan (✉) • X.-h. Xia • J. Cheng
Department of Port and Shipping Management, GuangZhou Marine College, Guangzhou 510725, P.R. China
e-mail: yyqyy168@sina.com; xiaxinhai@126.com; chj403@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_53,

The integration of Multi-Agent System means that each autonomous Agent arranges its objectives, resources, and state of mind etc. so as to adjust properly its own decisions and actions and to achieve their goals by the greatest extent. The coordination approach of Multi-Agent system is mainly divided into explicit coordination based on game theory and the implicit coordination based on social rules (Shi 2007). Multi-Agent System technology is increasingly being applied in the integration of container terminal logistic operations (Zhang Rong 2007), however, overall, it is limited to a local logistic operation of a terminal. Thurston and Hu (2002) also focused on berth allocation policies and cranes strategies, and tested various strategies to simulate a container terminal in Busan, South Korea through physical and logical Agents; Rebollo et al. (2000) proposed a Multi-Agent System mode to solve the problem of container terminal management, especially the reasonable and automatic allocation of the container to try to shorten ship berthing; Gambardella et al. (1998) combined operations research and multi-level Agent simulation and focused on the problem of scheduling, loading and unloading; Degano and Pellegrino applied Multi-Agent technology to the multi-functional container terminal operating areas (including export, import, loading and unloading), used Agent to detect the interference failure of the daily operation plan.

In order to use the terminal resources effectively, minimize entire time of port logistic operations, maximize efficiency, and avoid the phenomenon of the failure, emergence, congestion and waiting as much as possible, we need to integrate the logistic operations of the container terminal in view of the openness, complexity, and randomness of container terminal logistic operation system. Multi-Agent technology is applied to the integration of container terminal logistic operations. Based on conflict of logistic operation for container terminal, integration mechanisms for adjacent operation role via the combination of game theory and Q-learning are analyzed. The idea of Multi-Agent based integration of the container terminal logistics operations is proposed.

Agent Structure Model in Logistic Operational Integrated System for Container Terminal

Analysis of Logistic Operational Integrated Process for Container Terminal

The logistic operation for container terminal means the working process formed from container arrival at the port terminal to container departure (Zhang Rong 2007). The container terminal logistic handling equipments include quayside container crane (referred to as quay-crane), yard logistic bridge (referred to as yard bridge), container trailer (referred to as yard trailer) and so on. The quay-crane bears the ship's logistic operations, yard bridge is responsible for yard logistic and stacking operations, yard trailer performs the horizontal transport from the wharf apron to the yard and among yard box range. After packing ship arrives at port, the containers go through the flow process of "into the berth, unloading by quay-crane, horizontal transport, unloading by cross-car/gantry crane, stockpiling in yard, terminal internal transport, and transhipment by other modes", and export vice versa. Port container terminal operations include: berth allocation, quay-crane operations, horizontal transport (inner), yard storage, horizontal transport (outside), gates and so on. In the logistic operation of the container terminal, the scheduled resources include logistic handling equipment, berths, yards, port road, etc.

Definition for Related Agent Structure Model

Here, the design employs a role Agent for each operation that coordinates with neighbouring operation role Agent. According to the use of container terminal resources and the resulting scheduling problems for allocation of resources, the alliance of these operation role Agents forms a computation Agent. The relationship between the role Agents is equality and autonomy. Each autonomous role Agent is on behalf of the interests of an operation. The ultimate integration goal of computing Agents is not to optimize the interests of an individual operations, but to optimize the interests of the entire logistics operation system.

Computing Agent

The structural model for computing Agent is as follows (Shi 2007):

$$a = <E_a, RA_a, S_{a,} ca_a, RMA_a>$$

where, $\boldsymbol{E_a}$ is a computing entity set included in a; $\boldsymbol{RA_a}$ is a role Agent Set included in $\boldsymbol{a}$,

$\boldsymbol{RA_a}$ = {berth operating role agent, quay-crane operating role agent, horizontal transport I-agent, yard operating role agent, horizontal transport II-agent, gate operating role agent};

$\boldsymbol{S_a}$ is the possible states set of $\boldsymbol{a}$; $\boldsymbol{ca_a}$ is the current state of **a**. The state of computing Agent is the joint of that of each role Agent, public resource and tasks; $\boldsymbol{RMA_a}$ is a particular role Agent corresponding to $\boldsymbol{a}$, and responsible for the management of resources of $\boldsymbol{a}$. A role Agent of $\boldsymbol{a}$ updates the public status of the public task. $\boldsymbol{RMA_a}$ learns about the use of resources and schedules the role Agent, by task status, no need to have knowledge of the role Agent.

Operation Role Agent

For each operation role Agent,

$$ra = <e_{ra}, s_{ra}, cs_{ra}, M_{ra}, K_{ra}>$$

Where, e_{ra} is computing entities corresponding to $\boldsymbol{ra}$; $\boldsymbol{s_{ra}}$ is the operating status set of $\boldsymbol{ra}$; $\boldsymbol{cs_{ra}}$ is the current operating state set of $\boldsymbol{ra}$, including current task state, resource state and relationship with the other role Agents, etc; $\boldsymbol{M_{ra}}$, is the method set of $\boldsymbol{ra}$; $\boldsymbol{K_{ra}}$ is the control and reasoning core of $\boldsymbol{ra}$, interacting directly with the ***RME*** of the corresponding computing Agent.

The working process can be described as flows: First, the operating state detection module sends the detected state information to the learning module of role Agent, at the same time adjacent role Agent also provides with its self operating state information; Second, learning module offers decision-making reference for decision-making module according to the received or learned information and experience knowledge. Then, decision-making module selects and executes rational action. When the control action acts on the operation, it will alter the operation's state, after a certain time interval, operating state detection module sends the operation's state to role agent, and a reinforcement signal r will be sent to learning module. Finally, learning module will modify the Q-value (see section "Design of Integration of Logistic operations for Container Terminal Based on Agent"), and make a decision according to operation state again. The process above is repeated. The value of the feedback can be the ratio of passing traffic quantity of green light phase to passing traffic quantity of red light phase in decision-making interval.

For the operation integration between yard trailer and quay-crane, reinforcement signal $\boldsymbol{r}$ = reduction of idle running distance of yard trailer/augmenter of quay crane movement time.

Design of Integration of Logistic operations for Container Terminal Based on Agent

Integration Model for Computing Agent

Resource allocation of computing Agent i composed of n role Agents can be expressed as:

$$cfg_i = \langle R_i, \alpha_{i1}, \ldots, \alpha_{in}, \beta_{i1}, \ldots, \beta_{in}, \gamma_i \rangle.$$

where, R_i is resource description, including the resource costs; $\alpha_{i1},\ldots,\alpha_{in}$ are the required shares of resources for the n -role Agent respectively; $\beta_{i1},\ldots,\beta_{in}$ are the shares of idle resources assumed by the n – role Agent respectively;

γ_i is the share of idle resources to total resources.

For any role Agent, ra_{ij}, $a_{ij}>0$, $\beta_{ij}\geq 0$, and satisfy the formula: $\sum_{j=1}^{n} \beta_{ij} = 1$,

$\gamma_i + \sum_{j=1}^{n} \alpha_{ij} = 1$

Let $d(\beta_{ij},0) = 0$, when $\beta_{ij} = 0$; $d(\beta_{ij}, 0) = 1$, when $\beta_{ij} > 0$. When the demand for computing resources changes, assume that only one role Agent's share of required resources can change in each integration. Without loss of generality, assume that the share of required resources for role Agent ra_{ij} changed, $a_{in} \neq \alpha'_{in}$, then the idle resources change as follows:

$$\gamma'_i = \alpha_{in} - \alpha'_{in} + \gamma_i$$

For commitment to idle resources, ra_{ia} either remains the same; or changes with the needs and is computed as the following formula:

$$\beta_{ij} = \frac{d(\beta_{in}, 0) \times \alpha'_{in}}{\sum_{i=1}^{n} (d(\beta_{ik}, 0) \times \alpha'_{ik})}$$

For other role Agent ra_{ia} i.e., $j = 1,\ldots, n - 1$, if $\beta_{in} = 1$, then $\beta'_{ij} = \beta_{ij} = 0$; Otherwise, β'_{ij} is computed as by the following formula, maintaining the same relative share of each other.

$$\beta'_{ij} = \beta_{ij} \times (1 - \beta'_{in})/(1 - \beta_{in}), j = 1, \ldots, n - 1.$$

In the above algorithm, When the role Agent does not assume the idle resources, and still does not require to bear the overhead of idle resources after adjustment, i.e. $\beta_{in} = 1$, then $\beta'_{ij} = 0, \ldots, n$.

Realization of Integration of Adjacent Operation Role Agent

1. Analysis of conflict of logistic operation for container terminal

   There are three kinds of conflict types in logistic operation for container terminal (Yu Meng and Wang 2007; Legato and Mazza 2001; Li Ying 2004; Xia Xin-hai 2008; Gambardella et al. 2001): ① Resource conflicts. e.g. in the berth scheduling, multiple ships compete for limited berths resources at the same time, but the system does not meet their requirements. ②Target conflicts. e.g. in the quay crane scheduling, we aim for the rational allocation of the quay cranes to each berths in addition to no interruption of quay crane's operations, this will inevitably lead to yard trailer's waiting in line, and contrary to the goal of yard trailer's scheduling. ③ Results conflicts. It means the result achieved from the same problem in different operation is contrary to each other. From the overall point of view, the total logistic capability for all operating areas (such as quayside, yard) is fixed, but the resources assigned to various operations are limited. Since the operation of the original logistic operation system is simply overlying and lack of effective communication and integration, the operations conflict each other. The role Agents of container terminal perform administrator-defined tasks in a dynamic environment, constantly respond to changes in the terminal environment and production tasks, and integrate with each other to complete the task of container logistics operations aiming at the integrated optimization of container terminal logistic operations. In order to avoid being too frequent and complicated in the integration of adjacent role Agent, the key is the integration between the adjacent operation role Agent.

2. Analysis of adjacent logistic operation integration for container terminal

   Integration of adjacent logistic operation role Agent for container terminal mainly includes as follows: integration between berth and quay crane, integration between yard trailer and quay-crane.

   ① Integration between berth and quay crane

   Integrated optimization goal of berth and quay crane operations is to minimize the total lay time in port for all arrival ships including time of waiting for berth and service time. After allocation of quay crane and berthing, since there are not necessarily immediate quay crane services, ship service time is divided into time of waiting for the quay crane and working time. After the ship was allocated with berth, we can determine the quay crane number of the ship needed to be assigned according to the volume of loading and unloading container of the berthing ships and the required maximum handling time, and select continuous quay crane. Generally, the quay crane in container terminal is movable, but can not be leap-operation. In order to ensure the reasonable use of the quay cranes, the choice of ones near the berth which a ship docks is considered as much as possible. We set quay cranes near every berth according to the size of the quay crane and how many quay cranes a berth pier has.

   ② Integration between quay crane and yard trailer

   The quay crane is a major bottleneck restricting the efficiency of logistic operations for container terminal, and the operating time of the quay crane determines the total lay time in port for all arrival ships. In order to improve the operating efficiency of the pier, we usually schedule yard trailers and yard gantry crane according to the order of quay crane operations. However, operation scheduling based only on quay crane may cause the increase of traveling distance and the required number of yard trailer. Establishment of integrated mathematical model of the logistic operation for the container terminal can effectively improve the utilization of the yard trailers and reduced the total time of ship loading and unloading operations on the basis of the dynamic scheduling of yard trailers.

3. Realization approach for integration adjacent operation role Agent

   Game theory can be used to establish a dynamic interaction model of Multi-Agent System. Reinforcement learning is an interactive learning methods which is applicable to the interaction between Agent. Therefore, game theory and reinforcement learning is very suitable for the integration of adjacent operating role Agents. The integration between adjacent operating role Agents obeys following rules, firstly: Assume that the party to send the request of integration is ***A***, the party to accept request of integration is ***B***. ① If the actual operating amount ***B*** is below a certain threshold, then ***B*** should implement to the action which make ***A*** get the most reward value; ② If ***A*** and ***B*** were integrated, they no longer accept other requests in the two decision-making intervals. ③ When the controlled operation is in the operating peak or unable to get integrated policy, the role Agent stops the integration based on game theory, and $\boldsymbol{RMA_a}$ integrates on the basis of the experience and knowledge.

Following above rules integration for adjacent operation role Agent is realized via the combination of game theory and Q-learning (Shi 2007; Li Ying 2004). In container terminal logistic operating system, the type of game is a two-person, non-zero, cooperative game. The action set of every operation role Agent includes changing the operation state and maintain it, etc. Distributed Q-reinforcement learning algorithm has the characteristics of whole optimization and its convergent is rapid. Q-value reflects the property of policy, so here we adopt Q-value of role Agent as the benefit of policy.

In distributed Q-learning, each operation role Agent updates the value function according to reward function of the adjacent operation role of Agent (Li Ying 2004; Xia Xin-hai 2008):

$$Q_i(s_i, a_i) \leftarrow (1 - \alpha_i)Q_i(s_i, a_i) + \alpha_i[r_i(s_i, a_i) + \sum_j^n f(i,j) r_j(s_j, a_j) + \gamma_i \max_{a'_i \in A_i} Q_i(s'_i, a'_i)]$$

where, $\alpha_i \in [0, 1]$ it is the learning velocity of role Agent i; $\gamma_i \in [0, 1]$ is the discount gene of role Agent i; s_i is the current operating state of role Agent i in operating environment ; s'_i is the next state of operating environment; n is number of all other role Agents adjacent to role Agent i; $Q_i(s_i,a_i)$ is the function of Q-value of role Agent i; $r_i(s_i,a_i)$ is the reward function of role Agent i ; $r_j(s_j,a_j)$ is the reward function of role Agents adjacent to role Agent i; $f(i,j)$ is influencing weighting function which reflects how role Agent i depends on.

Application Analysis of Integration of Logistic Operations for Container Terminal

Here the integration between yard trailer and quay-crane is explored (Wang Gang et al. 2007). The results of integrated optimization are shown in Figs. 53.1 and 53.2. Level parameters of a container terminal logistic operations are as follows: Loading and unloading container are carried out by 2 quay cranes respectively; Operating efficiency of quay crane is 5 min/TEU, the moving speed is 2 km/h, the move time,

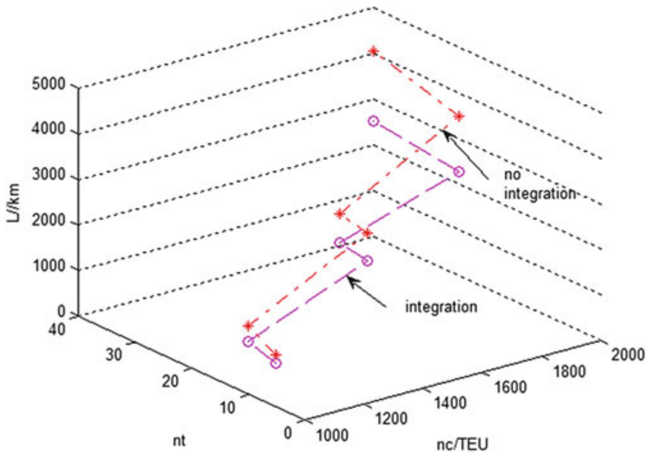


Fig. 53.1 Comparison of idle running distance (L) of yard trailer

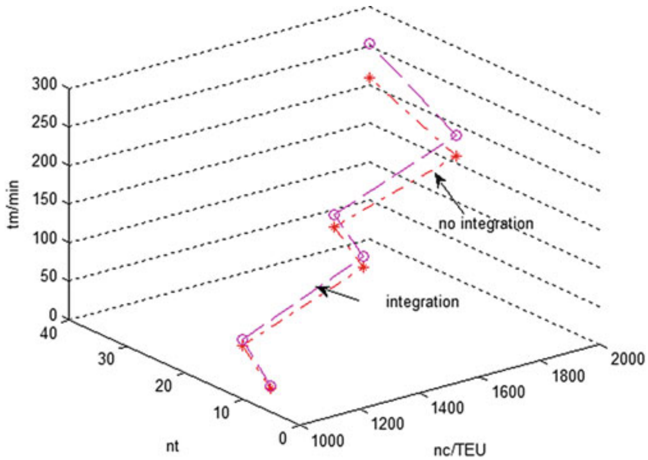


Fig. 53.2 Comparison of movement time (tm) of quay crane

start time of quay crane between adjacent bay is set to 2 min; Speed of yard trailer in the arterial road is 30 km/h, in the wharf apron and within yard the speed of yard trailer is 15 km/h; Yard is composed of 20 container areas. Locations of container storage are randomly generated by the program; Operating technology of the two quay crane driver is different, the impact factor values of ship unloading and loading are as follows: $\lambda_{D_i} = 0.4, \lambda_{L_j} = 0.6$; Assume that each task is completed by a quay crane, and each task is added to the operations sequence, there are no sub-tasks and overlapping jobs of quay crane. Locations of inbound and outbound container storage is determined in advance; Assume that each shipped container goes with each discharging container, and each container must be served once. The order of entire integration is as follows: firstly, give initial order of ship unloading operations, after that decide to the order of shipment operation according to the optimal results of yard trailer scheduling, next get the total time of shipment operations, then adjust the operations sequence. $\alpha = 0.9$, $\gamma = 0.95$. Define L as idle running distance of yard trailer, *tm* as movement time of quay crane, *nc* as number of loading and unloading container, and *nt* as the number of tasks.

It can be seen by analysis that after the integration, L decreases, though the *tm* increased, the proportion of reduction of L is much larger than the proportion of the increase in *tm*. With the increase in *nt*, the effect is more apparent.

From the combined effect above, integrated Optimization takes full account of the integration of quay crane and yard trailer. In case of a small amount of increase or not increase of the time of loading and unloading operations, it can significantly reduce L, thereby reduce terminal congestion, improve reliability of the operating system of container terminal logistics.

Conclusion

The structure of logistic operational integrated system based on Multi-Agent for container terminal is established via computation Agent and a role Agent. The computation Agent coordination model is designed. Based on the analysis of conflict of logistic operation for container terminal, integration mechanisms for adjacent operation role via the combination of game theory and Q-learning are proposed. Multi-Agent System has the characteristics of autonomy, adaptability, and sociality, so it has some technical advantages in solving complex integration problems. The applications of Multi-Agent to the integration of container terminal logistic operations meet the needs of the actual operation requirements, and are effective. The integration helps improve the reliability of the operating system of container terminal logistics.

References

Bish EK (2003) A multiple-crane-constrained scheduling problem in a container terminal. Eur J Oper Res 144(1):83–107

Gambardella LM, Rizzoli AE, Zaffalon M (1998) Simulation and planning of an intermodal container terminal. Simulation 71(2):107–116

Gambardella LM, Mastrolilli M, Rizzoli AE et al (2001) An optimization methodology for intermodal terminal management. J Intell Manuf 125(6):521–534

Jing-lei Yang (2003) Operation research on internal logistics networks of container terminals, PhD dissertation, Shanghai Maritime University

Kia M, Shayan E, Ghotb F (2002) Investigation of port capacity under a new approach by computer simulation. Comput Ind Eng 42(10):533–540

Legato P, Mazza RM (2001) Berth planning and resources optimization at a container terminal via discrete event simulation. Eur J Oper Res 133(3):537–547

Li Ying (2004) MAS and its application of forecast and ITS. East China University of Science and Technology Press, Shanghai, pp 154–158
Ng WC, Mak KL (2005) Yard crane scheduling in port container terminals. Appl Math Model 29:263–276
Rebollo M, Julian V, Carrascosa C et al (2000) A multi-agent system for the automation of a port container terminal. Autonomous agents 2000 workshop on agents in industry. Barcelona, Spain
Shi Chun-yi (2007) Computation based on agent. Tsinghua University Press, Bijing, pp 99–104
Thurston T, Hu H (2002) Distributed agent architecture automation. In: Proceedings of the 26th international computer software and conference, Oxford, UK, pp 81–90
Wang Gang et al (2007) Research on integrated optimization of logistics operation system in port container terminals based on multi-agent[J]. J Logist Technol 26(4):31–33
Xia Xin-hai (2008) Coordination & optimization of loading and unloading operation for container terminal distribution. J Guangzhou Marit Coll 16(2):16–19
Yu Meng, Wang Shaomei (2007) Research on modeling of multi-agent-based scheduling system for container terminal. J Wuhan Univ Technol (Transp Sci Eng) 31(3):495–497
Zhang Rong (2007) Information system model of rail-sea intermodal transportation based on multi-agent. J Tongji Univ (Nat Sci) 35(1):172–176

Chapter 54
Influence Analysis of Female Executives on Firm Performance in the Listed Companies of China

Lin-wan Wei, Lin Chen, and Shuang-yuan Wang

Abstract The relationship of board female ratio and firm performance has become a hotspot in foreign researches and discussions, but there is no agreement until now. Based on this, our article studies the relationship of board female ratio and firm performance on the basis of the data from listed companies in China by empirical research. We select a sample of 1,348 listed companies' financial statements from 2007 to 2009, and use Tobin's Q as a measure of firm performance. In order to investigate the impact of board female ratio on firm performance, empirical research is applied, and total number of company executives, average age of company executives, board size and firm size are applied as control variables. Our findings indicate that there is no significant relationship between board female ratio and firm performance, and we have mentioned some possible factors at the end of the paper.

Keywords Correlation analysis • Female executives • Firm performance • Regression analysis

Introduction

Senior management is an organization which controls the corporate affairs and business of a whole company. It goes without saying that senior management performs a significant function on modern enterprise's operation management. At present, the diversity in boardroom and in top executive positions has been

Project 10XJC630002 supported by the MOE Project of the West and Border Areas of Humanities and Social Science
Project 2009KRM12 supported by Shaanxi Soft Science Research Program

L.-w. Wei (✉) • L. Chen • S.-y. Wang
Department of Management, Northwestern Polytechnical University, Xi'an, China
e-mail: sisi0920@163.com; chenlin@nwpu.edu.cn; 903539537@qq.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_54,

the focus of public debate, academic research, government considerations and corporate strategy, and a very important aspect of board diversity is the gender ratio of company executives. With women coming into the workplace more, their special mode of thinking and ways of behavior have bring the company more new thoughts and ideas, and some women even have started their own business successfully. Some researches indicated that the masculine leadership style tend to be independent and competitive, while women pay great attention to exchanges and cooperation. To a certain extent, feminine leadership style seems more suitable for the company's senior management. The data demonstrate that 98% companies owned by female business owners are at the profit condition, all these success stories have attract public attention to female executives.

In recent years, more and more women tend to enter the workforce. But data demonstrate that female ratio of company executives is still low in companies all over the world: In the Americas, the board female ratio is only 13.6% in the Fortune 500 companies, the ratio in Canada is a little higher, approximately 15%. In Europe, the ratio in Norway and Sweden is 40 and 20%, respectively, while in other countries the ratios are all below 10%: in Spain and Italy, companies have few women on the board; German and Britain's females occupy 10% seats on the board; in Holland and France, the female ratio of company executives is 7 and 6% respectively. In Australia, the number reaches about 8.3%. In the Middle East, the highest ratio is 2.7% in Kuwait. In Hong Kong, only 8.9% board seats are owned by women, and the proportion drops to only 0.4% in Japan (Li 2010).

What effects will female executives bring to the board? Is it important to increase the percentage of board female executives? People started to think about the relationship of female executives and firm performance. Having a thorough research to this issue will have an important impact on companies' future development. Based on this, our article tries to find the link of board female ratio and firm performance, on the basis of data from 1,348 listed companies' financial statements from 2007 to 2009 in China by empirical research.

Theoretical Background

Some foreign articles have studied the relation between the ratio of female executives and firm value, including some empirical researches. For instance, the researchers in the US usually focus on the Fortune 500 companies and the Europeans pay more attention to data from large firms in Denmark, the Netherlands and Sweden. In China, the present method for the topic is very single. We put more effort into general description of management methods and management psychology of successful female executives. There are few articles focused on the special influence brought by female executives to firm performances. In addition, the findings have so far failed to reach an agreement, the different sample and method can bring to different results. Now there exist three different conclusions: the positive impact, the negative impact and no impact.

Many corporate managers and others interest in good governance believe that a positive link exists between female executives and firm performance. Reference (Adler 2001) studies 215 companies of US Fortune 500 firms. He compares the data with the average level of firm performance from 1980 to 1998, then he finds the significant relation of female ratio and firm performance (Adler 2001). A significantly positive effect is also found in (Carter et al. 2003) by using 2SLS to examine the relationship between the percentage of women and minorities on boards of directors and firm value (Carter et al. 2003). Reference (Catalyst 2004) shows the positive correlation by analyzing Rate of Return on Common Stockholders' Equity (ROE) and Earnings per Share (EPS) of the Fortune 500 firms (Catalyst 2004).

In contrast, a number of studies find that female ratio has negative impact on firm performance. Reference (Lee and James 2003) finds that the appointment of female CEOs will reduce the companies' market value, which shows a negative impact between female executives and firm value (Lee and James 2003). Reference (Wang Ming-jie and Zhu Ru-yi 2010) says there is no relationship of female executive directors and firm value, but female executives show negative impact on firms' Tobin's Q. But he also proposes that the negative impact may be decreased as the increase of women's scholastic performance (Wang Ming-jie and Zhu Ru-yi 2010).

There are some other articles find that this two factors are not relevant. Reference (Marinova et al. 2010) uses the same method as (Adler 2001), but the result shows that there is no significant relationship in 186 listed companies in 2007, of which 102 Dutch companies and 84 Danish companies (Marinova et al. 2010). Reference (Rose 2007) comes to the same conclusion by collected data from 1998 to 2001 of the Copenhagen Stock Exchange (Rose 2007).

Data Sources and Methodology

We collect data from listed companies' financial statements from 2007 to 2009 in China. To ensure higher accuracy, we select data through three steps. Firstly, the sample does not contain ST companies. Then, banks, insurance companies have been excluded as a result of their specific accounting, which poses difficulties for the calculation of performance measure. Thirdly, companies are also excluded in case of missing data during the 3 years. After selecting, the final data are from 1,348 listed companies from 2007 to 2009.

The data in this paper are collected from the CCERDATA, and the analysis software is SPSS 17.0.

There are several ways of measuring firm performance and there is hardly any agreement on which is the most efficient one. We choose to use Tobin's Q, which is the ratio of market value of a firm to replacement cost of its assets. Female executives are measured in two ways: (1) Percentage of female executives; and (2) Dummy variable indicating 1 if there is at least one female executive or 0 otherwise. Table 54.1 shows the meaning of variables in this paper.

Table 54.1 Meanings of variables in this paper

Variable	Variable symbol	Meaning
Explained variable	Tobin's Q	Ratio of the market value of a firm to the replacement cost of its assets
Explanatory variable	FemaRati (%)	Percentage of the female executives
	FemaRati (1/0)	Dummy variable indicating 1 if there is at least one female executive or 0 otherwise
Control variable	TotaNumb	Total number of company executives
	AverAge	Average age of company executives
	BoarSize	Board size
	FirmSize	Firm size

Table 54.2 Descriptive statistics for sample firms from 2007 to 2009

N	1,438								
Variables	Mean			Min			Max		
Year	2007	2008	2009	2007	2008	2009	2007	2008	2009
Tobin's Q	2.203	1.437	2.357	0.130	0.550	0.230	11.348	15.761	25.432
FemaRati (%)	0.1398	0.144	0.145	0.000	0.000	0.000	0.590	0.650	0.650
FemaRati (1/0)	0.890	0.900	0.910	0	0	0	1	1	1
TotaNumb	17.920	18.420	18.630	8	8	9	38	39	56
AverAge	46.730	46.880	47.430	36	37	33	58	59	57
BoarSize	6.130	6.210	5.880	2	2	0	14	15	13
FirmSize	21.537	21.475	21.766	18.720	14.110	17.750	27.630	27.350	28.000

Table 54.2 provides descriptive statistics for the sample firms from 2007 to 2009. We can see from the table that Tobin's Q of the listed firms in 2008 has experienced a sharp fall compared with 2007 and 2009. The percentage of female executives is 13.98% in 2007, 14.40% in 2008 and 14.50% in 2009, which maintains a steady upward trend. Some companies don't have female executives while the highest ratio is 65%. In the 3 years, the total number of the company executives is about 18, and the mean age of the directors is about 47 years old. The mean numbers of board size and firm size are about 6 and 21, respectively.

To find the relationship of firm performance and female ratio, OLS regression analysis is applied. Following Carter et al. (2003) we estimated the below-given system of simultaneous equations (54.1).

$$FirmPerf = \alpha_0 + \alpha_1 \times FemaRati + \sum_{i=2}^{n} \alpha_i X + \varepsilon \tag{54.1}$$

where the approximation of Tobin's Q is the measure of firm performance. We use both the percentage of female executives and the dummy variable indicating the presence of female executives, the variable symbols are FemaRati (%) and FemaRati(1/0). If there is no female executive on the board, the dummy variable set to 0, on the contrary, the result is 1. In order to examine the influence precisely, we introduce some control variables benefit from Carter et al. (2003) and Marinova et al. (2010). In the estimation, x is a vector of control variables like total number, average age, board size and firm size.

Estimation of our system of equations allows us to test the following null hypothesis:

Hypothesis: The ratio of female executives does not affect firm performance.

Rejection of the null hypothesis implies that female executives affect firm value. If the null hypothesis is rejected, the sign of the estimated α_1 could be either positive, suggesting firm performance is enhanced by the presence of women directors or negative, implying that the presence of women reduces firm value. Failure to reject the null hypothesis suggests that female executives do not add value.

Empirical Results

Table 54.3 shows correlation analysis results for sample firms.

In Table 54.3, the correction analysis shows that in the 3 years, Tobin's Q and the ratio of female executives is significantly related, the correlative coefficient are 0.077, 0.120 and 0.086. There is no significant relationship between Tobin's Q and the dummy variable, which shows no affection between these two variables preliminarily. We can also see from the table that there are negative correlations between Tobin's Q and total number, average age, board size and firm size. To some extent, they all have certain impact on firm performance, so we choose them as control variables in this paper.

Table 54.4 presents regression analysis results for the relationship between firm performance and the presence of female executives from 2007 to 2009.

The regression analysis reveals that the standardized coefficient of the percentage of female ratio and the dummy variable are not significant, which means that there is no relationship between female executives and firm performance. The regression analysis shows that the total number and the average age in 2007 and 2008 do not influence the firm performance, but the results of them in 2009 show positive impact. We can also see from Table 54.4 that the board size show negative influence on firm performance in the year 2008. As to the firm size, the result shows the negative correlation, larger firm size means poorer firm performance.

In conclusion, based on our sample and analysis, our findings provide evidence that there is no relation between female executives and firm performance. Our conclusion is different from other researches in China. Our finding is in line with some researches in the US like Marinova et al. (2010), Rose (2007) and Mohan and Chen (2004). But we have significant differences in the source of data.

Table 54.3 Correlation analysis

Year	Correlations		FemaRati (%)	FemaRati (1/0)	TotaNumb	AverAge	BoarSize	FirmSize
2007	Tobin's Q	Pearson correlation	0.077[b]	0.032	–0.102[b]	–0.105[b]	–0.082[b]	–0.299[b]
		Sig. (2-tailed)	0.005	0.246	0.000	0.000	0.002	0.000
2008	Tobin's Q	Pearson correlation	0.120[b]	0.029	–0.150[b]	–0.097[b]	–0.139[b]	–0.391[b]
		Sig. (2-tailed)	0.000	0.280	0.000	0.000	0.000	0.000
2009	Tobin's Q	Pearson correlation	0.086[b]	0.030	–0.107[b]	–0.097[b]	–0.060[a]	–0.461[b]
		Sig. (2-tailed)	0.002	0.275	0.000	0.000	0.026	0.000

[a]Indicates statistical significance at the 0.10 level
[b]Indicates statistical significance at the 0.05 level

Table 54.4 Regression analysis

Year	2007			2008			2009		
Variables	StanCoef	t	Sig.	StanCoef	t	Sig.	StanCoef	t	Sig.
(Constant)		13.124	0.000		14.732	0.000		17.436	0.000
FemaRati (%)	0.024	0.800	0.424	0.052	1.774	0.076	0.014	0.484	0.629
FemaRati (1/0)	−0.006	−0.211	0.833	−0.018	−0.617	0.537	−0.028	−1.013	0.311
TotaNumb	0.019	0.519	0.604	0.052	1.444	0.149	0.085	2.623	0.009
AverAge	0.000	0.007	0.994	0.041	1.514	0.130	0.054	2.084	0.037
BoarSize	−0.023	−0.659	0.510	−0.086	−2.482	0.013	−0.027	−0.891	0.373
FirmSize	−0.296	−10.126	0.000	−0.393	−13.959	0.000	−0.505	−18.567	0.000

Conclusion

Nowadays in China, the percentage of female executives is rising year by year, but the proportion is still quiet low. The ratio is about 14% from 2007 to 2009, this ratio has consistency with the low percentage of female executives around the world, and it is also connected with the traditional culture in our country. At the same time, in current times of economic crisis, the role of women as board directors and top executives in driving firm performance has become a very topical issue (Ryan and Haslam 2005). Many firms now begin to reform outdated rules, regulations and operation modes, in order to be the lead of the recovery in financial markets. The percentage of female executives is an important aspect of the reformation of companies.

The articles and researches which focus on the relationship of female ratio and firm performance are limited. In addition, the limited findings have so far failed to reach an agreement. We select a sample of 1,348 listed companies' financial statements from 2007 to 2009, and use Tobin's Q as a measure of firm performance. Our findings indicate that there is no significant relationship between the ratio of female executives and firm performance. The control variables such as total number, average age and board size also show no impact on firm performance; firm size has negative impact on firm performance.

Further more, the conclusion in our paper is based on data selected from 1,348 listed companies, it shows the situation of large firms which have excellent operating performances. Further studies should think more about some small companies to make the result more accurate. Future studies may also include more variables than our study to represent board characteristics to make the result more accurate. In this paper, we examine the data from 2007 to 2009; it seems useful to extend the time by including data for a longer period, like 5 or 10 years. We can find if their results match up and the wave character though the years. What's more, instead of using a market-based performance measure (Tobin's Q), an accounting-based measure should be used (e.g. ROA). Such a research design will allow finding the relationship between female executives and firm performance more comprehensively.

References

Adler RD (2001) Women in the executive suite correlate to high profits. Working paper, Pepperdine University, Malibu

Carter DA, Simkins BJ, Simpson WG (2003) Corporate governance, board diversity and firm value. Financ Rev 38(1):33–53

Catalyst (2004) The bottom line: connecting corporate performance and gender diversity. Catalyst, New York

Lee PM, James EH (2003) SHE'-E-OS: "Gender effects and stock price reactions to the announcements of top executive appointments". Working paper, University of Virginia, Virginia

Li Wei (2010) Economic effects of female directors in listed companies of China. Card World, p 6 (Chinese)
Marinova J, Plantenga J, Remery C (2010), Gender diversity and firm performance: evidence from Dutch and Danish boardrooms. University Utrecht, Utrecht
Mohan N, Chen C (2004) Are IPOs priced differently based on gender? J Behav Financ 5:57–65
Rose C (2007) Does female board representation influence firm performance? The Danish evidence. Corp Gov 15(2):404–413
Ryan MK, Haslam SA (2005) The Glass Cliff: evidence that women are over-represented in precarious leadership positions. Br J Manage 16:81–89
Wang Ming-jie, Zhu Ru-yi (2010) Impact analysis of board female directors on firm performance in listed companies. Stat Decis 5:145–148 (Chinese)

Chapter 55
The Model Design of Coal Enterprises Internal Control Auditing Based on Risk Management

Su-li Hao and Ling-ling Song

Abstract The coal is the mainly energy resources of China, and the coal industry enjoying a leading position in national economy. Low-carbon, environmental protection and energy saving bring great challenge to coal enterprises. Therefore, building the internal control system has become the important management measure for coal enterprises. The internal control auditing is the important pathway to ensure the internal control effectively been implemented, and it is important to control the enterprises risk. The paper design indicator system of internal control, and establish the risk-oriented internal control auditing model. The research result could provide reference to coal enterprises implement internal control auditing.

Keywords Coal enterprises • Risk-oriented • Internal control auditing • Audit indicator

Introduction

The internal control auditing is developing with the development of internal control. Early in 1934, the United States Securities Exchange Act required that public companies must include a management reporting of internal control about financial reporting in its annual report; In 1992, "Internal Control – Integrated Framework" (also known as the COSO Report) commissioned by the Committee on Sponsoring Organizations of Fraudulent Financial Reporting (COSO), was then recognized by the Audit Commission in the United States (COSO 2009). On July 25 2002, the U.S. Congress passed the Sarbanes – Oxley Act, and In March 2004 Auditing Standards No. 2 file (referred to as AS2) about the company's internal

S.-l. Hao (✉) • L.-l. Song
School of Management, China University of Mining and Technology (Beijing), Beijing, P.R. China
e-mail: sluckylh@126.com; 522078591@qq.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_55,

financial auditing and financial report auditing released by the U.S. Public Company Accounting Oversight Board. In 2007, the U.S. Public Company Accounting Oversight Board (PCAOB) released Auditing Standards No. 5 (AS5) to replace the AS2, the standards gave particular emphasis to the impact of enterprise-level control on the reliability of company financial information.

The research of internal control auditing is later in China. The first administrative norm on internal control and audit risk "Specific Independent Auditing Standard No. 9" been issued by the Ministry of Finance in 1996. In 2001, the Ministry of Finance promulgated the "Internal Accounting Control Standards – Basic Standards (Trial Implementation)" and 17 specific normative contents. In February 2002, the People's Bank of China promulgated the "Internal Control of Commercial Banks Guidelines (draft)"; In May 2003, the State Council issued the "Interim Regulations on Supervision and Management of State-owned Assets of Enterprises". China Internal Control Standards Committee (CICSC) was founded on 15th July, 2006. The Basic Standard for Enterprise Internal Control was published on 28th June, 2008. This is the first unified national norms on the internal control which marked that the construction of internal control auditing has entered a new stage (Zhang and Dai 2011; Wei 2011). Our academic study of internal control began in 1996, up to now there are 320 academic articles and papers on the internal control audit research (Xie et al. 2009; Xie 2010).

Based on the characteristics of coal enterprises internal control, the paper divide the internal control auditing of mining enterprises into two parts: the oneself auditing of internal control system and the implement auditing of internal control. And then design the indicators system of internal control. Furthermore comprehensively apply the method of risk management, internal auditing, and finance auditing and comprehensive evaluation to establish the risk-oriented internal control auditing model. The research result could provide reference to the coal enterprises implement internal control auditing.

The Characteristics of Coal Enterprises Internal Control Auditing

Characteristics of the Coal Industry

The development of the coal industry is affected by the national coal resource reserves and distribution. The development of the coal productions, advances in coal technology, entry and exit of coal enterprises, the supply and demand of coal products, and the formation of the competitive situation in the coal market are closely related to the natural features of the coal resources. So characteristics of the coal industry include the following aspects: the coal industry with a high risk; the coal production with stage; slow technological progress of the coal industry, competition within the industry is homogeneous; coal production covers large areas and it can not be ex-situ.

The Characteristics of the Coal Enterprises Internal Control

Based on the above characteristics of the coal industry, coal enterprises internal control features are mainly on the control environment and control activities, specific analysis is as follows.

- The internal control environment of coal enterprises

  In the external environment of restricted energy-intensive products, stringent environmental legislation and intense competition in the coal market, the internal control environment elements of the coal company should include fulfilling their social responsibilities of corporate culture, reasonable business philosophy, safety production organization, Safety production responsibility, harmonious labor relations, internal auditing system, the anti-fraud and sustainable development strategies (Hao and Ding 2011).
- The internal control activities of coal enterprises

  Coal enterprises are the underground resource extracting enterprises; coal production process has its own characteristics compared with other industries. Coal production process, a series of interrelated production processes and a number of auxiliary production processes of the coal production constitute the coal-specific production processes, and also constitute the unique value activities of the coal enterprises. Based on the value chain of the coal enterprises the framework of the coal enterprise internal control activities are divided into six modules: production management, financial management, supply marketing and inventory management, human resources management, energy conservation management, information systems management (Hao 2011).

Risk-Oriented Coal Enterprises Internal Control Audit Process

The main content of the risk-oriented coal enterprises internal control auditing includes two parts: one of them is the rationality of internal control system and the other is the implementation of internal control. The former could apply the method of off-site auditing, from the perspective of risk management to analyze the rationality of the internal control system design. And the later could apply the method of on-site auditing (compliance testing, walk-through testing, and effectiveness testing) which can guarantee to improve the efficiency of the auditing furthermore would improve the accurately of audit results.

Risk-oriented internal control auditing start from enterprise risk management (Wang 2010). And by the risk identification, analysis, assessment of the coal enterprises, the assessment result was given (Gu 2008). And the results will be compared to the internal control risk database, and then the rate of risk identification was determined. And then the recognition rate of internal control risk management would be gotten. And then control measures been analyzed to obtained preliminary residual risk. The effective rate of coal enterprises internal control

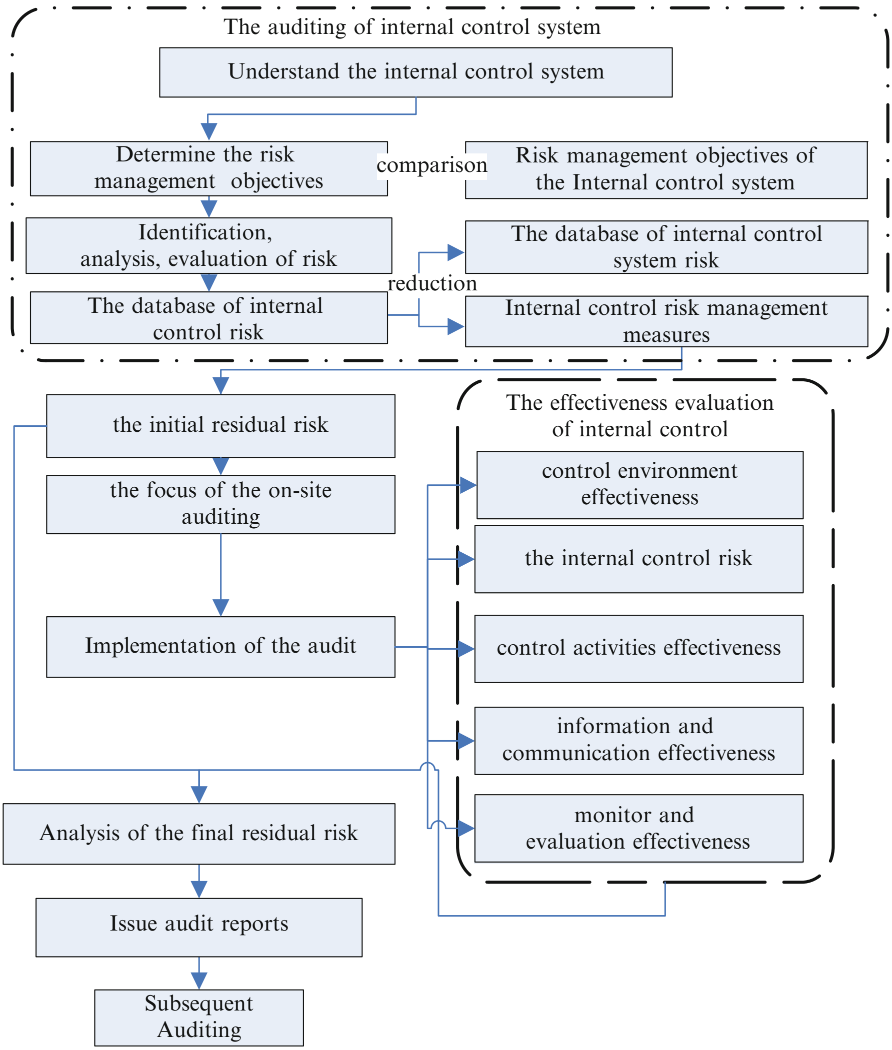


Fig. 55.1 Risk-oriented internal control auditing processes

implementation has been gotten. Based on the analysis, the preliminary residue risk would be found. According to the residue risk auditing emphasis was been ensured. And then the site auditing would be applied to found the risks of the internal control implementation. Finally the residual risks of the enterprise can be determined and audit reports can be issued. That can provide advice and reference on risk management and control for enterprises. Specific processes are shown in Fig. 55.1.

Design of the Coal Enterprises Internal Control Auditing Model

Risk-Oriented Coal Enterprises Internal Control Auditing Indicator System

Risk-oriented internal control auditing indicator system includes two aspects: the auditing of the internal control system and the auditing of implementation. The auditing of the internal control system can be evaluated by the rate of internal control risk identification, the rate of internal control risk response and the effective rate of internal control management (Hao and Ding 2012). The auditing of implementation of the internal control system can be evaluated by the control failure of the five elements of internal control: control environment, risk management, control activities, information and communication, monitor and evaluation. Specific indicators of the system shown in Table 55.1.

The Date Acquisition of Risk-Oriented Internal Control Auditing Indicators

It can be seen from the risk-oriented internal control auditing process and auditing indicator that the risk assessment and comparative analysis method is the main method to get the ratio of each indicator in the auditing of the internal control system. In the implementation auditing of the internal control system, it is necessary to have a systematical on-site auditing based on the identified auditing focus. The main possible methods include compliance testing, walk-through testing and validity testing. Then the implementation indicators of the internal control can be determined according to the results of the testing, and then the internal control auditing Conclusion can be made.

1. Compliance testing

   Compliance testing is suitable for the qualitative description of some of the overall level. The auditing indicator can be acquired by using individual interviews method, questionnaire method, discussion method, sampling method, check method and analysis method. For example, the control environment, its specific form shown in Table 55.2.
2. Walk-through testing

   This is the first step in the auditing of the implementation of internal control. Its main purpose is through a certain means to comprehend record and describe the internal control system and its implementation. Auditors should implement the following procedures to comprehend the special control design: first, gaining a certain understanding of the company's internal control by asking the right managers, supervisors and staff; second, checking the company's relevant

Table 55.1 The risk-oriented coal enterprises internal control audit indicator system

Target layer	Indicator layer	Feature layer	Indicator calculation
The results of the audit of the risk-oriented internal control auditing	Auditing of Internal control system (0.25)	The rate of Internal control risk identification (Rn) (0.35)	$R_n = 1 - \frac{\text{The risk points of the internal control system}}{\text{The total number of risk points found in auditng}}$
		The rate of Internal control risk response (Tn) (0.28)	$T_n = \frac{\text{The number of risk points with response measures}}{\text{The total number of risk points in the internal control system}}$
		The effective rate of internal control management (En) (0.37)	$E_n = \frac{\text{The control measures of audited effective}}{\text{The total control measures in the internal control system}}$
	Auditing of implementation of the internal control system (0.75)	Implement efficiency of internal control environment (Ee) (0.15)	$E_e = 1 - \frac{\text{The risk points of the ineffective control environment}}{\text{The total number of control environment risk points}}$
		Implement efficiency of risk management (Re) (0.15)	$R_e = \frac{\text{Initial residual risk}}{\text{Preliminary residual risk}} - 1$
		Implement efficiency of control activities (Ae) (0.43)	$A_e = 1 - \frac{\text{The risk points of ineffective control activities}}{\text{The total number of control activities risk points}}$
		Implement efficiency of information and communication (Ie) (0.10)	$I_e = 1 - \frac{\text{The risk points of ineffective information and communication}}{\text{The total risk points of information and communication}}$
		Implement efficiency of monitor and evaluation (Me) (0.17)	$M_e = 1 - \frac{\text{The risk points of ineffective monitor and evaluation}}{\text{The total risk points of monitor and evaluation}}$

Table 55.2 The internal control environment compliance testing

Elements of the control environment	Specific audit content
Professional ethics	Whether it has been established the Code of Ethics covered all levels of employees of the company.
Competence of employees	Whether it has been set up and improved the description of the employees' job responsibilities, established and improved the full vocational education and training and skills assessment mechanism.
...	...

Table 55.3 The internal control walk-through testing table

Number	Regulatory requirements	The practical control measures	Testing steps	Exception	Effectiveness Yes/No/NA	Control after rectification
1	(1)	(1)	(1)			
	(2)	(2)	(2)	No	Yes	N/A
	...	...	...			

Instructions for filling out: the regulatory requirements: completed according to "The Basic Standard for Enterprise Internal Control" released by the Ministry of Finance. The description of the practical control measures: filled with the control flow according to requirements of "The Basic Standard for Enterprise Internal Control". Walk-through testing steps: describe the contents of the walking-through testing on the control points.

documents; third, observing the application of company's specific control; fourth, tracking the transactions related to financial reporting through the financial information system.

3. Validity testing

   Validity testing is used to test the effectiveness of critical control points in the internal control system. Testing the establishment of appropriate control measures and the effectiveness of controls can provide data support for the internal control system auditing indicators (Table 55.3).

The Evaluation of Risk-Oriented Coal Enterprises Internal Control Auditing

The paper applies the Analytic Hierarchy Process (AHP) to determine the weight of the internal control auditing indicators. And determine the final score of the internal control auditing can be determined by the comprehensive evaluating method (Table 55.4).

1. Applying AHP to Ensure the Weight of Internal Control Auditing Indicators

Table 55.4 The internal control validity testing table

Serial number	Control point	The description of the practical control measures
	Control environment	
1		
2		
…	…	

AHP is a decision method for many objects, and it combined the intelligence of experts and the rational analysis. The dicey factors are been depressed by firsthand compare. Therefore AHP been applied to ensure the indicator weight. However the measure matrix is the starting point of AHP, so it is the first step to establish measure matrix. Delphi can collect the intelligence of experts, and have a satisfying result by feedback and modification. The paper combines AHP and Delphi to ensure the weight of indicator system of internal control auditing. The particular processes are follows:

① Applying Delphi to establish the measure matrix
Based on the basic steps of Delphi, view of the experts been integrated, and then the measure index been confirmed. And based on the date, the measure matrix table is obtained. For instance:

	Auditing of internal control system	Auditing of implementation
Auditing of internal control system	1	1/3
Auditing of implementation		1

② Applying sophisticated AHP to ensure the weight
Based on the Delphi, the measure matrix is follow:

$$A = \begin{bmatrix} 1 & 1/3 \\ 3 & 1 \end{bmatrix}$$

Based on the matrix A, the matrix B is obtained. $B = \lg A$:

$$B = \begin{bmatrix} 0 & -0.477 \\ 0.477 & 0 \end{bmatrix}$$

Based on the matrix B, the matrix C is obtained.

$$c_{ij} = \frac{1}{n} \sum_{k=1}^{n} \left(b_{ik} - b_{jk}\right)$$

$$C = \begin{bmatrix} 0 & -0.477 \\ 0.477 & 0 \end{bmatrix}$$

And the A* = 10^C, so the A^* is:

$$A^* = \begin{bmatrix} 1 & 0.333 \\ 3 & 1 \end{bmatrix}$$

The characteristic vector of A^* is:

$$\bar{W}_1 = 0.577, \bar{W}_2 = 1.732$$

The characteristic vector is normalized.

$$W = [w_1, w_2]^T = [0.25, \quad 0.75]$$

And then the weight can be showed in Table 55.1.

2. Applying Fuzzy Comprehensive Evaluation to Ensure the Composite Score of the Internal Control Auditing
   Fuzzy comprehensive evaluation is a synthetical evaluation method that apply the principle of fuzzy relation to quantitative the factors of borderline mistiness based on the mathematics. The fuzzy comprehensive evaluation includes follow steps:

① Ensure the factors aggregate;

$$U = \{U_1, U_2, \ldots, U_N\}$$

② Ensure the comparisons aggregate;

$$V = \{V_1, V_2, \ldots, V_m\}$$

③ Calculate the weight of the indicator system;

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

④ Evaluate the score of commercial banks customers.

$$\sum_{j=1}^{m} r_{ij} = 1, (i = 1, 2, 3, \ldots, n)$$

Conclusion

Coal enterprises want to have a healthy development, they must establish a scientific, reasonable and effective internal control mechanisms to ensure that the accounting information is true, accurate and reliable, to ensure the effectiveness and legality of the corporate finance balance of payments, to ensure that enterprises in the property material aspects of security, integrity. The paper make a research of the implementation of risk-oriented coal enterprises internal control auditing on the aspects of auditing process, auditing methodology, auditing indicators and auditing evaluation. Starting from the internal control risk management system to evaluate the effectiveness of internal control design and to find the weak point and the key point and to audit on the key point not only can save audit resources, but also can ensure the auditing effectiveness, it can provide reference for coal enterprises.

Acknowledgments The work is supported by central universities fundamental scientific research professional expenses. "The researched on coal mining enterprises internal control system". And the authors sincerely appreciate the invested SHEHUA NINGXIA COAL INDUSTRY GROUP and all experts for their date and advice.

References

COSO (2009) Guidance on Monitoring Internal Control Systems by the ministry of finance. CSRC, Audit commission and CIRC

Gu DL (2008) Modern risk-based internal audit in the hospital risk management and internal control. Nanjing University of Science and Technology

Hao SL (2011) Design of coal enterprises internal control activities system. In: The central universities fundamental scientific research professional symposium, Beijing, pp 930–934

Hao SL, Ding RJ (2011) Design of the coal enterprises internal control environment system based on social responsibility. China Mining II:36–42

Hao SL, Ding ZX (2012) Design of internal control risk management system of coal mining enterprises based on system engineering. Adv Res Eng Mater Energy Manag Control, pp 424–425

Wang L (2010) Researched on use of internal control and control testing under modern risk-based auditing. Commun Financ Account, pp 28–30

Wei XY (2011) Combination of analysis of risk-based internal audit and internal control assessment. West Financ Account, pp 67–68

Xie XY (2010) Researched on audit of internal control. Inner Mongolia University of Agricultural, pp 75–76

Xie XY, Zhang LP, Zhou Y (2009) Researched on internal control audit: review of the literature. Commun Financ Account, pp 22–25

Zhang XZ, Dai WT (2011) Study on internal control evaluation system for Chinese enterprises. Audit Res, pp 69–78

Chapter 56
Segmentation of the Bank Client Value Based on Fuzzy Data Mining

Hong-bo Wu and Ming-hui Guan

Abstract First, this paper will analyze the connotation of individual bank clients' value in-depth. Based on this foundation, the main factors that reflect the client value will be selected. Then it will use the expert method to build a client value evaluation system. Finally, using the fuzzy data mining algorithms, this paper will obtain the basic model of bank client value segmentation, which will provide the basis for effective prediction of high-value clients.

Keywords Fuzzy data mining • Customer value • Evaluation system

Introduction

With the fierce competition in the financial industry, how to effectively analyze the client data has become the key of the bank-client relationship management (Adrian and Sue 2001; Wolf 2001). Analysis showed that the cost of attracting new clients is five times of retaining old clients. Therefore, tapping high-value clients from existing clients will become the central force driving the development of banks in the future. Since the relevant data of bank clients possess a high degree of complexity and ambiguity, it is difficult to use the conventional method to accurately predict the high value. Aiming at this issue, this article advises to breakdown the bank clients into segments from the client value point of view (Frederick 1996), and then predict the high-value clients. The study found that, at current stage, there are two ways to study the client values: One is the client segmentation based on the life cycle value model (Hwang et al. 2008). However, this method requires the estimation and calculation of all the costs and income related to the clients within the bank

H.-b. Wu • M.-h. Guan (✉)
Department of Information Management and Information System,
Harbin University of Science and Technology, Harbin, China
e-mail: guanminghui1988@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_56,

throughout the life cycle, which definitely increased the difficulty of evaluation (Boyce 2000). The other way is to create a client value assessment system (Qi Jiayin et al. 2002). Although this method can either analyze the clients' current situation or emphasize the importance of clients' potential of development on the banks (Quan Mingfu et al. 2004), the analysis of combining the AHP method (Wang Fengliu et al. 2009), the model method (Qian Weining and Zhou Aoying 2002), and the K-Means evaluation methods (Deng Guangli et al. 2005) showed that some only stayed in analyzing certain aspects of the client value, and some segmented the client but only getting a rather vague result. None of them could predict the high-value clients generally and comprehensively. As a result, this paper first analyzed the main factors of client value, and then designed the evaluation indexes for the bank client value. Finally, it used the fuzzy data mining algorithm to obtain the basic pattern of the value segmentation (Li Liang and Chen Gang 2003; Gao Hongshen 2005), and predicted and evaluated the clients based on the integration of practical examples.

The Analysis of the Factors That Impact the Bank Client Value

Client value refers to the benefits from the bilateral relationship and cooperation (Qi 2002). The factor which reflects the client value most is the cash earnings to the bank, such as the amount of deposits, the amount of interest received, the investment amount of wealth management business, a variety of transaction charges, and so on. The cash earnings include the contributed ones and the ones that could bring benefits for the banks in the future. They are based on the variety of banking business, including the business factors that have occurred and the business factors that may occur in the future. The possible future businesses also include the potential capacity of clients and the possibility that particular client introduces the banking business to other clients.

Further study shows that the income value is reflected from the building of client relationship to the present value brought by the clients for the bank currently. The specific businesses include the interest business, cash business, and intermediate business. For the individual bank client, the value of interest business is that individual client takes up the bank funds by applying for bank loans or overdrawing the credit cards, thus needs to pay a certain amount of interest to the banks so that banks earned incomes. The value of cash business is that individual client provides sources of funding for the bank through deposits. The bank gets the income through fund management. The specific businesses include the savings deposits, certificate of deposits (CD), and investment banking business. Intermediate business refers to the business that does not constitute the bank statement assets or bank statement liabilities, namely bringing the earnings value for the bank through the intermediate business, such as the transaction costs of a variety of activities and so on.

The potential value of clients is the intangible and prospective value of clients (Zheng Xiangyu and Dong Zhiwei 2006). It is mainly determined by the client's own properties and characteristics, and is summarized into two aspects, including the potential development and the potential value. The potential development: is the synthesis of all the basic elements of individual clients, such as age, education level, income, personal credit rating and so on. Since the quality index is a description of the actual situation, it does not possess the property to be directly quantified in calculation. Thus, it is necessary to segment the properties and classify the corresponding value assigned to each index. The potential value refers to the value that the clients may bring to the banks in the future, such as the possibility of additional consumption of the client, the number of products that the clients need but haven't purchased yet, and the possibility to recommend their own businesses to other clients.

The Establishment of the Bank Client Value Evaluation Index

The Basic Ideology of the Index Design

The design of the customer value evaluation index system complies with the actual situation of the financial industry, combines the properties and characteristics of clients to achieve practical and applicable requirements, and provides the basis for banks to manage client needs better (Hu Shaodong 2005). Whereas there are many factors that affect the value of bank clients, there are also many evaluation indicators to choose from. Therefore, when designing the evaluation index system, we must start from a macro view to grasp the characteristics of banks in general based on the advanced international or national management concept, use the existing evaluation theory as a guide, and comprehensively reflect the customer's own situation. In addition, to make the evaluation index system more scientific, we should choose the quantitative indexes as many as possible to help the evaluation. The choice of indexes should also be able to connect with the banking business and converge with the actual data.

References the Design Method of Bank Client Value Evaluation Index

Through the above analysis, we can find out that there are still some problems with judging the value of bank clients such as the different types of uncertainty, the large amount of data, vague definition, the difficulty comprehensively and scientifically determine the evaluation index system by the general method. Therefore, this article uses expert scoring method as the basic method to establish the evaluation index. The expert scoring method has the following characteristics. It has specific objects to base the evaluation on. It can determine the appropriate evaluation indicators and develop the evaluation classifications and standards. The strong intuitiveness reflects each class standard by scoring. The simple calculation method enlarges the range of choices. Through synthesizing the experience and judgment of several experts, we will consider the evaluation factors that both can carry out a quantitative calculation or cannot be calculated, and make a reasonable estimation for the qualitative factors.

The Steps of Index Design

- Choose the experts. This article selected 18 experts in bank management, customer value evaluation, and other fields, among which are 6 university professors, 6 senior bank managers, and 6 clients.
- Anonymous survey. Selected a large number of factors that would impact the bank client value evaluation, use the method of five-scale rating tables to quantify the importance of these factors, and design the questionnaire with clear content to issue to all the experts. All the factors could be graded as the following five levels: very worthy of using, somehow worthy of using, average, less worthy of using, and not worthy of using. The numbers 5, 4, 3, 2, 1 are used as the score for the rating scale table.
- Statistical induction. Took back the anonymous questionnaire, collected the statistics on each question, and selected the median as the collective opinion of the experts.
- Communication and feedback. Give the statistical feedback to the experts and let the experts provide advises according to the statistical result. After three times of survey and feedback, this article finally obtained the relatively concentrated opinions. The result of the final decision is shown in Table 56.1.
- Through the questionnaire, obtain the personal information, such as age, personal income, education level, and number of customer recommendation. Finally it used the score of each scale by the experts and the credit rating to define (as shown in Table 56.2).

Quantify the Index

- The interest business value index:
  Personal loan amount = same day loan amount + previous day's cumulative loan amount;

Table 56.1 Evaluation indexes

Dimensions	Level one index	Level two index
Profit value P	Interest business value P_1	Personal loans interest amount P_{11}
		Bank card overdrafts interest amount P_{12}
	Cash business value P_2	Savings amount P_{21}
		CD amount P_{22}
		Total amount of investment and wealth management business P_{23}
	Intermediate business value P_3	Total amount of other non-interest business P_{31}
Potential value Q	Development value Q_1	General client status (age, education, annual income) Q_{11}
		Personal credit level Q_{12}
	Behavior value Q_2	Client recommendation amount Q_{21}
		Number of needed but unused bank businesses Q_{22}

Table 56.2 Level classification

Client factors	Natural properties	Class level	Client factors	Natural properties	Class level
Age	Below 25	40	Education level	Middle school or lower	40
	26–35	70		High school (technical high school)	50
	36–50	100			
	51–65	70		Technical college	60
	Above 65	60		Undergraduate	70
Personal annual income	Below 5,000	10	Credit level	Graduate or higher	80
	5,000–10,000	20		AAA	100
	10,000–20,000	30		AA	90
	20,000–30,000	40		A	80
	30,000–50,000	50		BBB	70
	50,000–100,000	70		BB	50
	100,000–200,000	90		B	30
	Above 200,000	100		C	0

Bank card consumption overdraft interest amount = same day overdraft amount + previous day's cumulative overdraft amount.

- The cash business index:
  Savings deposits = same day deposit amount + previous day cumulative deposit amount;
  CD amount = same day deposit amount + previous day cumulative deposit amount;
- The intermediate Business Index:
  Total amount of investment business = same day investment amount + previous day's cumulative investment amount;

Total amount of other non-interest business = same day business amount + previous day's cumulative business amount.

- The development value:
Development potential score = (Age score + education score + personal annual income score)/3. (Rounded to the nearest integer)

The Discovery of the Client Value Model

Data Processing

Obtain the client profile of 15 clients from the customer information department of one back. Then get the value of each indicator through transformation, as shown in Table 56.3.

In order to make all the index data between (0–1), the following data processing is needed:

The sample set has 15 samples in total. One indicator K of the sample can get 15 numbers "$u'_{1k}, u'_{2k}, u'_{3k}, \ldots, u'_{15k}$", the "$u'_{ik}$" in the equation refers to the number obtained from the sample in sequence "i". The average value of the numbers is calculated according to the Eq. (56.1):

$$u'_{\overline{k}} = (u'_{1k} + u'_{2k} + L + u'_{15k})\frac{1}{15} = \frac{1}{15}\sum_{i=1}^{15} u'_{ik}$$

$$i = 1, 2, 3 \ldots 15 \quad k = 1, 2 \ldots 10 \tag{56.1}$$

Then calculate the standard deviation "S_k" of the raw data according to the Eq. (56.2):

$$S_k = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(u'k - u'\overline{k}\right)^2} \tag{56.2}$$

Then calculate the standard value "u''_{ik}" of each data according to the Eq. (56.3):

$$u''_{ik} = \left|\frac{u'_{ik} - u'_{\overline{k}}}{s_k}\right| \tag{56.3}$$

Table 56.3 Client data

Client number	Overdraft amount	Personal loan amount	Other non-interest business amount	General client status	Personal credit level	Client recommendation amount	Savings amount	C D amount	Investment and wealth management amount	Number of businesses needed but not purchased
1	74.00	111,697.00	802.00	76.00	20.00	0.00	0.00	10,000.00	10,000.00	3
2	827.00	20,106.00	512.00	38.00	50.00	2.00	18,990.00	0.00	50,000.00	2
3	490.00	11,099.00	42.00	45.00	0.00	3.00	0.00	10,000.00	0.00	5
4	0.00	18,900.00	84.00	48.00	0.00	8.00	21,887.00	50,000.00	50,000.00	0
5	23.00	11,077.00	388.00	56.00	50.00	10.00	65,000.00	0.00	20,000.00	1
6	0.00	26,099.00	197.00	41.00	20.00	0.00	50,000.00	10,000.00	0.00	1
7	900.00	20,129.00	312.00	66.00	50.00	5.00	38,792.00	8,500.00	30,000.00	3
8	1,718.00	23,844.00	201.00	44.00	70.00	8.00	20,000.00	0.00	50,000.00	4
9	0.00	28,339.00	90.00	88.00	80.00	11.00	5,049.00	10,000.00	100,000.00	2
10	0.00	17,439.00	461.00	60.00	0.00	12.00	110,899.00	2,106.00	0.00	0
11	1,510.00	13,288.00	851.00	40.00	0.00	0.00	99,887.00	55,040.00	50,000.00	7
12	2,921.00	17,283.00	904.00	60.00	20.00	4.00	0.00	23,677.00	60,000.00	5
13	1,986.00	14,848.00	192.00	50.00	20.00	6.00	43,000.00	85,000.00	0.00	9
14	3,001.00	16,211.00	18.00	83.00	50.00	9.00	150,000.00	200,000.00	30,000.00	2
15	536.00	21,099.00	26.00	59.00	80.00	11.00	60,000.00	30,000.00	50,000.00	1

$$u'{}'_{ik} = \begin{bmatrix} 0.84 & 1.24 & 1.56 & 1.26 & 0.50 & 1.43 & 1.04 & 0.55 & 0.83 & 0.00 \\ 0.10 & 0.39 & 0.58 & 1.25 & 0.57 & 0.95 & 0.61 & 0.74 & 0.60 & 0.40 \\ 0.43 & 1.36 & 1.00 & 0.79 & 1.20 & 0.71 & 1.04 & 0.55 & 1.19 & 0.80 \\ 0.91 & 0.16 & 0.86 & 0.59 & 1.20 & 0.50 & 0.54 & 0.21 & 0.60 & 1.20 \\ 0.89 & 1.36 & 0.17 & 0.06 & 0.57 & 0.98 & 0.45 & 0.74 & 0.48 & 0.80 \\ 0.91 & 1.55 & 0.48 & 1.05 & 0.50 & 1.43 & 0.10 & 0.55 & 1.19 & 0.80 \\ 0.03 & 0.39 & 0.09 & 0.60 & 0.57 & 0.23 & 0.16 & 0.58 & 0.12 & 0.00 \\ 0.77 & 1.12 & 0.46 & 0.85 & 1.27 & 0.50 & 0.59 & 0.74 & 0.60 & 0.40 \\ 0.91 & 1.99 & 0.84 & 2.05 & 1.63 & 1.22 & 0.93 & 1.16 & 2.38 & 0.40 \\ 0.91 & 0.13 & 0.41 & 0.20 & 1.20 & 1.47 & 1.50 & 0.70 & 1.19 & 1.20 \\ 0.56 & 0.93 & 1.73 & 1.12 & 1.20 & 1.43 & 1.24 & 0.30 & 0.60 & 1.60 \\ 1.94 & 0.16 & 1.91 & 0.20 & 0.50 & 0.47 & 1.04 & 0.29 & 0.95 & 0.80 \\ 1.03 & 0.63 & 0.49 & 0.46 & 0.50 & 0.02 & 0.06 & 0.87 & 1.19 & 2.40 \\ 2.02 & 0.37 & 1.08 & 1.72 & 0.57 & 0.74 & 2.39 & 3.05 & 0.12 & 0.40 \\ 0.39 & 0.58 & 1.05 & 0.14 & 1.63 & 1.22 & 0.33 & 0.17 & 0.60 & 0.80 \end{bmatrix}$$

Then normalize according to the Eq. (56.4): the matrix obtained "u_{ik}, u''_{maxk}" and"u''_{mink}" respectively represent the minimum and maximum in "($u''_{1k}, u''_{2k}, u''_{3k}, \ldots, u''_{nk}$)".

$$u_{ik} = \frac{u''_{ik} - u''_{mink}}{u''_{maxk} - u''_{mink}} \tag{56.4}$$

$$u_{ik} = \begin{bmatrix} 0.41 & 0.60 & 0.81 & 0.06 & 0.00 & 0.98 & 0.42 & 0.13 & 0.32 & 0.00 \\ 0.04 & 0.14 & 0.27 & 0.60 & 0.06 & 0.64 & 0.24 & 0.20 & 0.21 & 0.17 \\ 0.20 & 0.66 & 0.50 & 0.37 & 0.63 & 0.48 & 0.24 & 0.13 & 0.47 & 0.33 \\ 0.44 & 0.02 & 0.42 & 0.27 & 0.63 & 0.33 & 0.21 & 0.01 & 0.21 & 0.50 \\ 0.43 & 0.66 & 0.04 & 0.00 & 0.06 & 0.67 & 0.17 & 0.20 & 0.16 & 0.33 \\ 0.44 & 0.77 & 0.21 & 0.50 & 0.00 & 0.98 & 0.02 & 0.13 & 0.47 & 0.33 \\ 0.00 & 0.14 & 0.00 & 0.27 & 0.06 & 0.14 & 0.04 & 0.14 & 0.00 & 0.00 \\ 0.37 & 0.53 & 0.21 & 0.40 & 0.69 & 0.33 & 0.23 & 0.20 & 0.21 & 0.17 \\ 0.44 & 1.00 & 0.41 & 1.00 & 1.00 & 0.83 & 0.37 & 0.34 & 1.00 & 0.17 \\ 0.44 & 0.00 & 0.18 & 0.07 & 0.63 & 1.00 & 0.62 & 0.18 & 0.47 & 0.50 \\ 0.27 & 0.43 & 0.90 & 0.53 & 0.63 & 0.98 & 0.51 & 0.05 & 0.21 & 0.67 \\ 0.96 & 0.02 & 1.00 & 0.07 & 0.00 & 0.31 & 0.42 & 0.04 & 0.37 & 0.33 \\ 0.50 & 0.27 & 0.22 & 0.20 & 0.00 & 0.00 & 0.00 & 0.24 & 0.47 & 1.00 \\ 1.00 & 0.13 & 0.55 & 0.83 & 0.06 & 0.50 & 1.00 & 1.00 & 0.00 & 0.17 \\ 0.18 & 0.24 & 1.53 & 0.04 & 1.00 & 0.83 & 0.12 & 0.00 & 0.21 & 0.33 \end{bmatrix}$$

Establish the modulus similarity relation R. There are many methods to calculate "r_{ij}". Here we adopt the maximum and minimum method, namely the Eq. (56.5), to obtain the following matrix.

$$r_{ij} = \sum_{k=1}^{m} min\left(u_{ik}, u_{jk}\right) \bigg/ \sum_{k=1}^{m} max\left(u_{ik}, u_{jk}\right) \quad (i, j \ldots n) \tag{56.5}$$

$$\begin{array}{cc}
\begin{array}{c}1\\2\\3\\4\\5\\6\\7\\8\\9\\10\\11\\12\\13\\14\\15\end{array} &
\left[\begin{array}{ccccccccccccccc}
1.00 &&&&&&&&&&&&&& \\
0.50 & 1.00 &&&&&&&&&&&&& \\
0.55 & 0.45 & 1.00 &&&&&&&&&&&& \\
0.35 & 0.39 & 0.57 & 1.00 &&&&&&&&&&& \\
0.45 & 0.44 & 0.48 & 0.37 & 1.00 &&&&&&&&&& \\
0.64 & 0.47 & 0.56 & 0.37 & 0.59 & 1.00 &&&&&&&&& \\
0.17 & 0.31 & 0.19 & 0.16 & 0.18 & 0.18 & 1.00 &&&&&&&& \\
0.46 & 0.51 & 0.66 & 0.61 & 0.50 & 0.49 & 0.24 & 1.00 &&&&&&& \\
0.51 & 0.39 & 0.57 & 0.39 & 0.38 & 0.51 & 0.12 & 0.51 & 1.00 &&&&&& \\
0.43 & 0.37 & 0.54 & 0.57 & 0.43 & 0.49 & 0.10 & 0.47 & 0.46 & 1.00 &&&&& \\
0.65 & 0.44 & 0.63 & 0.54 & 0.38 & 0.50 & 0.13 & 0.52 & 0.50 & 0.58 & 1.00 &&&& \\
0.44 & 0.29 & 0.42 & 0.45 & 0.32 & 0.33 & 0.08 & 0.31 & 0.28 & 0.40 & 0.42 & 1.00 &&& \\
0.27 & 0.27 & 0.35 & 0.37 & 0.34 & 0.44 & 0.15 & 0.35 & 0.27 & 0.36 & 0.30 & 0.32 & 1.00 && \\
0.40 & 0.39 & 0.35 & 0.30 & 0.27 & 0.30 & 0.15 & 0.32 & 0.38 & 0.31 & 0.36 & 0.41 & 0.22 & 1.00 & \\
0.38 & 0.39 & 0.55 & 0.54 & 0.41 & 0.39 & 0.11 & 0.47 & 0.47 & 0.50 & 0.56 & 0.33 & 0.24 & 0.25 & 1.00
\end{array}\right] \\
& \begin{array}{ccccccccccccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 \end{array}
\end{array}$$

Client Value Segmentation

Get the maximum spanning tree (MST) shown in the exhibit using the MST method in the cluster analysis (Fig. 56.1):

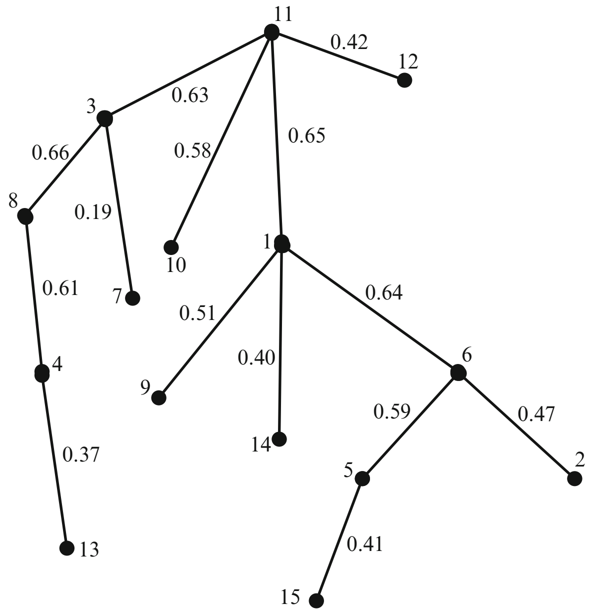
When $\lambda = 0.66$, segment into 14 classes: {3, 8}, all others are the same class;
When $\lambda = 0.51$, segment into 7 classes: {4,8,3,11,10,1,9,6,5}, all others are the same class;
When $\lambda = 0.40$, segment into 3 classes: {4,8,3,11,10,12,1,9,14,6,2,5,15}, all others are the same class;
When $\lambda = 0.19$, all of the data are the same class.

Finally, select to segment the clients into three classes, including the high-value clients, general-value clients, and low-value clients. Taking the cash value into consideration as the most important basis of the client value factors, this article classified the clients that represent the largest cash value index as the high-value clients.

Client Value Evaluation

According to the above calculated discovery model, we can start the evaluation and prediction of the client value. For example, take a random client's information as Table 56.4.

Fig. 56.1 The maximum spanning tree



Client Classification

Take the classification model under $\lambda = 0.40$, and calculate the average index according to the Eq. (56.6), as shown in Table 56.5:

$$Mode_{ij} = \sum u_{kj}/p \qquad i = 1, 2, \ldots, s, j = 1, 2, \ldots, m \tag{56.6}$$

Prediction

Set the client to be predicted as "X" then

$$X = (2015.00, 25630.00, 200.00, 48.00,$$
$$20.00, 5.00, 56000.00, 75633.00, 5000.00, 7.00)$$

Table 56.4 Predicted client

Classification objects	Overdraft amount	Personal loan amount	Other non-interest business amount	General client status	Personal credit level	Client recommendation amount	Savings amount	C D amount	Investment and wealth management amount	Number of businesses needed but not purchased
Predicted client	2,015.00	25,630.00	200.00	48.00	20.00	5.00	56,000.00	75,633.00	5,000.00	7.00

Table 56.5 Classification objects

Classification objects	Overdraft amount	Personal loan amount	Other non-interest business amount	General client status	Personal credit level	Client recommendation amount	Savings amount	C D amount	Investment and wealth management amount	Number of businesses needed but not purchased
Class A client	1,986.00	14,848.00	192.00	50.00	20.00	6.00	43,000.00	85,000.00	0.00	9.00
Class B client	853.85	18,190.85	352.00	56.77	33.85	6.00	46,285.54	37,755.62	36,153.85	2.54
Class C client	900.00	20,129.00	312.00	66.00	50.00	5.00	28,792.00	8,500.00	30,000.00	3.00

Standardize “X′” as

$$X' = (0.02063, 0.26237, 0.00205, 0.00049, 0.00051,$$
$$0.00006, 0.57327, 0.77425, 0.05118, 0.00007)$$

Then standardize the abovementioned model, and calculate the approaching degree between them: (In the formula (56.7), symbol “$\bullet$” and “ $\odot$ ” respectively represent the inner product and the outer product of fuzzy arithmetic).

$$(X, Mode_i) = (1/2)[X \bullet Mode_i + (1 - X \odot Mode_i)] \tag{56.7}$$

For Class A: inner product = 0.77, outer product = 0.00006, approaching degree = 0.887
For Class B: inner product = 0.57, outer product = 0.00007, approaching degree = 0.785
For Class C: inner product = 0.57, outer product = 0.00007, approaching degree = 0.785

According to the approximation principle, the approaching degree between the client we predict and Class A clients is the largest. Therefore, “X” is a high-value client.

Conclusion

Through building the bank client value evaluation index system and using the fuzzy data mining method to segment the clients, this article proposed to classify the segmentation result as high-value clients, general-value clients and low-value clients. In this way we can evaluate and predict any clients, establish the corresponding business packages and management for the high-value clients, and reduce the cost of customer relationship management for the banks.

References

Adrian P, Sue H (2001) Diagnosing customer value: integrating the value process and relationship marketing. Br J Manag 12(2):159–182

Boyce G (2000) Valuing customers and loyalty: the rhetoric of customer focus versus the reality of alienation and exclusion of (de valued) customers. Crit Perspect Acc 11(6):649–689

Deng Guangli, Liu Qiang, and Chen Xindu (2005) A exploring about implementing the framework of improving customer value based on data mining (in Chinese). Modular Mach Tool Autom Manuf Tech (3):91–93

Frederick R (1996) The loyalty effect: the hidden force be-hind growth, profits, and lasting value. Harvard Business School Press, Boston

Gao Hongshen (2005) Decision support system. Tsinghua University Press, Beijing, pp 104–108, ch.5

Hu Shaodong (2005) Analysis of customer segmentation (in Chinese). Ind Technol Econ 24(7):66–69

Hwang H, Jung T, Suh E (2008) A ltv model and customer segmentation based on customer value: a case study on the wireless telecommunication industry. Expert Syst Appl (26):26

Li Liang, Chen Gang (2003) The application and research of data mining technology-fuzzy clustering analysis in crm. Indus Control Comput 16(8):8–9 (In Chinese)

Qi Jiayin (2002) Research on enterprise customer value. PhD dissertation, University of Xi'an, China

Qi Jiayin, Han Xinmin, Li Huaizu (2002) A new index system to assess customer. J Indus Eng Eng Manag 16(4):4–8 (In Chinese)

Qian Weining, Zhou Aoying (2002) Analyzing popular clustering algorithms from different viewpoints. J Softw 13(8):1382–1394

Quan Mingfu, Qi Jiayin, Shu Huaying (2004) An evaluation index system to assess customer value. Nankai Bus Rev 7(3):17–23 (In Chinese)

Wang Fengliu, Liu Jingao, Chen Yahua (2009) Customers' value assessment model in ahp-based telecommunication (in Chinese). Comput Syst Appl (1):26–28

Wolf UG (2001) Customer value in business markets. Ind Market Manag 30(30):315–319

Zheng Xiangyu, Dong Zhiwei (2006) The segmentation model and new methods of customer relations in the enterprise market (in Chinese). Inquiry Econ Issues (11):16–17

Chapter 57
Brief Analysis on Ancillary Product Design Ideas of Visually Handicapped

Zong-gang Bai and Yu Ma

Abstract Visually handicapped belong to special groups, they are eager to blend into social life, on the basis of analyzing demands and handicap of visually handicapped, came up with ancillary product design ideas of visually handicapped in order to help them blend into life.

Keywords Visually handicap • Life quality • Restrictiveness • Sense compensation • Systematization

Introduction

Vision is the most important sense channel that connected human and external world. Eight percent of external information is from vision, therefore visually handicapped are the weakest groups for going out. To design safe, comfortable, smooth, convenient ancillary product is not only the basic protection that helps the special groups blend into society but also reveals humanistic brightness of "people first".

Z.-g. Bai (✉)
Institute of Art & Fashion, Tianjin Polytechnic University, Tianjin, China
e-mail: sdhmbaizg@126.com

Y. Ma
School of Mechanical Engineering, Tianjin Polytechnic University, Tianjin, China
e-mail: mayu_101@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_57,

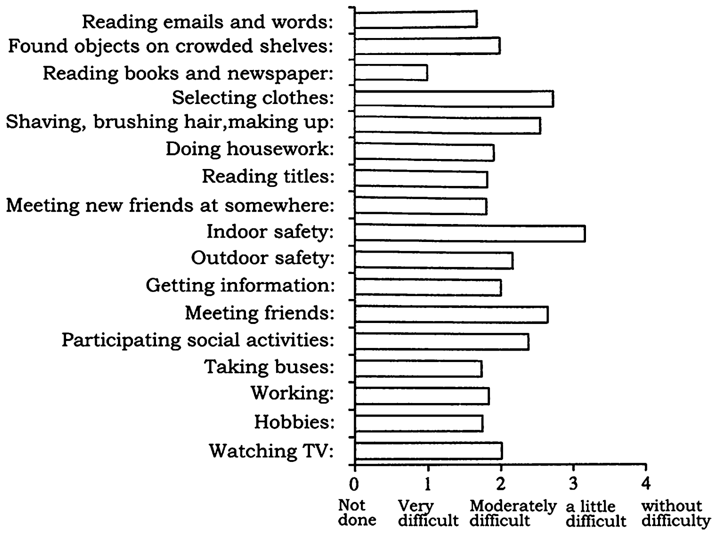


Fig. 57.1 Questionnaire of visually handicapped life quality

Visually Handicapped and Their Demand Analysis

Definition of Visually Handicap

Visual refers to vision, view, color vision, light sense, refraction, adjustment, eye movement and eyes focusing. Normally visually handicap refers to poor eyesight and tunnel vision handicap, also composite situation like view damaged, tunnel vision and color anomaly.

Visually handicap groups mainly divided into three types, congenital visually handicap, pathological visually handicap and low vision with age increasing of old people. All three types have their particularities, therefore ancillary product should have pertinency.

Analysis on Visually Handicapped Demand

Visually handicap affects life quality obviously, because low vision can easily limit visually handicapped daily life, especially reading, indoor and outdoor activities, learning and casual living. Visually handicap can cause depression, loneliness and melancholy.

Investigation of visually handicap life quality participated by visually handicapped and held by Beijing Tongren Hospital shows (Fig. 57.1), the most difficult part of daily life for visually handicapped is participating in social activities, getting information, reading books and newspaper and taking buses. Many visually handicapped are lack of confidence and rather stay at home (Sun Baochen 2009). Therefore, for visually handicapped, to solve the demands of travel safety, getting information, reading, taking buses, going shopping and leisure activities are of priority.

Visually handicapped are eager to participate and blend into in society, experience and express themselves. They are eager to receive respect and admiration. However, lacking of ancillary product and facility and social concern, visually handicapped can participate less social place and project. Some extremely low vision handicapped even can not going out by themselves. To rely on blind rob and friendly track to judge surroundings aggravated their solitary.

Analyzing Ideas for Visually Handicapped

I think visually handicapped ancillary product design should emphasize on followings:

Fully Consideration About Different Visual Handicapped Groups' Particularity

1. Congenital visually handicapped and part pathological visually handicapped: due to long time visual function incomplete, their hands and feet feeling, hearing and smelling are more incisive. Therefore, to design ancillary product for them should highlight feeling, hearing and smelling. Meantime, special situation for pathological visually handicapped should be considered such as patients with cataract should not use lens type ancillary product for long time.
2. Low vision of old people caused by increasing ages: two aspects need to be considered, one is old age, and the other is low vision. With the increasing of ages, physical function decline, disease will increase through whole body, along with memory deterioration, hearing decline and feeling insensitive. Therefore, design ancillary product uses hearing and feeling to compensate vision loss is not wise. Reading and going out are the biggest blocks for vision decline old ages, therefore, design ancillary product for old ages should pay more attention on safety, portability and enhancing reading ability (Fig. 57.2).

Restrictive Design

"Restrictiveness" refers to specialized range, degree, which can not surpass limits. Restrictiveness builds upon the basis of high rationality, is to control human

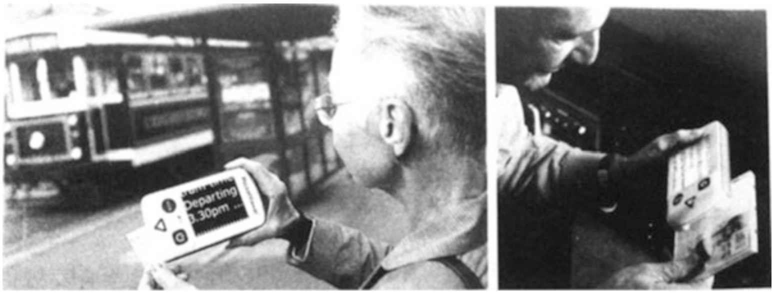


Fig. 57.2 Pocket type magnifier

activity restrictively through product design. Donald Norman mentioned in Design Psychology about restrictive design of car doorknob, doorknob consists of a overcover and groove, when customers sees it, they know to put hands into it then pull, which will not be any question or mistake during this operation (Norman 2010). We can see from this example that clear operation of product will bring people enjoyment in operating. Visually handicapped need easily handled ancillary product the most, if with too much bottoms and complicated assignment, they will be fed with the products when using, thus totally give the products up. Ancillary product design should enhance restrictiveness, an ancillary product function should be as simple as it can, no matter the degree, experience, knowledge, understanding, focusing of visually handicap, visually handicapped can easily use.

Sense Compensation Design

Human sense organ do not work alone, every organ affects each other and receives processing external information together, therefore the reaction of human to objective world is processed entirely. Different feelings will have compensation and cooperation for each other. When one organ is damaged, other organ function will enhance accordingly. Visually handicapped can not get information through vision, they usually get information through feeling and promoting of SIG signal. These two ways both use visually handicapped sense compensation to design ancillary product, also the best design approach aiming at visually handicapped.

Fault Tolerance Design

Fault tolerance refers to no dangerous due to wrong and unconscious operation. Due to visually handicap, these groups easily lead to misuse when using ancillary product, which needs designers to pay more attention when designing and to

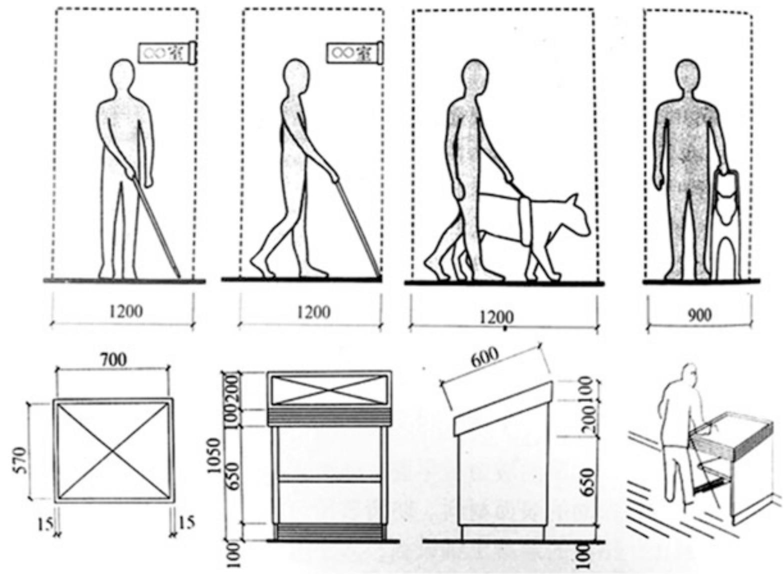


Fig. 57.3 Sample of movement scale and touch guide platform size for visually handicapped

provide error feedback when operating error occurred. The feedback can be feelings, such as earthquake reaction, error display in sound. Of course, even though it is operating error, the safety of ancillary product must be guaranteed.

Special Requirements of Visually Handicapped Human Engineering

Statistic of visually handicapped going out shows their way of going out is mainly still walking. Analyzing from human dimensions, oriented tools like blind rub affected by its way of movement, also will occupy some certain activity space (He Canqun 2006). For example, the range of using blind rub is 900–1,200 mm (Fig. 57.3). In building entrance, touching blind guide platform should be suitable for using habit of visually handicapped at human engineering interactive scale (Fig. 57.3). Usually when the height is 1,000 mm, touching board is at user's waist (Wang Xiaorong 2011). Touching board should have slope, which is convenient to watch and inquiry also reduces reflection of light of screen.

Product Color Consideration

Color has feelings, its symbolization and effect of emotion is heavier than form and quality of object. However, for visually handicapped, color discrimination and

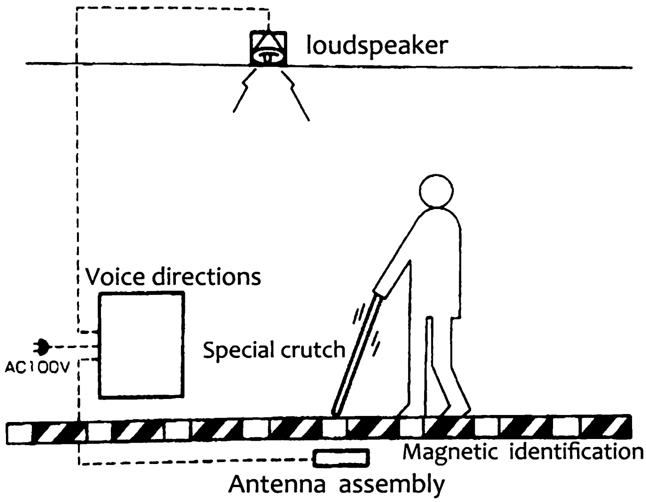


Fig. 57.4 Hearing guidance system for visually handicapped

safety are the most important (Tian Zhongzhiren and Yan Tiansanqianzi 2004). For example, the yellow friendly track is for color discrimination, the red traffic lights have longer transmitting distance than green. The selection of color also needs to consider the safety, such as blind rub can use luminous material, which will enhance the safety of visually handicapped going out at nights.

Systematic Auxiliary Mode of Visually Handicapped

Japan proposed to build "welfare city" a long time ago, barrier free design is used into building welfare city as a basis concept, which mainly aiming at to get rid of barriers in life (Tian Zhongzhiren and Yan Tiansanqianzi 2004). However, until now, both domestic and overseas barrier free designs focus on wheel chair users. For visually handicapped, it is just some simply caring facilities. So far the measures and plans we took for visually handicapped about barriers in life are partial, inadequate and inclusive, which requires us to double think and exam former measures and methods (Wickens et al. 2007).

Systematic design should fully consider the relationship among human, engineering and environment, emphasize the coordination of the three (Zhang Xufang 2010). Taking human as the core, clearing the division and coordination of human and product, adapting environment so that can achieve reasonable and best balance (James et al. 2002). To finish complicate activities, visually handicapped need coordination of the three. Visually handicap guide system uses magnetic identification as the guide (Fig. 57.4), when special crutch steps into this area, voice will be played at branch point, meantime will lead users to destination.

Magnetic identification is a whole product made up of ferrite magnet or amorphous metal, which can be used as road surface material or lay under the floor tile. When magnetic sensor of special crutch cusp tests magnetic identification, crutch will shake and convey the right direction to users. This systematic design combined human, engineering and environment very well, which consisted accessory system that helped visually handicapped going out safely and conveniently.

Conclusion

As vulnerable groups, visually handicapped deserve to enjoy the convenience, comfort, safety and experience brought by design. This paper proposes a few ideas aiming at visually handicapped ancillary product design through demand analyzing and definition of visually handicapped. To design safe, comfortable, smooth and convenient ancillary product for visually handicapped to help them blend into social basic protection reflects social progress and humanistic concern, which is also one of the most important factor of building harmonious society.

Acknowledgment The research work in this paper is supported by Scientific Research Program of Tianjin Education Bureaus (20082303)

References

Architectural Institute of Japan (2006) Barrier free building design information integration (Barrier free design) (trans: Yang Yifan, Zhang Hang, Chen Hongzhen). China Architecture and Building Press, Beijing, p 8

He Canqun (2006) Product design of human engineering (Barrier free design). Chemical Industry Press, Beijing, pp 8–11

HuangQun (2009) Barrier free and universal design (Barrier free design). China Machine Press, Beijing, pp 59–68

James HS, Selwyn Goldsmith, SunHe, WangYongzhi, ZhangDa (trans) (2002) Barrier-free design/ universal design (Barrier free design). Dalian University of Technology Press, Beijing, pp 75–83

Li Sanmao (2010) Visually handicapped accessibility design. ShanXi Archit J 36(11):14–15 (in Chinese)

Norman DA (2010) Design psychology (Barrier free design). China Citic Press, Beijing, pp 108–115

Pan H, Doulet J-F (2008) Ville, handicap ET accessibilite (Barrier free design). TongJi University Press, Beijing, pp 59–68

Sun Baochen (2009) Life quality and recovery of low vision handicapped. People's Medical Publishing House, Beijing, pp 247–260 (in Chinese)

Tian Zhongzhiren, Yan Tiansanqianzi (2004) Environment identification generic design (Barrier free design). China Architecture and Building Press, Beijing, pp 82–83

Wang Shiwei (2009) Semantic symbols of barrier-free design. Art Des J 8:268–269 (In Chinese)

Wang Xiaorong (2011) Barrier free design. China Architecture and Building Press, Beijing, pp 131–132 (In Chinese)

Wickens CD, Christopher D, Lee JD, Liu Y, Gordon-Becker S (2007) An introduction to human factors engineering (Barrier free design). Huazhong Normal University press, Beijing, pp 51–52

Wu Qiong (2009) Industrial design techniques and taboo. China Machine Press, Beijing, pp 78–81 (in Chinese)

Xiang Fan (2009) Orientation system identifier design (identifier design). JiangXi Fine Arts Press, Beijing, pp 13–17

Zhang Mangmang (2007) Obstacle free design of visual information (Barrier free design). Mod Art Des J 173:66–67

Zhang Xufang (2010) Simple discussion on color universal design (Barrier free design). Art Des J 2:17–19

Zhu Tuling (2010) Foundation and application of assistive devices for persons with disability (Barrier free design). QiuZhen Press, Beijing, pp 70–92

Chapter 58
Evaluation of Impact Factors on Reforming Military Research Institute of Technological Type

Jian-peng Pu, Fei Gao, Deng-zhou Zhang, Zhang-lin Peng, and Zhen Shao

Abstract Military research institute of technological type focuses on product development, and the institute faces a series of opportunities and challenges when it transforms into enterprise. How to grasp the direction of the reform efficiently is crucial both in theory significance and practical value. This paper describes the mean of military research institute of technological type, and constructs the index system of factors which influence the reform. Use quantitative analysis method with three dimensions to choose an appropriate type of enterprise for different military research institutes reform.

Keywords Military research institute • Reform • AHP

Introduction

After entering "the Twelfth Five-year Plan", China has witnessed changes in the progress of society, along with its achievements in developing the economy. As one of pillar industries of the country, military industry need implementation spans development, definitely due to it's importance for the country' economy and crucial to national defense security (Central Compilation & Translation Bureau 2011). Therefore, as core force of research and development in military industry, the institute reform step need speed up unceasingly to the purpose of civil-military integration (Yao Guang-ning 2008). The technological one is the most representative type in military research institute. Other study on how to reform is qualitative mostly, but in this paper we use the quantitative analysis and make standard for the institutes with different features. So they can transform into enterprise which suitable for their own.

J.-p. Pu (✉) • F. Gao • D.-z. Zhang • Z.-l. Peng • Z. Shao
School of Management, Hefei University of Technology, Hefei, China
e-mail: feigao1030@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_58,

Based on the above, military research institute of technological type has been defined and an evaluation index system of the influencing factors for the reform is established.

The Definition of the Military Research Institute of Technological Type

According to the document that General Office of the State Council issued about the institutions classification reform in 2011, existing institution can be divided into three categories: the one undertake administrative function, the one engaged in the production and business operation activities and the one engaged in public service. To the military research institute, according to the above and review of literatures, it also can be divided into three categories: The military research institute of strategy type engaged in strategy research and long-term planning, policies and regulations, system engineering, technical economic and other fields. The military research institute of service type engaged in measurement, intelligence and other fields, not to make profits, but to support the national military industry infrastructure. And the military research institute of technological type which sets scientific research of military products, technical development, product design, manufacture, operation management in one.

In three types, the technological accounts for the largest proportion. It undertakes the research and development work of Military supplies and has the production of the strength and manufacturing ability. So it is for-profit obviously. In this case, with the reform of market economy gradually advance (Borkowski 2001), the technical research institutes reform is the inevitable trend.

Constructing Index System of Factors Which Influence the Reform

First of all, according to the principles of scientific, comprehensive, and operable, considering the characteristics of military research institutes of technological type, and referencing a number of literatures, the basic framework of the evaluation system is designed. Then the Delphi method is used (Dalkey and Helmer 1963). Through consulting from 15 experts in the national bureau of statistics, Anhui province, Hefei university of technology, after three rounds feedback, three dimensions, 8 first-class indexes, 20 second-class indexes are selected (as the Table 58.1). The original measure data of quantitative index is subject to the annual final accounting statements and other financial accounting information. The experts score for qualitative index must be familiar with the military industry and have the professional knowledge of the enterprise management (XU Ning 2008; Liu Chun-yan 2008; Wu Ci-sheng et al. 2001).

Table 58.1 The critical value and weight of the indexes

Dimension	Critical value	First-class index	Weight	Critical value	Second-class index	Weight	Total weight	Critical value
R&D X	3.48	Basic conditions A_1	0.281	3.26	Awarded rate of the scientific and technical personnel A_{11}	0.515	0.14472	3.1
					Senior title rate of scientific and technical personnel A_{12}	0.192	0.05395	3.2
					Per capita value of instrument and equipment A_{13}	0.293	0.08233	3.6
		Innovation ability A_2	0.33	4.1	Technology innovation ability A_{21}	0.463	0.15279	4.0
					Process management and innovation ability A_{22}	0.217	0.07161	4.2
					Project selection and implementation ability A_{23}	0.32	0.1056	4.2
		Scientific research achievements A_3	0.389	3.1	technology transfer rate A_{31}	0.604	0.23496	2.9
					Per capita turnover of technology personnel in technology market A_{32}	0.396	0.15404	3.4
Commerciality Y	3.79	Organization management A_4	0.368	4.06	Organization image and brand building ability A_{41}	0.33	0.12144	3.7
					Human resources management ability A_{42}	0.22	0.08096	3.9
					Management innovation and organizational transforming ability A_{43}	0.45	0.1656	4.4
		Operation ability A_5	0.377	3.8	Financing investing ability A_{51}	0.31	0.11687	3.4
					Cost control ability A_{52}	0.22	0.08294	4.2
					Market development ability A_{53}	0.47	0.17719	3.9
		Income structure A_6	0.25	3.43	The proportion of utilities income A_{61}	0.27	0.0675	3.5
					The proportion of sales income A_{62}	0.73	0.1825	3.4
Marketability Z	3.47	Market conditions A_7	0.465	2.9	Saturation of market capacity of the industry A_{71}	0.566	0.26319	2.9
					Market competition of the industry A_{72}	0.434	0.20181	2.9
		Market prospect A_8	0.535	3.97	The market demand of the indaustry A_{81}	0.56	0.2996	4.1
					The industrialization ability of research achievements A_{82}	0.44	0.2354	3.8

Influencing Factors

Three dimensions include research and development, commerciality, marketability. In the dimension of R&D, there are there first-class indexes: basic conditions, innovation ability, and the scientific research achievements. In the dimension of commerciality, it is mainly to if the organizational structure is optimized, if the ability to operate can adapt to the transfers the demand, or if the income structure is reasonable. In the event of the market conditions can't be well known, the reform pattern will not select appropriately. The dimension of marketability can be considered from two aspects: market conditions and market prospect.

Weight Determination

- Establish hierarchical structure model
  Usually the hierarchical structure chart has three layers: target layer, rule layer and scheme layer (Saaty 1980). In the construction of the hierarchical structure model, pairwise comparison could be carried out between the elements of next layer and a certain element of neighboring layer. There are four layers in this paper. Target layer is Study on transform military research institute of technological type into enterprise. Rule layer is the dimensions. The last two index layers mean the first-class index and the second-class index.
- Judgment matrix and Calculating weight
  Normal matrix:

$$B = \begin{pmatrix} 1 & B_{12} & \cdots & B_{1l} \\ B_{21} & 1 & \cdots & B_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{B_{1l}} & \frac{1}{B_{2l}} & \cdots & 1 \end{pmatrix} \tag{58.1}$$

AHP method is used here, The specific calculation process as follows:

1. Calculate the product of elements in each row of the judgment matrix V_i

$$V_i = \prod_{j=1}^{l} B_{ij} \quad i = 1, 2, \ldots, l \tag{58.2}$$

2. Calculate the l times root of V_i and obtain the result $\overline{H_i}$

$$\overline{H_i} = \sqrt{[l]}V_i \tag{58.3}$$

3. Normalized treatment of the vector $\overline{H} = \left[\overline{H}_1, \overline{H}_2, \ldots, \overline{H}_l\right]^T$:

$$H_i^1 = \frac{\overline{H_i}}{\sum_{j=1}^{n} \overline{H_j}} \tag{58.4}$$

$H^1 = \left[H_1^1, H_2^1, \ldots, H_l^1\right]^T$ is the requested characteristic vector, just as the first expert determined.

For a lot of important decisions in the real life are not made by a single person, but by a decision-making group consisted of several experienced experts. Cultural background and social environment, experience and preferences of different people are not all the same, so the matrix and the vector obtained are different. In this paper we take all experts' average weight as the final.

$$H = \frac{H^1 + H^2 + \cdots + H^n}{n} = [H_1, H_2, \ldots, H_n]^T \tag{58.5}$$

- Consistency test
  For the factors always judged roughly when the exports give the scores, the consistency check of judgment matrix is needed. Random coincidence coefficient *CR* is used in *AHP* to calculate if the judgment matrix meets with consistency. If $\mathrm{CR} < 0.1$, it has good consistency. If $\mathrm{CR} > 0.1$, the consistency is bad. The formula is as follows.

$$\lambda_{\max} = \frac{1}{l} \sum_{i=1}^{l} \frac{(BH)_i}{H_i} \tag{58.6}$$

$$CI = \frac{\lambda_{\max} - l}{l - 1} \tag{58.7}$$

$$CR = \frac{CI}{RI} \tag{58.8}$$

$(BH)_i$ means the ith element of vector BH, $\mathrm{RI} = \mathrm{constant}$

Critical Value

Calculate critical values of three dimensions and their subordinate indexes through questionnaires. In the questionnaires, basic indexes are assigned points from 1 to 5 (Likert 1932). The experts are invited to fill in the questionnaires and give advices.

Get statistical analysis of the data from the questionnaires to calculate the coefficient of variation and the coordinating degree of the experts' answers. The coefficient of variation gets smaller, the coordinating degree gets higher, and the result gets more reliable. The specific formula is as follows.

Suggest the number of the index and experts are m and n. X_{ij} means the score that the ith expert gives the jth index.

- J's standard deviation

$$S_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_{ij} - \overline{X_j})^2} \tag{58.9}$$

$$\overline{X_j} = \frac{1}{n}\sum_{i=1}^{n} X_{ij} \tag{58.10}$$

- J's coefficient of variation

$$K_j = \frac{S_j}{\overline{X_j}} \tag{58.11}$$

- J's coordinating degree

$$P_j = 1 - K_j \tag{58.12}$$

When the coordinating degree bigger than 0.5, the calculation of critical value can be continued. If not, feedback to the experts, find the reason and modify it. Finally, use the average score as the critical value. Get the table as follows

Analysis of Reform Direction

As demarcation point, the critical values divide the dimensions into high level and low level, like X is divided into "high level of R&D and low level of R&D". So a three-dimensional model for the reform is established (Fig. 58.1). According to different performances in the dimensions, the model gives different positioning for the institutes.

As shown in Fig. 58.1, area A means high level of R&D, high level of commerciality, and high level of marketability. The institutes have these characteristics can transform into independent enterprise. Because high level of R&D indicates that the technology innovation ability, human resources and advanced equipments is a very strong support to this reform (Freeman 1995). High level of commerciality indicates that the marketing management ability is strong. The institutes who have

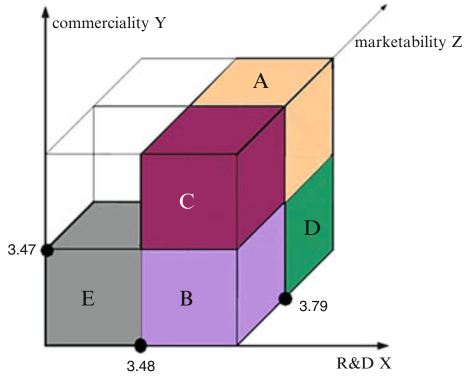


Fig. 58.1 The three-dimensional model

high level of marketability can meet market needs, and turn the technical advantages into market advantages (Christensen 2003).

Area B means the level of commerciality and marketability is low. So the institutes' financing ability is not strong, and they're hard to transform into independent enterprise. They can be the science and technology intermediary, and provide technical service.

Area C means only the level of marketability is low. These institutes can cooperate with other production-oriented enterprises by merger and reorganization. Meanwhile, the large asset scale of the institutes who want to transform in this way is required. In that way the debts of the enterprise integrated can be undertaken.

Area D is opposite to area C in some degree. For the low level of commerciality, the institutes can transform into a part of large enterprises, to coalesce into the technical department.

Other areas means the institutes are not reasonable logically or need to be revoked.

Conclusion

In this paper, the concept about military research institute of technological type is put forward. And we use critical value method and AHP to establish the three-dimensional positioning model. So the reform of the institutes can carry on with pertinence. The study of this paper just is limited to the technological type institutes. So the next research can focus on other types.

Acknowledgment This research is supported by the key program belongs to the National Natural Science Foundation of China under the grant no. 71071045.

References

Borkowski SC (2001) Transfer pricing of intangible property: harmony and discord across five countries [J]. Int J Account 36(3):349–374

Central Compilation & Translation Bureau (2011) The twelfth five-year plan for national economic and social development of the People's Republic of China [M]. Central Compilation & Translation Press, Beijing

Christensen C (2003) Outlook 2003: Innovation, economy & supply chain [J]. Glob Cosmet Indus 171(1):24–28

Dalkey N, Helmer O (1963) An experimental application of the Delphi method to the use of experts [J]. Manag Sci 9(3):458–467

Freeman C (1995) The national system of innoviation'in historial perspective [J]. Camb J Econ 19:5–24

Likert R (1932) A technique for the measurement of attitudes [J]. Arch Psychol 22(140):1–55. http://www.citeulike.org/user/robertlischke/article/2731047

Liu Chun-yan (2008) Demonstration analysis of performance appraisal index system for military enterprise [J]. Sci Technol West China 27(7):75–78

Saaty TL (1980) Multicriteria decision making: the analytic hierarchy process [M]. McGraw-Hill, New York

Wu Ci-sheng, Wang Min, Li Xing-guo (2001) A Research into the evaluation target system and comprehensive evaluation method about the science and technology development of provinces [J]. J Syst Sci Syst Eng 10(3):343–349

XU Ning (2008) Combinatorial analysis of industrialization mode of domestic scientific research institutes [J]. Sci Technol Indus 8(6):62–82

Yao Guang-ning (2008) The research on military and civil amalgamation of state-owned military enterprises [J]. J Xidian Univ (Social Science Edition) 18(3):92–94

Chapter 59
Research on Network News Evaluation

Jian-guo Yu, Hua-qing Min, Zhi-pin Cao, Shao-wu Peng, and Shi-chao Qu

Abstract Network news is more and more important and more and excessive, consequently news evaluation gradually becomes hot spot, and it is also complicated problem. In the paper, same batch news evaluation and all news evaluation are respectively analyzed. Elite degree conception is defined and news evaluation indexes are set up, and consequently new news evaluation methods are put forward. News should be evaluated by both news transmitter and news audience. News transmitter evaluates news from activation value, information value, education value, entertainment value and society value, and news audience evaluates news from visit quantity, response quantity and the ratio of response quantity of visit quantity. Finally the network news evaluation process is shown by specific instance.

Keywords Network news evaluation • Elite degree • Visit quantity • Response quantity

J.-g. Yu (✉)
School of Economics, South China University of Technology, Guangzhou, China

Zhejiang Changzheng Vocational and Technical College, Hangzhou, Zhejiang 310023, China
e-mail: scutyjg@gmail.com

H.-q. Min • S.-w. Peng
School of Software Engineering, South China University of Technology, Guangzhou, Guangdong 510006, China

Z.-p. Cao
School of Journalism and Communication, South China University of Technology, Guangzhou, Guangdong 510006, China

S.-c. Qu
Department of Research and Development, Shenzhen Chaojiedian Network Technology Co. Ltd, Shenzhen, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_59,

Introduction

After network news was brought into the selection scope of the16th and 17th online journalism awards, they are paid attention to more and more (Xu 2010). However, with the extensive application of network and rapid development of society, all kinds of news overspread. Which news is on earth the ones people need and which news fit teachers and students in school very much, and how to maximize the news value? Hence, it's necessary to evaluate the news. However, what method can be adopted to evaluate the news? Since hundreds of years ago, many people hope to find a supernatural method which can select valuable news from lots of news. But the method isn't found as yet. Now many people adopt visit quantity to evaluate the news, but Professor Xiguang Li of Tsinghua university thought "if news is evaluated only by visit quantity, the mistaken direction of public opinion will be formed." News evaluation is so valuable and difficult, so the paper will study the seductive problem, and tries to find a fit method to evaluate the news.

Guo thought that the traditional news evaluation has obvious defect, so journalism need new news evaluation method which is more scientific (Guo 2006). Yang analyzed the composition and attribute of news morality evaluation, and thought that evaluation criterion can be divided into normalization standard and quality standard (Yang 2010). Qasem evaluated the online news using usability and web content and the results of the research showed that the usability factor is relatively good for all Jordanian online newspapers whereas the web content factor is moderate (Ai Radideh Qasem et al. 2011). Literature (Wang 2004; Ruan 1997; Guo 2009; Xie 1999; He 2008; Dong 2008) also analyze the news evaluation, but they don't study it in-depth. The research status showed that there is no ideal evaluation method for network news as yet.

Evaluation for Same Batch News

Most of time, news is evaluated by people subjectively. Sometimes some indexes are established and news is evaluated by people according to the indexes, and the method isn't objective and exact yet. In fact, besides news evaluation in advance, there is news evaluation afterward which is commonly more objective. In addition, besides news is evaluated by expert, it can also be evaluated by audience which maybe exacter. But news audiences are so many, and it's impossible to let all audience evaluate news, and even if only little part of audience. In addition, if news is directly evaluated by audience, there are still many subjective factors. So the indirect and objective method should be adopted for audience to evaluate the news. In fact, the receiving initiative and response degree represent the evaluation of audience to news. Hence, it's necessary to consider the news evaluation from audience, and the receiving initiative and response degree can be regarded as the news evaluation from audience.

Based on above analysis, new news evaluation method is put forward, and can be applied to evaluate same batch news. The method integrates the evaluation from news transmitter and the evaluation from news audience, and takes both news release status and news value into account synthetically. The method adopts news elite degree to evaluate the news. So the conception about news elite degree is put forward at first, and its definition is as follows:

Definition 1. News elite degree: news elite degree is a integrative index to evaluate news which is made up of news value and news spread degree, and news value expresses the news usefulness and news spread degree expresses the degree of news spread and pervasion, and they are expressed with positive real number and bigger number indicates that the news is better.

The computational formula of news elite degree is as follows:

$$y_i = (w_s y_{si} + w_r y_{ri}) \frac{y_{ri}}{y_{si}} \tag{59.1}$$

$$y_{si} = w_a A_i + w_b B_i + w_c C_i + w_d D_i + w_e E_i \tag{59.2}$$

$$y_{ri} = \frac{w_f F_i + w_g G_i}{w_f \max(F_j) + w_g \max(G_j)} \frac{G_i}{F_i} \tag{59.3}$$

Here

y_i: elite degree of i-th news
y_{si}: news value of i-th news evaluated by news transmitter
y_{ri}: news spread degree of i-th news evaluated by news audience
F_i: visit quantity of i-th news
G_i: response quantity of i-th news
A_i: activation value of i-th news
B_i: information value of i-th news
C_i: education value of i-th news
D_i: entertainment value of i-th news
E_i: society value of i-th news
w_s: weight of news value
w_r: weight of news spread degree
w_a: weight of activation value in news value
w_b: weight of information value in news value
w_c: weight of education value in news value
w_d: weight of entertainment value in news value
w_e: weight of society value in news value
w_f: weight of visit quantity in news spread degree
w_g: weight of response quantity in news spread degree

The method put forward evaluates news from both news transmitter and news audience, and news transmitter performs before evaluation and news audience evaluates performs post evaluation. Thus the method is more comprehensive and objective than single news transmitter evaluation or single news audience evaluation.

Here, news transmitter evaluates news from five aspects and five aspects include: activation value, information value, education value, entertainment value and society value. Activation value expresses the impact of news to audience and the index is related with news timeliness, news importance and abnormality. Information value expresses amount of information and the information value to new audience at the moment. Education value expresses assistance degree by which new audience cognize the nature law and society phenomenon. Entertainment value expresses enjoyment degree of news audience mentally. Society value expresses the influence of news to society, which includes positive impact and negative impact. News transmitter evaluates news from five aspects and accordingly obtains five evaluation values, then adds up five values and obtains the news value from news transmitter.

The evaluation of news audience is affected by two variables which are news visit quantity and news response quantity. News visit quantity is reading quantity of people, and visit quantity of network news is described with click rate. News response quantity is the action of people after they read the news, and news response quantity of network news is reflected in comment, collection, share and other operations. Both visit news and response news are related with news quality. The visit quantity is larger, and then generally the news is hot and better. The response quantity is larger, and then generally the news is more popular. Based on above analysis, it's thought that the relation between news spread degree and the weighted sum of visit quantity and response is positive correlation.

It is worth to mention that news visit quantity can't indicate the news is good or bad. For example, if a piece of news is visited by many people and isn't responded by anybody, then can it indicate that the news is good? The answer is negative by all appearances. If the visit quantity of a piece of news isn't lot, but the response quantity is lot, then can it indicate that the news is good? The answer is positive. Hence, when evaluate news, it's necessary to not only consider the visit quantity and the response quantity, but also take the relation between them into account. Based on above analysis, the ratio of the response quantity to visit quantity is regarded as a part of news evaluation index in the paper, and the ratio and the weighted sum above are combined. In addition, the final news evaluation index is made up of many parts, and every part should be comparable, so the value of every part should be normalized into the district of [0, 1]. Hence, the evaluation formula of news transmitter is add up a denominator, and the denominator is made up of the weighted sum of visit quantity maximum and response quantity maximum of all news.

After news value and news spread degree are calculated out, they can't be simply added up. They deem independent each other, but in fact there is internal relation between them. News transmitter evaluation belongs to forward evaluation and news audience evaluation belongs to post evaluation, and the former will affect the latter very much. For example, generally news transmitter will put the news which is regarded as good news by news transmitter into excerption or recommendation section, even into top in network. The news audience commonly visits the news in excerption or recommendation section at first, so the forward evaluation will affect the post evaluation very much. Hence, it's necessary to consider this when the news elite degree index is designed. Theoretically, the evaluation of news transmitter should accord to the evaluation of news audience. But in fact, they maybe often differ very much, and even reverse. Then what do the difference indicates? If the forward evaluation is good, but the post evaluation is bad, in other words, the evaluation of news audience isn't good even if under the guidance effect of the news transmitter. On the contrary, if the forward evaluation isn't good, but the post evaluation is good, in other words, news audience can still find the news value even if the news transmitter put the news into inferior environment, and this indicate that the news is good. Based on the analysis, the ratio of the news spread degree (the post evaluation) to the news value (the forward evaluation) is introduced into the news elite degree index in order to increase the accuracy in the paper.

Evaluation of All News

Above news evaluation method is fit for the news of same batch which are released at the same time. For example, everyday evaluate or sort the news released in today in school news information system, and to select some good news into popular section. In practice, the news evaluation isn't always toward only the news of same batch, and generally is toward all news which is not same batch. Evaluation of all news has more universality and application value. However, the evaluation method of same batch designed above isn't fit for evaluation of all news. New news is continually put into the school news information system every day, and the total news become more and more. Some news is new news released just now and more news is old news released before. Their existence time is different and the difference is large, so they can't be compared simply and can't be evaluated by visit quantity. Apparently, with time goes, visit quantity will gradually increase though the news quality isn't good. So it's further revealed that visit quantity isn't equal to the news quality. Because of effect of time, the time factor should be deleted or considered when news is evaluated in order to pull all news into same evaluation point. According to above analysis, all news evaluation method is put forward based on the same batch news evaluation method above. The formulas of all news evaluation method are follows:

$$y_i = (w_s y_{si} + w_r y_{ri}) \frac{y_{ri}}{y_{si}} \tag{59.4}$$

$$y_{si} = w_a A_i + w_b B_i + w_c C_i + w_d D_i + w_e E_i \tag{59.5}$$

$$y_{ri} = \left(w_1 \frac{y_{ri1}}{q_1} + w_2 \frac{\sum_{j=1}^{N_s} \frac{y_{rij}}{\frac{q_j}{N_s}}}{N_s} + w_3 \frac{\sum_{j=1}^{n_i} \frac{y_{rij}}{\frac{q_j}{n_i}}}{n_i} \right) \frac{\sum_{j=1}^{N} q_j}{N} \tag{59.6}$$

$$y_{rij} = \frac{w_f F_{ij} + w_g G_{ij}}{w_f \max(F_j) + w_g \max(G_j)} \frac{G_{ij}}{F_{ij}} \frac{\min(F_j)}{w_g \max(G_j)} \tag{59.7}$$

Here

y_{rij}: news spread degree of i-th news in j-th time point
q_j: system visit quantity in j-th time point
N: time span of news evaluation
n_i: time section amount from release of i-th news to evaluation time
N_s: time section amount from release of i-th news to s-th time point
F_{ij}: visit quantity of i-th news in j-th time point
G_{ij}: response quantity of i-th news in j-th time point
w_1: weight of news spread degree in 1-th time point since release in total spread degree from audience
w_2: weight of average news spread degree in s-th time point since release in total spread degree from audience
w_3: weight of average news spread degree from release to evaluation in total spread degree from audience

According to above formulas, the main different between all news evaluation method and same batch news evaluation is evaluation from news audience. All news evaluation method include three ideas: (1) regard news evaluation as a process which is a dynamical process; (2) analyze news spread degree from three phase; (3) consider the relation between news visit quantity and system visit quantity. Generally speaking, 1-th time point since release is visit peak, and visit will decrease quickly, and then turn into stabilization gradually. According to the law of news, synthetically evaluate the news from 1-th time point since release, a little time segment since release and whole segment. Here, 1-th time point is usually first day since release, and a little time segment since release is usually is first week since release, and whole segment is usually the period from release time to evaluation time.

News visit quantity is affected by system visit quantity. Apparently news visit quantity will be more if system visit quantity is more. So news can't be simply evaluated according to news visit quantity, but news evaluation need consider effect of system visit quantity. For example, when all people are busy and seldom read news, and this result in small news visit quantity, and the small news visit quantity can't indicate that the news isn't good. Hence adopt the ratio of spread degree from audience of every time point to system visit quantity at the same time to describe

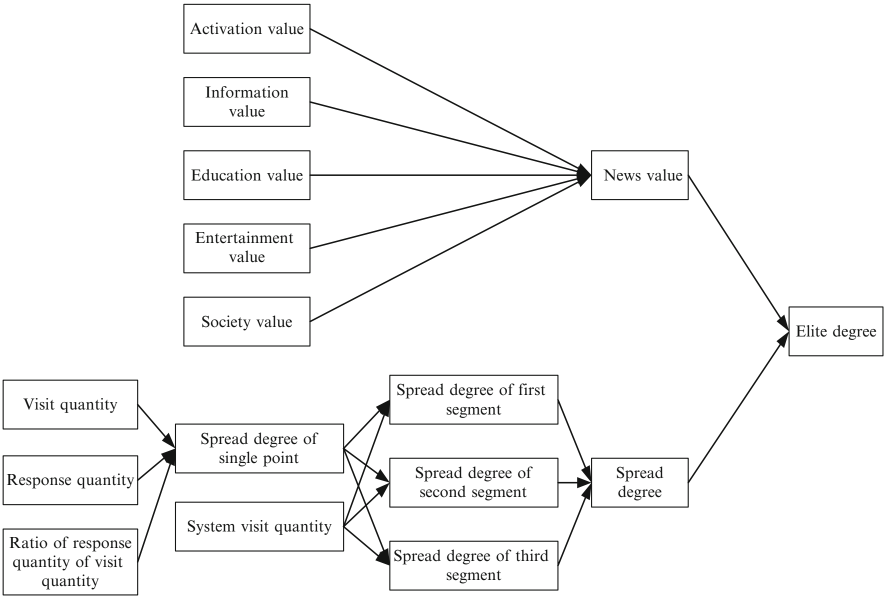


Fig. 59.1 All news evaluation flow

the news quality. In addition, in order to put different evaluation values into same comparison reference, above evaluation values need multiply with average system visit quantity of whole time segment.

Formula 59.7 above is to calculate the spread degree in certain time point of certain piece of news according to visit quantity and response. Formula 59.6 is to calculate the spread degree of certain piece of news by three time segments. When calculate the spread degree of every time point, at first let spread degree calculated by Formula 59.7 to be divided by system visit quantity of corresponding time segment, and then multiply by average visit quantity of whole time segment. The spread degrees of three time segments are respectively given different weight. General speaking, 1-th time point is given maximal weight, and the weight is usually set 0.6. The weight of a little time segment is usually set 0.3. The weight of whole time segment is usually set 0.1. If news is released just in evaluation day, the news has first time segment. So only spread degree of 1-th time point is considered and its weight is set 1. If news is released earlier than evaluation day only a little, the news has first time segment and part of second time segment. So only spread degree of 1-th time point and a little time segment is considered, and spread degree of a little time segment is calculated according to actual time length. According to above analysis, the flow all news evaluation is Fig. 59.1.

News Evaluation Instance

Assume that school news information system has normally run in CZ colleges, in December 31, 2012, select eight pieces of news from all news of whole year to evaluate. The related data about eight pieces of news is as Table 59.1. The known data include release time, news visit quantity in release day, news response quantity in release day, news visit quantity in second segment, news response quantity in second segment, news visit quantity from release to evaluation, news response quantity from release to evaluation, news transmitter evaluation in five aspect. 1-th time point is the release day, and second time segment is the week since news release and third segment is from release to December 31, 2012. Every month system visit of this year in turn is 1,040,523; 853,031; 2,518,417; 2,230,760; 2,130,571; 2,034,382; 1,047,584; 681,700; 2,577,305; 2,323,485; 1,977,269; 2,234,826. Related parameters are as follows: w1 = 0.6, w2 = 0.3, w3 = 0.1, wf = 1, wg = 20, wa = 0.2, wb = 0.2, wc = 0.2, wd = 0.2, we = 0.2.

System visit quantity of every piece of news in release day, System visit quantity of second segment and system visit quantity of third segment can be calculated according to every month system visit quantity. Spread degree y_{ri1} in release day can be calculated according to visit quantity and response quantity in release day. In detail, firstly visit quantity and response quantity are added up with weight, then to be divided by the weighted sum of maximal visit quantity and maximal response quantity in release day, and then multiply by the ratio of response quantity to visit quantity. In addition, in order to normalize the result into the range of [0, 1], above result need multiply by the ratio of maximal visit quantity to maximal response quantity in release day. Accumulated y_{rij} of seven since release day can be calculated with similar method. If the days from release day to evaluation are less than seven, calculate according to actual days. For example, News 3 has no second segment or third segment, and accordingly only consider first segment. Second segment of News 4 has only 4 days, and accordingly its y_{rij} is calculated according to 4 days. Then calculate accumulated y_{rij} from release to evaluation. Then y_{rij} of every segment is divided by system visit quantity of corresponding time segment. If second segment is involved with 2 months, the system visit quantity should be calculated according to system visit quantity of 2 months. Second segment and third segment still need to be divided by segment length to obtain the spread degree of unit time. Then multiply by average system visit quantity of news system in whole year. The spread degree reflected by audience can be obtained by weighted sum of three segments. On the other hand, the news value evaluated by transmitter can be obtained by weighted sum of five aspects of evaluation data. At last, final elite degree can be obtained by weighted sum of evaluation data from transmitter and evaluation data from audience, and the result is as last column of Table 59.1. The result shown that the sorting sequence of eight piece of news from big to small according to elite degree is 7, 2, 3, 5, 4, 1, 6, 8.

Table 59.1 News evaluation instance data

	News 1	News 2	News 3	News 4	News 5	News 6	News 7	News 8
Release time	5–12	2–22	12–31	12–28	1–15	4–18	8–6	9–27
Visit in release day	4,265	3,589	5,167	4,856	3,848	3,982	4,178	5,215
Response in release day	234	218	320	310	196	215	195	225
Visit of second segment	9,542	8,452	5,167	7,886	7,935	7,482	7,468	8,765
Response of second segment	456	547	320	487	375	389	386	486
Visit of third segment	12,845	9,851	5,167	7,886	16,578	8,857	11,895	11,245
Response of third segment	547	496	320	487	758	417	597	689
System visit in release day	68,728	29,415	72,091	72,091	33,565	74,359	21,990	85,910
System visit of second segment	481,097	205,904	72,091	288,365	234,957	520,511	153,932	568,494
System visit of third segment	14,251,113	19,991,618	72,091	288,365	21,179,939	15,973,785	9,684,633	6,879,221
y_{ri1}	0.4738	0.4662	0.6917	0.6815	0.3821	0.4318	0.3640	0.4047
Accumulated y_{rij} of second segment	0.4113	0.5788	0.3304	0.5020	0.3364	0.3660	0.3620	0.4727
Accumulated y_{rij}	0.3320	0.3263	0.2348	0.3568	0.4757	0.2654	0.3921	0.5026
y_{ri}	0.2566	0.6046	0.5602	0.3617	0.4240	0.2158	0.6214	0.1800
A_i	0.42	0.29	0.33	0.64	0.15	0.83	0.71	0.44
B_i	0.28	0.38	0.84	0.92	0.37	0.76	0.68	0.25
C_i	0.79	0.84	0.21	0.37	0.85	0.64	0.35	0.89
D_i	0.54	0.65	0.67	0.58	0.63	0.38	0.65	0.24
E_i	0.73	0.45	0.37	0.47	0.54	0.24	0.52	0.67
y_{si}	0.552	0.522	0.484	0.596	0.508	0.57	0.582	0.498
y_i	0.3452	0.5798	0.5374	0.4320	0.4492	0.3221	0.6096	0.2754

Conclusion

In the paper, network news evaluation is researched and new news evaluation methods are put forward, and same batch news evaluation and all news evaluation are respectively analyzed. Research shows that both forward evaluation and post evaluation should be adopted synthetically, which is more scientific. News transmitter should evaluate news from activation value, information value, education value, entertainment value and society value, which are more comprehensive. News audience should evaluate news from visit quantity, response quantity and the ratio of response quantity of visit quantity, which is more reasonable. Specific instance indicates that the methods put forward in the paper are not only feasible but also exact.

Acknowledgment This project is supported by national natural science foundation of China (No. 71071059), Specialized Research Fund for the Doctor Program of Higher Education of China Education Ministry (No. 20100172120040), and the Fundamental Research Funds for the Central Universities.

References

Ai Radideh Qasem A, Abu Shanab E, Hamam S (2011) Usability evaluation of online news websites: a user perspective approach [J]. World Acad Sci Eng Technol 74:1058–1066

Dong FJ (2008) News website revaluation methods and the applied research [D]. MsD dissertation, Huazhong University of Science and Technology, Wuhan

Guo P (2006) News value evaluation need new standard [J]. J Ocean Univ China 2:91–93

Guo XS (2009) Thought on news evaluation of value and effectiveness [J]. Public Bus 103:259

He Y (2008) The research on news assessment of the value [D]. MsD dissertation, Hunan University, Changsha

Ruan GR (1997) Which news can easily win award [J]. 11:17–19

Wang MF (2004) Thought on news evaluation system establishment [J]. Today's Mass Media 7:21–22

Xie J (1999) Scientific news evaluation system establishment [J]. J Univ 1:34–35

Xu JF (2010) Evaluation system of network news [J]. News Knowl 1:77–78

Yang BJ (2010) An Analysis of the constitution and attributes of the journalistic morality evaluation criteria [J]. J Shanxi Univ 33(4):118–122

Chapter 60
Based on the Jump-Diffusion Process of the Coal Resources Development Investment Project Evaluation Model

Tao Wang, Jin-suo Zhang, and Shao-hui Zou

Abstract Coal resources development projects have many characteristics of large investment, irreversibility, long cycle and uncertainty and so on, due to the inherent defects of the traditional NPV method, which can't effectively deal with the uncertainty faced by the coal resources development investment, thus, the real value of the coal development investment projects are hardly assessed scientifically and rationally. Using the real options method, the paper builds a evaluation model on coal resources development investment project. The results show that using the model to assess the project value of coal resources development investment will be more scientific and rational, parameter analysis leads to the result that interest rates and convenience yields have a negative effect on the critical investment value of the projects, and the high jump frequency will reduce the critical investment value of the projects, while positive changes on jump range can increase.

Keywords Coal resources • Development investment • Evaluation model • Real option

Introduction

Based on China's energy structure, coal resources plays a decisive role in China's energy strategy, thus, rational development and utilization of coal resources is very essential to make the national economy maintain steady and rapid growth. Coal resources development projects have many characteristics of large investment, irreversibility, long cycle and uncertainty and so on, thus, how to scientifically and rationally assess the value of the projects has been a hot issue to be solved.

T. Wang (✉) • J.-s. Zhang • S.-h. Zou
Energy Economy and Management Research Center, Xi'an University of Science and Technology, Xi'an, China
e-mail: boban863@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_60,

Based on rigidity in decision-making, traditional NPV method fails to consider flexible decision-making changing the value of a project under uncertainty factors, which leads to the result that the real value of the projects are hardly assessed scientifically and rationally. The real option method is a thinking mode which applies the financial option theory to strategic decision-making. Using this method, decision-makers are able to adjust their strategies timely according to development and changes of the uncertain factors and projects. It will improve management flexibility to maximize project value.

The real option method, which evolved from Black, Scholes and Merton's option pricing theory, was first proposed by Myers (1977). Brenman and Schwartz (1985) had combined real option pricing with asset pricing methods for the first time, they established a valuation model of mining investment value, which calculated the impact of management flexibility on project value, afterwards, Domestic and foreign scholars including Frimpong, Abdel, Amram, Paddock, Trigocgric, Pindyck, Copeland, Slade, Saito, Jin-suo Zhang, Neng-fu Zhang, Lei Zhu, Yong-feng Zhang etc. (Frimpong and Whiting 1997; Abdel Sabour 2001; Amrma and Kulatilaka 1998; Paddock et al. 1988; Trigeorgis 1996; Pindyck 1999; Copeland and Antikarov 2001; Slade 2001; Saito et al. 2001; Jin-suo Zhang 2002; Jin-suo Zhang and Shao-hui Zou 2006, 2009; Neng-fu Zhang et al. 2002, 2003; Lei Zhu et al. 2009; Yong-feng Zhang et al. 2006), who studied investment decision approach in the field of mineral resources based on the real option method. In field of investment for dedicated coal resources, Jin-suo Zhang and Shao-hui Zhou (Jin-suo Zhang et al. 2012) conducted a research on the formation mechanism of coal mining option value, then developed the investment decision method of coal resources on the basis of the real options method. Tao Wang (Tao Wang et al. 2012) discussed the option characteristics of coal resources exploration and investment using the real option method, they founded a project evaluation model under the coal exploration results if the prices change in a random manner. From the above, we can see that there are abundant studies on the oil and gas resources investment, which lacks dedicated coal resources investment. Therefore, based on related research, the paper builds a evaluation model of coal resources development investment project, in order to make rational decisions of coal resources development investment.

Risk Characteristics and Option Characteristics

There are many risk factors that impact coal resources development investment projects, in general, we can divide into the following aspects, in the first place, we call it market risk factors which mainly reflect the volatility of coal prices, due to the substitutability between coal and oil, fluctuations in oil prices caused by International incident would inevitably lead to changes in domestic coal prices, moreover, fluctuations in coal prices is also affected by the supply and demand of the domestic coal market situation. Secondly, risk factors on resource endowments, which are peculiar to mineral resources investment projects, with no exception for coal resources investment projects. Resources endowments mainly refers to the resource reserves, coal types, geological structure etc., rich resource endowments will not only get more recoverable reserves but also reduce development costs, and increase the project value, however, poor resource endowments have the opposite effects. Last but not least, we consider risk factors on policies and regulations. Related environmental policies will have an impact on investment projects when the coal resource development investment will inevitably cause damage, such as vegetation destruction, soil erosion and so on, in addition, technical and managerial aspects of risk factors can also lead to changes in the value of coal resource development investment projects, these risks are controllable, so we don't explore them in the paper.

The above-mentioned risks what coal resources deep processing project equipped with risk factors bring to the project value, because of uncertainty about these risk factors, policymakers should make investment decisions according to its changing. In the project preparation stage. policymakers can delay investment if policy guidance is not clear, or relevant taxes and interest rate are higher than what it would to be. In the project production stage, policymakers can expand production when the coal prices are high. While the coal prices are low, then policymakers will suspend production, waiting for market conditions to improve, and they may abandon the project if the market continued to fall. The risks from the option to delay investment, expand production, suspend production and abandon the project are avoided, which add value to the project.

Model Construction

Market risk, resource endowments, policies and regulations are the main risk factors for coal resource development investment projects, changes in these factors may cause fluctuations in coal prices and the project value, even lead to jump the change, thence, on the basis of the literature references (Dixit and Pindyck 1994), the coal prices are assumed to be a mixed Brownian motion/jump process.

$$dP = aPdt + \sigma Pdz + Pdq \tag{60.1}$$

In the formula one, dz is the increment of a Wiener Process, $dz = \varepsilon_t \sqrt{t}, \varepsilon_t$ is said to be normally distributed random variables, with a mean of zero and a standard deviation of 1, a is a drift parameter, σ is variance parameter, q is called a Poisson Jump Process.

$$dq = \begin{cases} 0, & \text{Probability } 1 - \lambda dt \\ \phi, & \text{Probability } \lambda dt \quad (\phi > -1) \end{cases} \tag{60.2}$$

In the formula two, coal prices will fluctuate as a geometric Brownian motion. For each time interval dt, it will be $(1+\phi)$ times its initial value by probability of λdt, then continue to fluctuate towards the occurrence of another event. We assume that $\phi \in (-1, +\infty)$, the unexpected events have a negative effect on coal prices when ϕ is negative, In contrast, the events are positively correlated with coal prices while ϕ is positive.

According to the literature which is reviewed by Dixit and Pindyck, they consider that $F(P)$ represents option value of coal resource development investment projects, and $V(P)$ is representative of project value of coal resources development investment, then option value and project value are expressed as follows

$$0.5\sigma^2 P^2 F''(P) + (r-\delta)PF'(P) - (r+\lambda)F(P) + \lambda F[(1+\phi)P] = 0 \tag{60.3}$$

$$0.5\sigma^2 P^2 V''(P) + (r-\delta)PV'(P) - (r+\lambda)V(P) + \lambda V[(1+\phi)P] + P - C = 0 \tag{60.4}$$

In the formula three and four, $\delta = r - a$, which stands for the convenience yield, r is used as the risk-free interest rate, the unit cost of the project of deep processing of coal resources, C represents the unit cost of coal resources deep-processing project.

The option pricing method had been brought forward by Dixit and Pindyck, project option value and project value can be expressed as follows.

$$F(P) = A_1 P^{\beta_1} \tag{60.5}$$

$$V(P) = \begin{cases} K_1 P^{\beta_1}, P>C \\ B_2 P^{\beta_2} + \frac{P}{\delta - \lambda\phi} - \frac{C}{r}, P>C \end{cases} \tag{60.6}$$

A_1, K_1 and B_2 are undetermined coefficient, β_1 and β_2 can be obtained by formula 60.7,

$$0.5\sigma^2 \beta(\beta - 1) + (r-\delta)\beta - (r+\lambda) + \lambda(1+\phi)^{\beta} = 0 \tag{60.7}$$

According to value-matching condition and smooth pasting condition

$$\begin{cases} F'(P^*) = V'(P^*) \\ F(P^*) = V(P^*) - I \end{cases} \tag{60.8}$$

Solutions form of A_1, K_1, B_2 are as follows

$$A_1 = \frac{(1-\beta_2)P^{*(1-\beta_1)}}{(\delta - \lambda\phi)(\beta_1 - \beta_2)} - \frac{\beta_2 P^{*-\beta_1}}{(\beta_1 - \beta_2)}\left(\frac{C}{r} + I\right) \tag{60.9}$$

$$K_1 = \frac{C^{1-\beta_1}}{\beta_1 - \beta_2}\left[\frac{\beta_2}{r} - \frac{\beta_2 - 1}{\delta - \lambda\phi}\right] \tag{60.10}$$

$$B_2 = \frac{C^{1-\beta_2}}{\beta_1 - \beta_2}\left(\frac{\beta_1}{r} - \frac{\beta_1 - 1}{\delta - \lambda\phi}\right) \tag{60.11}$$

We can use the following formula 60.12 to obtain the value of P^*

$$(\beta_1 - \beta_2)B_2(P^*)^{\beta_2} + (\beta_1 - 1)\frac{P^*}{\delta - \lambda\phi} - \beta_1\left(\frac{C}{r} + I\right) = 0 \tag{60.12}$$

Empirical Research

Basic Data of Coal Resource Development Projects

After obtaining exploitation rights of some mining areas in Jurassic coalfield, a mining company of Northwest had better analyze the next investment decisions based on survey report and market situation. The survey report shows that minefield area covers 31.6 km^2, with recoverable reserves of 60 million tons, the main coal type is long flame coal with mid-ash, low-sulfur and high calorific value. According to the coal price data between 2001 and 2010 in the region, we conclude that annual volatility of coal price is around 15%, we set risk-free interest rate called r at 4%, based on interest rate of government bonds in 2011. Through past experiences and literature retrieval, the convenience yield of project δ is set at 0.02 (Table 60.1).

Testing Results

Due of the presence of uncertain risk factors, it's feasible for mine enterprises to invest on coal resource development projects, only when coal resources development investment projects worth more than the investment critical value. It can be seen that critical investment value is much larger than the project's initial investment (Table 60.2).

Parameter Analysis

It can be seen from the evaluation results, the presence of uncertainty increases the critical value of the coal development investment projects, which impacts critical investment value of the projects that needs further analysis. According to influence

Table 60.1 Basic data and parameter settings of coal development investment projects

Model parameters	Parameter values
Project's initial investment (unit: million yuan)	145
Production cost (unit: yuan)	216
Estimated total yield (unit: million tons)	60
Mine service life (unit: year)	30
Annual output capacity design (unit: million tons)	2
Convenience yield (unit: %)	2
Risk-free interest rate (unit: %)	3.9
Annual volatility of coal price (unit: %)	40

Table 60.2 Calculated results

Project's initial investment.	Critical investment value	Critical investment price
145 (million yuan)	1,654.7 (million yuan)	278 (yuan/ton)

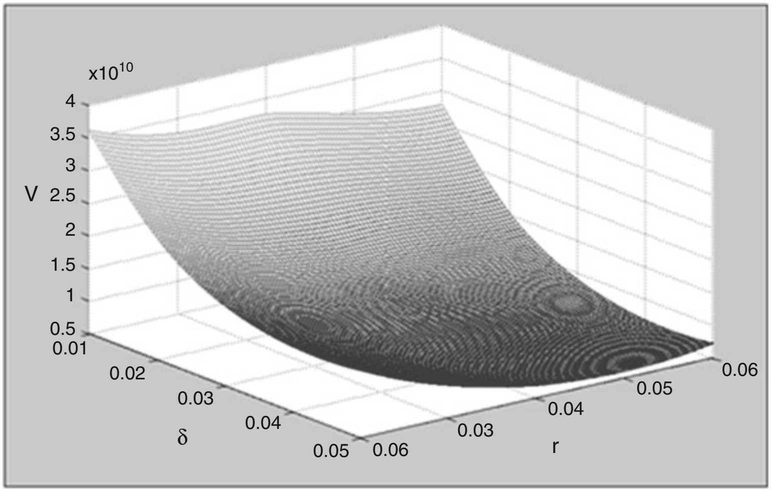


Fig. 60.1 Influence of interest rates and convenience yield on critical investment value

of interest rates and convenience yield on critical investment value, from Fig. 60.1, we can find that interest rates and convenience yield have a negative effect on critical investment value of the projects. Increase of interest rates will reduce critical investment value of the projects, namely, it will lower the access threshold of investment projects. The convenience yield reflects the abundance of resources, the greater the convenience yield, the higher resource abundance. High convenience yield will facilitate completion of the project as soon as possible, also lower the access threshold of investment projects.

It can be seen from Fig. 60.2, when jump frequency level is fixed, critical investment value of the project is improving with the increase of coal price volatility,

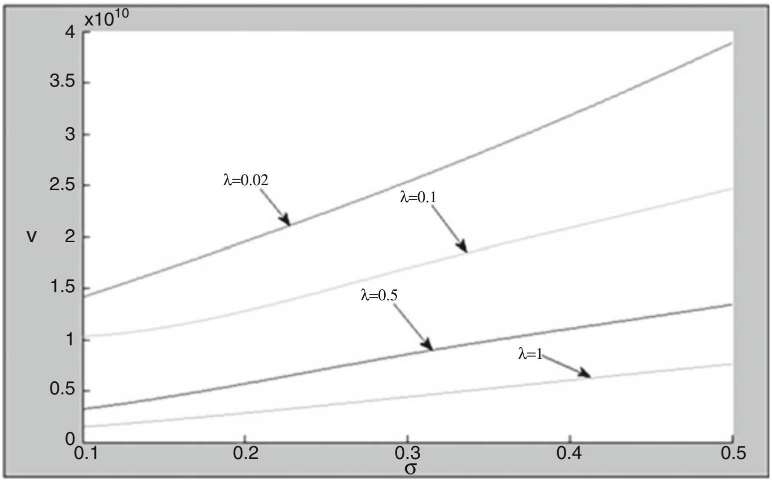


Fig. 60.2 Influence of coal price volatility and jump frequency on the critical investment value

Table 60.3 Influence of jump frequency on critical investment value

Unit: million yuan

ϕ	−0.9	−0.6	−0.3	0	0.3	0.6	0.9
V	8,809.5	10,949	15,208	20,476	34,055	70,292	258,730

this means that the high volatility of coal prices will improve the access threshold of investment projects. In the case of fixed coal price volatility, the high jump frequency will reduce the critical investment value of the projects, namely, it lower the access threshold of investment projects, and facilitate completion of the project quickly.

By Table 60.3, we can find that jump-amplitude changes from the negative to the positive, the investment critical value of projects have increased, when other parameters are kept constant, it can be considered that adverse events will reduce investment value of projects, while favorable events contribute to the value of projects to a certain extent, which will lead to invest on projects by decision-maker in higher investment thresholds.

Conclusion

Coal is China's major energy resource. In recent years, with the rapid growth of coal consumption, coal resource development investment projects are gradually gaining mass attention, how to scientifically and rationally assess the value of coal resource development investment projects has important significance. Using the real options method, the paper builds a evaluation model of coal resources development investment project, and uses the model through empirical research, the results show that interest rates and convenience yield have a negative effect on critical investment value of the projects, the high interest rates and convenience yield will lower the access threshold of investment projects, and increase the attractiveness of projects. The high jump frequency will reduce the critical investment value of the projects, namely, it lower the access threshold of investment projects, and facilitate completion of the project quickly. Jump-amplitude changes from the negative to the positive, the investment critical value of projects will increase, but adverse events can reduce it. Favorable events contribute to the value of projects to a certain extent, which will lead to invest on projects by decision-maker in higher investment thresholds.

Acknowledgment This work was financially supported by the National Natural Science Foundation of China (No. 70873094).

References

Abdel Sabour SA (2001) Dynamics of threshold prices for optimal switches: the case of mining [J]. Resour Policy 27(3):209–214

Amrma M, Kulatilaka N (1998) Real options: managing strategic investment in an uncertain world [M]. Harvard Business School Press, Boston, pp 87–98

Brennan M, Schwrts ES (1985) Evaluation natural investments [J]. J Bus 57:135–157

Copeland T, Antikarov V (2001) Real options [M]. Texere, New York, pp 121–136

Dixit A, Pindyck RS (1994) Investment under uncertainty [M]. Princeton University Press, Princeton, pp 56–65

Frimpong S, Whiting JM (1997) Derivative mine valuation: strategic investment decisions in competitive markets [J]. Resour Policy 23(4):163–171

Jin-suo Zhang (2002) Study on evaluation methods of mineral resources assets [D]. Xi'an Jiaotong University, Xi'an, pp 36–56 (In Chinese)

Jin-suo Zhang, Shao-hui Zou (2006) Study on mechanism of coal mining option [J]. J Xi'an Univ Sci Technol 26(1):121–124 (In Chinese)

Jin-suo Zhang, Shao-hui Zou (2009) Study on methods of the coal resources investment decision based on real option [J]. China Min Mag 18(9):21–26 (In Chinese)

Jin-suo Zhang, Shao-hui Zou, Tao Wang (2012) An investment decision model for coal resource development based on multiple real option. J Xi'an Univ Sci Technol 32(1):19–24 (In Chinese)

Lei Zhu, Fan, Yi-ming Wei (2009) An optimal investment model for mineral resources based on real option theory [J]. Chin J Manag Sci 17(2):36–41 (In Chinese)

Myers SC (1977) Determinants of corporate borrowing [J]. J Financ Econ 5:147–175

Neng-fu Zhang, Si-jing Cai, Chao-ma Liu (2002) Application of option pricing theory to decision-making on mining projects [J]. J Univ SciTechnol Beijing 24(1):5–7 (In Chinese)

Neng-fu Zhang, Si-jing Cai, Chao-ma Liu (2003) Real option evaluation method of investment value of mining projects. J China Univ Min Technol 32(4):455–458 (In Chinese)

Paddock J, Siegel D, Smith J (1988) Options valuation of claims on physical assets: the case of offshore petroleum lease [J]. Q J Econ 103(3):479–508

Pindyck RS (1999) The long-run evolution of energy prices [J]. Energy J 20(2):1–27

Saito R, de Castro GN, Mezzomo C, Schiozer DJ (2001) Value assessment for reservoir recovery optimization [J]. J Pet Sci Eng 32:151–158

Slade M (2001) Valuing managerial flexibility: an application of real-option theory to mining investments [J]. J Environ Econ Manag 40:193–233

Tao Wang, Jin-suo Zhang, Shao-hui Zou (2012) An evaluation model for coal mining exploration and investment projects based on real option. J Xi'an Univ Sci Technol 32(1):13–18 (In Chinese)

Trigeorgis L (1996) Real options: management flexibility and strategy in resource allocation [M]. MIT Press, Cambridge, pp 98–102

Yong-feng Zhang et al (2006) Study on strategic economic evaluation of oil & gas exploration projects based on compound real options [J]. Nation Gas Ind 26(3):138–141 (In Chinese)

Chapter 61
Structure and Optimization of the Business Ecosystem—Case Study on Jinguang Group

Li-jun Yue

Abstract Different from the strategic view which places the emphasis on how an enterprise grabs the leadership in a business ecosystem, this paper focuses on how an enterprise strategy builds a successful business ecosystem. Based on a summary of the business ecosystems connotations, this paper analyzes the structural models in business ecosystem, explores the strategic positioning and strategic choice of enterprises in business ecosystem, and finally comes up with recommendations for optimizing the business ecosystem combining with the actual case of the Jinguang Group.

Keywords Business ecosystem • Core business circle • Strategic positioning

With the rapid development of social economy and technology, competition among enterprises turns from competition between single enterprises into competition in supply chain, and gradually evolves into competition in ecosystem and business model. Enterprises which can build a more exceptional business ecosystem and create a more complete business model will be able to take a more advantageous position in the future competition.

Connotations of Business Ecosystem

Since James F. Moore originated the concept of "business ecosystem", the business ecosystem theory has been widely researched by the academia with great progress.

L.-j. Yue (✉)
Business School, Shandong Jianzhu University, Jinan, China
e-mail: lidiayue@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_61,

The Concept of Business Ecosystem

The metaphor of ecosystem was first used in business research by James F. Moore, who published in the *Harvard Business Review* an article of "Predators and Prey: A New Ecology of Competition". In this article he first proposed the concept of "business ecosystem". He defines the business ecosystem as an economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. A business ecosystem includes consumers, lead producers, competitors and other stakeholders. Among them, lead producers are the "key species" in a business ecosystem, which plays an important role in co-evolution (Moore 1993). Later, James F. Moore further improved the connotation of business ecosystem, defining it as an "extended system of mutually supportive organizations; communities of customers, suppliers, lead producers, and other stakeholders, financing, trade associations, standard bodies, labor unions, governmental and quasigovernmental institutions, and other interested parties. These communities come together in a partially intentional, highly self-organizing, and even somewhat accidental manner (Moore 1996)".

Members in a business ecosystem constitute a value chain, similar to the food chain in the natural ecosystem. Through interacting with their business environment, the members form a complex co-evolutionary system in a symbiotic relationship of mutual cooperation with each other (Moore 1998). The business ecosystem is a complex system. The boundary of a business ecosystem is not limited to the system size and its geographical location; it may exist within the conventional industry limit or cross several industries (Agiza et al. 1997). Cooperation and competition between members of the business ecosystem is under the premise of trust, commitment and agreement. They, mainly in the forms of supply chain, subcontract, insertion compatibility and virtual collaboration and through information exchange for interactive participation, form a dynamic alliance with mutual influence and achieve common development. This relationship of cooperation and competition require attention of the enterprises to their own development and the influence of other enterprises on them (Kauffman 1993).

The Nature of Business Ecosystem

Seen from the perspective of business ecosystem, such a system does not only focus on the symbiosis and dependence between enterprises in the core layer, but also is concerned about the external environment and stakeholders, as well as the capital flow, logistics, information flow, and personnel flow among various interfaces (Power and Jerjian 2001). The business ecosystem is committed to coordinated development among the members, realizing the seamless integration of demands among the members (Anderson 1999). Therefore, co-evolution is the nature of the business ecosystem and the goal of its evolution. Co-evolution is not simply a collective evolution; it refers to joint development of the system members in cooperation and competition.

Table 61.1 The differences

	Difference	Traditional business system	Business ecosystem
1	Business philosophy	Life and death, limited cooperation	Survival of the fittest, co-evolution
2	Mode of competition	Competition between individual enterprises	Competition between business ecosystems
3	scope of stakeholders	Direct suppliers, brokers and direct customers	Core ecosystem, extended ecosystem, maintenance system and external environment system
4	Mutual relationship	Pure buyer-seller relationship and contractual relationship	Mutually beneficial symbiotic relationship for co-evolution
5	Information	Blocked	Shared
6	Drivers	Maximizing profits	Maximizing the profits of the business ecosystem as a whole

In traditional business systems and business ecosystems, the management philosophy, mode of competition, as well as the relationship between enterprises, show significant differences, as shown in Table 61.1.

Structure Model of Business Ecosytem

A business ecosystem contains subsystems of a variety of types and multiple layers, such as enterprise subsystem, customer subsystem, and environment subsystems. The interaction between different layers and components in the business ecosystem gives rise to the structural complexity of the business ecosystem (Merry 1999).

Core Business Circle

The innermost layer of a business ecosystem is the core business circle, which is the core of the entire business ecosystem. This layer is mainly composed of core enterprise and its direct customers, direct suppliers and distributors, who can be seen as the primary species of the business ecosystem. The starting point for formation of a business ecosystem is the appearance of core products and services. Core products and services are generally provided by the core enterprise, which defines the core value of meeting the consumer's demand and lies at the core of the core business circle. Around core products and services, the rightward extension is sales channels and complementary suppliers of products and services, which link is the basis for an enterprise to realize profits; leftward extension is direct suppliers, which link is premise to ensure the quality of core products. In summary, the internal driver of the core business circle is customer demand.

Extended Business Circle

The second is the extended business cycle. The extended business circle is mainly composed of suppliers of suppliers, customers of customers, which can be seen as the influencing or constraining persons of primary species. The full consumer experience depends not only on the core product or service, but also on a variety of complementary products and services which increase the customer experience.

Support and Maintenance Circle

The third is the support and maintenance circle. This circle mainly includes governmental organizations and support organizations. It, on the basis of the core business circle and the extended business circle, further incorporates government departments, regulatory bodies and other stakeholders (such as investors, owners, trade associations, standard-setting organizations and trade unions).

External Environment Circle

The last is the external environment circle where the business ecosystem exists, including political environment, market environment, competitive environment, technological environment, regional environment and cultural environment.

These species or groups are established consciously to some extent, the result of which is to enhance the leadership of the core enterprise through the strengthening of marketing, determination of standards and resolution of disputes. The other members strive for the common development of the system by making their own contribution. The members perfect and complement each other, thereby enhancing the overall competitiveness of the system. In this way, the core business circle, extended business circle, support and maintenance circle as well as external environment circle constitute a business ecosystem with interrelationships (Xing-yuan Wang 2005).

Optimization of Jinguang Group's Business Ecosystem

Company Introduction

Jinguang group is based on Jinguang FRP Group which is one of the leading manufactures of FRP (Fiber Glass Reinforced Plastic) products in China established in 1971, has the total assets of over 620 million RMB, with a total

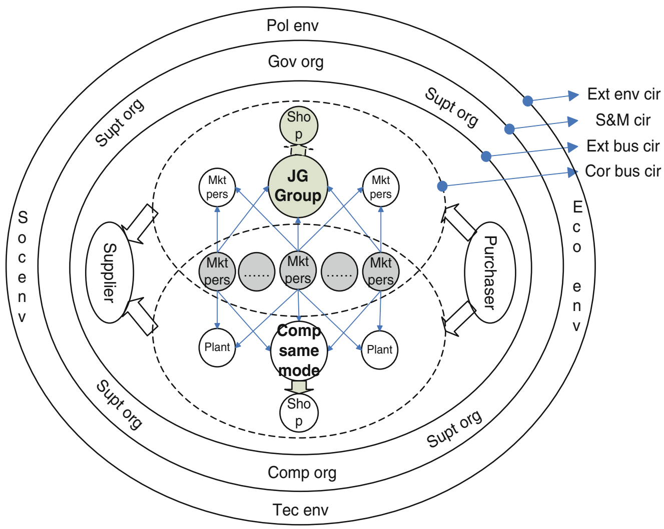


Fig. 61.1 Jinguang Group's business ecosystem structure

500,000 m^2 and more than 2,600 employees. Its major products are fiberglass high pressure pipe, steel structure, fiberglass high composite material, which enjoy a high reputation in 25 countries and regions.

Structure of Jinguang Group's Business Ecosystem

Jinguang Group's business ecosystem consists mainly of the core business circle, expand business circle, support and maintenance circle, and external environment, as shown in Fig. 61.1.

Core Business Circle

The core business circle is mainly composed of its core enterprises and its customers, suppliers. The core enterprise is an enterprise, which through building a business ecosystem platform, creates a reasonable value sharing mechanism, attracts and integrates with other organizations to join the system, and effectively expands the final product or service consumer markets, and achieves the healthy development of the entire business ecosystem (Geng-shen Zhong and Zhen-zhen Cui 2008). In the core business circle, the Jinguang Group is at the core position, with marketing personnel being the enterprise's customers, and its manufacturing plants and other production plants outside of the Jinguang Group being the suppliers. The function of the core business circle of the Jinguang Group business ecosystem is similar to enterprise, but its mode of operation is completely different.

The Jinguang Group provides an operating platform for the marketing personnel and production division, including financial, qualification, and brand services; it is responsible for coordinating the marketing personnel and production division, project owner and after-sales service. Marketing personnel through the operating platform provided by the Jinguang Group seek project contracts from outside organizations. After signing ofcontract, the use of important products or components is controlled by the Jinguang Group. The marketing personnel can look for outside manufacturing plants for other products. The suppliers are divided into two categories: the Jinguang Group's production division and independent manufacturers outside the four plants. The Jinguang Group's production division mainly receives orders through the Jinguang Group, and it has the priority for receiving orders for controlled products specified by the Jinguang Group in contract. Independent manufacturing plants outside the Jinguang Group obtain orders through their relationship with the marketing personnel or by providing more competitive products or pricing.

Extended Business Circle

The extended business circle is mainly composed of suppliers of suppliers, customers of customers, and competitors of the same mode. Suppliers of suppliers mean suppliers who supply raw materials and components to suppliers in the core business circle (workshop and production plants) required for production. Customers of customers mean customers faced by the marketing personnel. Currently, the Jinguang Group's customers of customers are mainly in large and medium-sized cities in the northern areas, involving 19 sectors including real estate, electricity, school, oil, dairy, chemical, textile, coal, steel, paper making, and hospital. Competitors of the same mode mean the other three local enterprises which adopt the same mode of operation as the Jinguang Group. They share customer resources with the Jinguang Group and produce similar products to meet the same customer needs.

The core business circle procures parts and raw materials from external suppliers for manufacturing, thus completing the customers' projects. External suppliers can be divided into two types: existing suppliers and potential suppliers. Existing suppliers include parts suppliers (such as suppliers of main machine for brand central air conditioner and other production parts) and raw material suppliers (such as glass fiber manufacturers; installation and construction suppliers, such as water and heating engineering brigades). Potential suppliers mean enterprises whose products may replace the existing raw materials or parts in the future. Customers are divided into existing customers and potential customers. Existing customers include enterprises in the real estate, rail transport and chemical industries, and potential customers mean enterprises which are currently not using our products but may use our products in the future.

Support and Maintenance Circle

The support and maintenance circle includes the extended business circle, government organizations, support organizations (including banks, consulting firms, advertising agencies), and competitors (other enterprises which share products, services, processes and organizational arrangements, such as plastic pipe, steel pipe enterprises). These groups are established consciously to some extent, the result of which is to enhance the leadership of the core enterprise through the strengthening of marketing, determination of standards and resolution of disputes. The other members strive for the common development by making their own contribution. The members perfect and complement each other, thereby enhancing the overall competitiveness of the system.

External Environment Circle

The external environment means the social macroeconomic environment in which the business ecosystem sustains and develops, including political environment, economic environment, social environment and technological environment. The business ecosystem is not only subject to the limitation of the natural environment, more importantly, it is subject to the influence of changing social and economic environment.

The Jinguang Group's Strategic Positioning in the Business Ecosystem

In the core business circle, different participants are responsible for different activities in the value chain: the marketing personnel are responsible for sales activities, the production division, or other plants are mainly responsible for production, and the Jinguang Group provides enterprise infrastructure, such as financial, qualification, and overall management. Participants cooperate with each other, completing the traditional functions of enterprises in a different model. These different participants can be divided into three types of business patterns: operating platform provider, agent, and product manufacturer, as shown in Table 61.2.

The positioning of the Jinguang Group in the business ecosystem is the operating platform provider, which takes the central position in the core business circle, provides shared assets to system members and makes efforts to find effective methods to create value and ensure the efficient operation of the share creation activities in the entire chain, and shares value with other members. The position of marketing personnel in the business ecosystem is an agent, which, through the operating platform, seeks project contracts from external enterprises and provides product distribution channels; manufacturing plants outside the production division

Table 61.2 Classification of different business patterns

	Business pattern	Main features	Profit model	Representative
1	Operating platform provider	Provides infrastructure for value creation activities, indirectly completes the value creation activities, has considerable control capability over partners	The income is mainly from management fees of agents projects rent for buildings or equipment paid by some manufacturing plants	Jinguang Group
2	Agent	Take use of the operating platform, provides product sales channels, responsible for product sales in the value chain	Procure products from manufacturers or external suppliers to complete enterprise's outside projects and make money out of the difference in price	Marketing personnel
3	Product manufacturer	Manufactures products in leased or self-owned buildings and equipment, and responsible for the quality of products during use	Making profit through cost-effective completion of orders	Production division, manufacturing plant

and the Group is positioned in the business ecosystem as manufacturers, responsible for the manufacturing of products in project contracts.

Through the mutual collaboration and cooperation of the operating platform provider, agent, and product manufacturers, the core business circle has the functionality of a traditional enterprise, capable of providing core products and services, with the ability to bring great value to external customers.

Optimization of Business Ecosystem Based on Industrial Chain Cooperation Analysis Framework

The industrial chain cooperation analysis framework for the Jinguang Group based on business ecosystem has the four major considerations as follows:

Identify Key Drivers to Build a Business Ecosystem in the HVAC Industry

The operation driver of business ecosystem is not from outside the system or top layer of the system, but from the relationship or interaction among members within the system, who spontaneously interact to produce system rules. Currently, the operation driver of the business system in which Jinguang Group is a member comes mainly from the interaction between Jinguang Group, marketing personnel, and the division. Among these relationships, the relationship between Jinguang Group and the marketing personnel is dominant, which is a key driver of the business ecosystem. Around the market demand represented by the marketing personnel, Jinguang Group and the division should try to provide support to ensure product quality and safety. In the meantime, the drive means should be adjusted around the key driver. For example, R&D investment should be increased and new technologies should be introduced in future development to provide more quality products and achieve the healthy functioning of the business ecosystem.

Build a Value Creation and Sharing Mechanism in Jinguang Group's Business Ecosystem

The establishment of a value creation and sharing mechanism is the basic condition for a business ecosystem to maintain and attract members. Creating value is the basis for the existence of a business ecosystem, and a good value sharing mechanism is the measure to guarantee sustainable development of a business ecosystem (Geng-shen Zhong and Zhen-zhen Cui 2009). The core enterprise only creates value, but cannot effectively transfer and share this value in the entire ecosystem, in which case the enterprise can only make huge profits for a short time.

First of all, build a value creation platform that deals with the common problems in the ecosystem. This platform can be a tool or a technique, or a service. All partners of Jinguang Group sharing the platform, they can improve efficiency, enhance stability, and use this platform as a cornerstone for innovation. This platform can help member enterprises in the ecosystem reduce duplicated investment and costs; technology and resources are shared among system members to strengthen cooperation among themselves.

Second, coordinate the relationships between the three core elements of the business ecosystem in value creation, which are customer value, core competencies, and member relationships.

Third, establish a scientific value sharing mechanism. The key element of value sharing is the proportion of resources taken by members in the value creation process and their contribution to value creation. The members, based on their contribution to the value and the proportion in the provision of key advantageous resources, share the value created.

Attract Supportive and Auxiliary Drivers to Join Jinguang Group's Business Ecosystem

A system wishing to develop must have an open environment, continue to accept system members and exchange with the outside world. The principal role with the leadership (often the key driver) integrates all interested parties to form a network to obtain the support of government and broad alliances (Geng-shen Zhong et al. 2010).

First, seek government support. The behavior of the system has to be consistent with government policy, coordinated with public values, and the system has to establish a symbiotic relationship, only in this way, the value creation activities of the business ecosystem do not result in opposition from the government and society. In order to achieve its own interests, the system has to actively participate in public activities, seek influence on government policies or actions, actively participate in government's formulation of policies and regulations on the development of enterprises get involved in promoting government regulation to monitor its behavior, participate in government efforts to create a social environment suitable for enterprise development.

Second, attract NGO participation. Actively participate in NGO, particularly the activities of trade associations, support their activities, and gradually guide them to participate in the business ecosystem and play a role in the healthy development of the system.

Reorganize or Restructure the Business Ecosystem According to Environmental Changes

To cope with the dynamic uncertain environment, the business ecosystem forms a co-evolution mechanism. In their self-improvement and transformation, each member must pay attention to and cooperate with other members of the system, and the other members should make self-investment and work with efforts to achieve the goal of reorganization or restructuring. In this process, the backbone or core member plays a more critical role.

Jinguang Group can split the business in accordance with the strength of capability, leaving the most important and core business and splitting the rest, thereby reviving the entire business ecosystem through the strong market incentives; Jinguang Group may also take the dominant position in the market by developing and maintaining industry standards, and investing in expanding the alliance community; at the same time, it may attract more members to joint its business ecosystem sharing values with the member enterprises or disseminating related values. For example, it may build its image through technical guidance and training of personnel.

Conclusion

Committed to building a successful business ecosystem, many enterprises have achieved great commercial success. Currently, the ecological environment of enterprise is increasingly complex. In order to survive and develop in the fierce competition in the future, enterprises should overcome the defects and bounds in traditional concepts, reconsider the positioning and development from the new perspective of business ecosystem, and look for their own ecosystem and explore new space for development.

References

Agiza HN, Elettreby MF, Ahmed E (1997) On a generalized model of biological evolution. J Stat Phys 88(3/4):985–989 (Periodical style)

Anderson P (1999) Complexity theory and organization science. Organ Sci 10(3):216–232 (Periodical style)

Geng-shen Zhong, Zhen-zhen Cui (2008) The value and limitations of business ecosystem metaphor. J Shandong Univ (Philos Soc Sci) 6:117–121 (Periodical style)

Geng-shen Zhong, Zhen-zhen Cui (2009) Business ecosystem theory and its development direction. Dongyue Trib 6:27–33 (Periodical style)

Geng-shen Zhong, Hai-hua Yang, Fang Wang (2010) Internal risk identification and control of business. Ecosyst Shandong Soc Sci 12:81–84 (Periodical style)

Kauffman S (1993) The origins of order: self-organization and selection in evolution. Oxford University Press, New York, 709 p (Book style)

Merry U (1999) Organizational strategy on different landscapes: a new science approach. Syst Pract Action Res 12(3):257–278 (Periodical style)

Moore JF (1993) Predators and prey, the new ecology of competition. Harvard Bus Rev 71 (3):75–83 (Periodical style)

Moore JF (1996) The death of competition: leadership and strategy in the age of business ecosystems. Harper Business, New York, 297 p (Book style)

Moore JF (1998) The rise of a new corporate form. Wash Q 21(1):167–181 (Periodical style)

Power T, Jerjian G (2001) Ecosystem: living the 12 principles of networked business. Pearson Education Ltd., London, 392 p (Book style)

Xing-yuan Wang (2005) Business ecosystem theory and its research significance. Sci Technol Prog Policy 22(2):175–177 (Periodical style)

Chapter 62
The Management and Relationship Between Different Frequency Noise and Subjective Annoyance

Shi-qiang Wang, Liu Xu, Ling Zhang, and Xian-kuan Li

Abstract This paper is aimed to explore the influence of different frequency noises to subjective annoyance. In order to analyze the impact, the surveying community-citizens were divided into different groups in accordance with the purposes of the analysis, and the different degrees of the noise-influence was analyzed by contrast with different groups. The results showed that the subject annoyance was influenced by the noise and has the positive correlation with the noise level and the noise frequency, especially the low frequency noise having obvious influence on the elders.

Keywords Different frequency noise • Subject annoyance • Low frequency noise • High frequency noise • Water pump's noise • Subway' noise

Introduction

Noise is one of the four major pollutions, and it exists everywhere (Yu-jun Tian et al. 2003). The noise pollutes the environment and hazards human health (World Health Organization 1980). The high-intensity noise may induce hearing loss and the low-intensity noise may interfere with human rest, so the noise has harmful effect on the quality of human's daily life, such as the subject annoyance and sleep quality (Zhi-suo Liu et al. 2003; Gaab et al. 2008). The serious subject annoyance

S.-q. Wang (✉) • X.-k. Li
The Research Center of Noise and Vibration, Beijing Municipal Institute of Labor Protection, Beijing, China
e-mail: wangshiqiang0819@163.com

L. Xu
The Research Institute of Henan Coal and Chemical Industry Group, Zhengzhou, China

L. Zhang
ANHUI Academy of Safety Science and Technology, Hefei, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_62,

can cause sleeplessness, so assessing individual annoyance is mainly to investigate the sleep quality of the residents (Ana Lucia Rios and Geruza Alves da Silva 2005). The subject annoyance is in connection with the environment of sleeping, while the sound environment is one of the important factors. Many people have suffered from sleep disorder, because their bodies could not adapt to sound environment of their bedrooms. The sound in the bedrooms makes them uneasy, even leading to sleepless (American Sleep Disorder Association 1990; Pedemonte et al. 1997). The sound is a very complex component, which is composed of many different frequency pure tones, and different persons have different reactions to various sounds. The certain frequency noises that are sensitive to these people made them suffering sleep disorder (MuzetAlain 2007; Eberhardt and Akselsson 1987). So the high quality of sleep needs the good sound environment and to keep away the sensitive frequency noise from them.

Subjects and Methods

Subjects

For the questionnaires and investigation, we have collected 59 residents, asking them to live in the different sound environments, namely, the quiet environment, the environment with the water pump noise and the environment with the subway noise that were tested by Norsonic Type 118. The frequency spectrum data of the three kinds of noises are shown in Figs. 62.1, 62.2, and 62.3 respectively.

The investigated residents are composed of 28 males and 21 females. The eldest is 67, the youngest is 5 years old, and average age is 52.5. As to the noise levels, the quiet environment is 27–34 dB, the noise of water pump is 28–39 dB and the subway noise is 29–41 dB. As to the noise types, the quiet environment stands for no-outside noise, while the noises of the water pump and the subway represent to the low frequency noise. In addition, the investigated subjects have no disease to sleepless, and the control group and exposure group have no statistics signification ($F = 0.24$, $F = 5.27$; $P > 0.05$).

Methods

The collected data were divided into different groups in accordance with the purpose of the analysis, and after the comparison the differences of the groups were concluded. The 59 residents were divided into 3 groups according to the types of noises mentioned above. People living in quiet were in group 1 including 20 persons, the residents living with water pump noise made up group 2 including 17

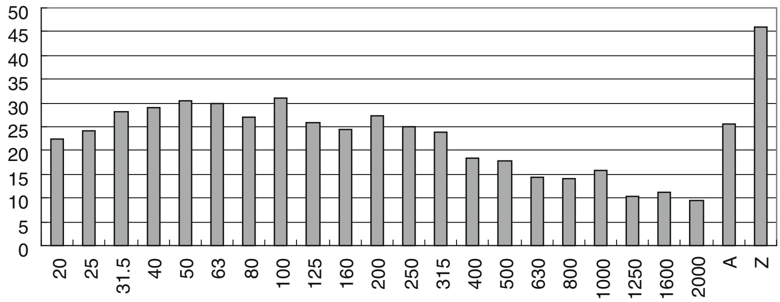


Fig. 62.1 The frequency spectrum figure of background noise in bedroom

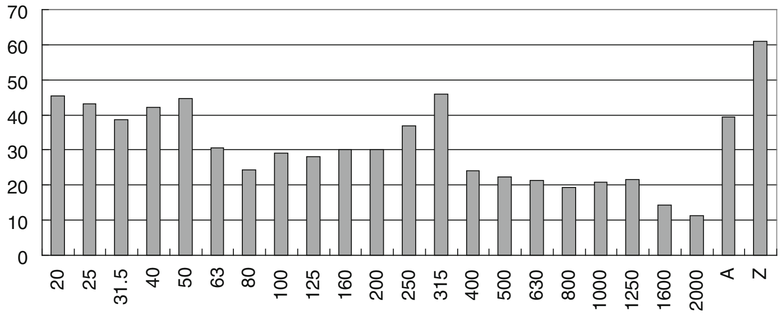


Fig. 62.2 The frequency spectrum figure of water pump's noise in bedroom

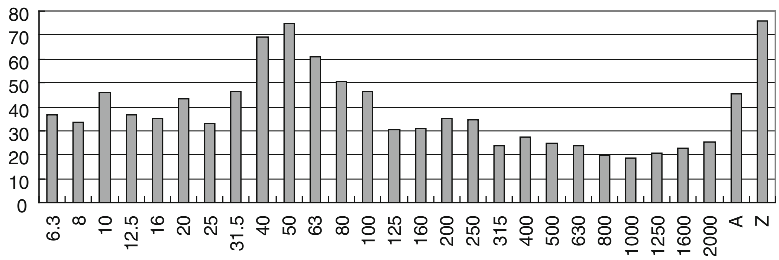


Fig. 62.3 The frequency spectrum figure of subway's noise in bedroom

persons and the rest members were in group 3 including 22 persons living with the subway noise.

Meanwhile the group 1 was also a control group, and the group 1 and 2 were known as the exposure groups. The next step is to analysis the relations between the three types of noises and subject annoyance individually.

The questionnaires were sent to the residents and collected after the subjects finished. The questionnaires were 59 in total and the investigation subjects were 59 persons, so the rates of sending and taking-back about questionnaires is 100%. With

Table 62.1 The relation between subjects annoyance and age

			Incident rates (%)	
Age (year)	Controlled group	Exposure group	Control	Exposure
~25	5(0)	7(1)	0.00	14.29
~40	6(0)	9(7)	0.00	77.78
~55	4(1)	10(5)	25.00	50.00
>55	5(2)	13(10)	40.00	76.90
Total	20(3)	39(23)	15.00	58.97

regard to the questionnaire contents, it primarily contains subject annoyance, sleep quality and other information such as age, and gender. Since the different grades of subject annoyance may cause varying influence to human health, assessing the subject annoyance was the key item to investigate sleep quality of the residents.

Results

The Relation Between Subject Annoyance and Age

Concerning the age composition of the investigated residents, the 59 people were divided into four ranges as shown in Table 62.1.

Table 62.1 explores the relationship between age and subject annoyance that the subject annoyance has declined markedly with the age increasing in the both columns of control group and exposure group. And by the comparison with the two groups, the subject annoyance of exposure group is worse than control group, which prove that the age is an important factor to influence the subject annoyance.

The Relationship Between Subject Annoyance and Type of Noise

In terms of subject annoyance, it could be divided into three levels according to the difficulties of sleep. They are Normal which means non-impacted by noise, Moderate representing interruptive but no insomnia, and Severe expressed suffering insomnia. That information was acquired by the interview and the questionnaires investigation, and after analyzing the results of statistic are shown in Table 62.2.

In Table 62.2, 17 persons of control group have normal sleep which takes the percentage of 85% while the moderate is only 15%. However, as to exposure group 1 that lived in a water pump noise environment, there are 29.41% persons' sleep been impacted by the noise moderately and 29.41% persons' sleep been severely influenced. As to exposure group 2, there are 34.36% persons' sleep been impacted by the noise moderately and 32.82% persons' sleep been severely disturbed. Through the comparison with three groups, the data figured that people living in

Table 62.2 The statistic of different subject annoyance of three groups

		Normal		Moderate		Severe	
Group	No.	No.	%	No.	%	No.	%
Controlled group	20	17	85.00	3	15.00	0	0.00
Exposure group 1	17	7	41.18	5	29.41	5	29.41
Exposure group 2	22	7	32.82	8	34.36	7	32.82
Total	59	31	52.54	16	27.12	12	20.34

Table 62.3 The relationship between different-intensify noise and subject annoyance

		Normal		Moderate		Severe	
Group (dB)	No.	No.	%	No.	%	No.	%
<30	28	21	75.00	5	17.86	2	7.14
30–35	16	6	37.50	8	50.00	2	12.50
>35	15	3	20.00	4	26.67	8	53.33
Total	59	30	50.86	17	28.81	12	20.33

the quiet environment can have a better sleep than those who were surrounded by the noise. Furthermore, the comparison with exposure group 1 and exposure group 2 indicated that the influence from the subway noise, which contained moderate vibration and was discontinuous, was more serious than the water pump noise to human health. In a word, when the noise level is certain, the noise type is an important factor to the grade of subject annoyance.

The Relationship Between Different-Intensify Noise and Subject Annoyance

Through above analysis, it is known that the subject annoyance is impacted by the age and the noise types, and the two factors impact the subject annoyance badly. Besides of the two factors, the level of noise may also have effect on sleep. In this investigation, the collected data about noise is from 27 to 41 dB, and the average sound pressure level (SPL) is 29.8 dB. In order to analyze the relationship between SPL and subject annoyance, the noise data were divided into three groups according to the different SPLs, which are shown in Table 62.3.

The Table 62.3 explicated the relationship between different-intensify noise and subject annoyance. The Table 62.3 indicated that, when the level of noise is less than 30 dB. there were 21 persons owning the normal sleep which took the percentage of 75.00%, and the moderate and the severe were 17.86 and 7.14% individually However, when the level of noise was more than 30 dB and less than 35 dB, the number of normal sleep declined quickly to 37.5%, and the moderate and the severe raised to 50, 12.5% respectively. When the level of noise was over 35 dB, the normal decreased to the minimum which only has three persons own the normal sleep, on the contrary, the percentage of the severe sleep disorders increased to 53.33% rapidly. So the level of noise is also an important factor which impacts the subject annoyance.

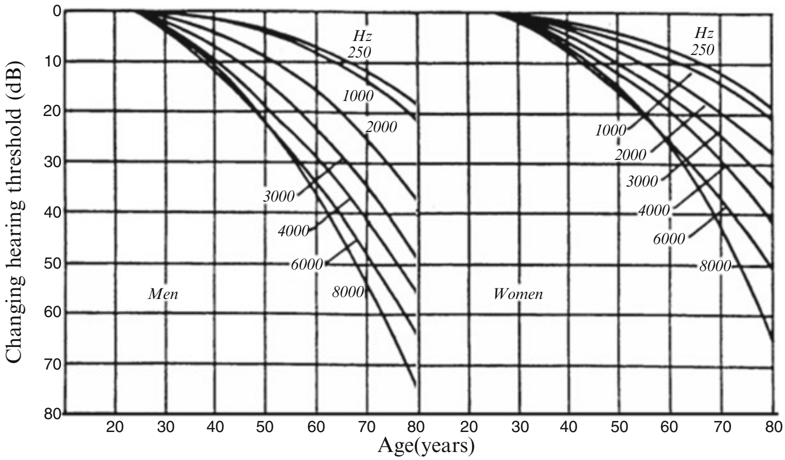


Fig. 62.4 The relation between age and hearing threshold

The High Frequency Noise and Subject Annoyance

The high frequency noise may also impact the subject annoyance. But the high frequency noise is easy to be attenuated by using the high-quality wall of windows, so the high frequency noise was not taken into account in this paper.

Conclusions

The people have different subject annoyances in various noise environments. As we all known, the serious subject annoyance can cause insomnia (Eberhardt and Akselsson 1987), while the quiet environment is prone to sleeping, but sever people know the decibel of the upper limit of the noise which the people can sleep with. To this question, we can conclude that a person's subject annoyance has a great relation with the age and the type of noise through the analysis. The people in different ages have different hearing abilities, just taking the elders for example, the elders' different frequency hearing ability will decline with the age adding graduate, but hearing ability declining is not with the same rate attenuation. In fact, the declining of hearing ability of high frequency is faster than the low frequency. This is the reason why the elders are more sensitive to low frequency noise, the relation is shown in Fig. 62.4 (GB/T 7582 2004).

On the other side, the type of noise is also an important factor that has great influence on the subject annoyance. According to the investigation, the noise can not interrupt sleep at level of 40 dB of wide frequency noise, but to the low frequency noise will interrupt people's sleep when the noise is not higher than 40 dB. The low intensity and low frequency noise interrupt people subject annoyance badly, that is why we should pay attention on it, and need to find the effective methods to eliminate it.

References

American Sleep Disorder Association (1990) The international classification of sleep disorder's. Allen Press, Lawrence, p 396

Ana Lucia Rios, Geruza Alves da Silva (2005) Sleep quality in noise exposed Brazilian workers. Noise Health 7(29):1–6

Eberhardt JL, Akselsson KR (1987) The disturbance by road traffic noise of the sleep of young male adults as recorded in the home. J Sound Vib 114(3):417–434

Gaab N, Gabrieli JD, Glover GH (2008) Resting in peace or noise: scanner background noise suppresses default-mode network. Hum Brain Mapp 29(7):858–867

GB/T 7582 Acoustics-Statistical distribution of hearing thresholds as a function of age, 2004

Muzet A (2007) Environmental noise, sleep and health. Sleep Med Rev 11(2):135–142

Pedemonte M, Pena JL, Torterolo P, Velluti RA (1997) Auditory deprivation modifies sleep in the guinea-pig. Neurosci Lett 223:1–4

World Health Organization (1980) Noise. World Health Organization, Genebra, pp 32–77

Yu-jun Tian, Tian-zhen Ju, Zhen-wu Ren (2003) Progress on urban environmental noise pollution research in China. Chongqing Environ Sci 25(3)

Zhi-suo Liu, Jing-shen Shen, Zhen-lin Wei (2003) Cause analysis and control measures of occupational noise hazard in China. China Saf Sci J 13(12)

Chapter 63
The Application of Rough Set in Bid Evaluation Method

Li-hua Chen, Kai-hu Hou, Shao-peng Sun, Jin-yuan Zhong, and Chang-li Hu

Abstract Whether the bid evaluation method is scientific, reasonable and justice, can directly affect the bidding and influence the results of the competition. The bid evaluation method based on Rough Set was put forward. The evaluation indexes were determined according to the specific requirements of the project and the goals of the employers, the indexes were reduced adopting the attribute reduction based on the information quantity, the significance of indexes was used to determine the index weights, and the comprehensive evaluation values of the contractors were calculated. The case of hospital project was studied and analyzed, it shows that this method reduces the subjectivity of experts to a great extent and provides objective and quantitative decision basis for decision makers. The ideal contractor is chosen and the advantages of the integration of design, purchase and construction are expressed.

Keywords Attribute reduction • Bid evaluation method • Information quantity • Significance

Introduction

In recent years, the general contracting (EPC) model develops rapidly because of its own disadvantages in international construction market. In China, the EPC model has been applied gradually in practice and supported by our related law in

---

L.-h. Chen (✉) • K.-h. Hou • S.-p. Sun • J.-y. Zhong
Department of Industrial Engineering, Kunming University of Science and Technology, Kunming, P.R. China
e-mail: chenlihua_love2006@126.com; kaihu_kmustie@163.com; sunshaopeng@live.cn

C.-l. Hu
Management Department, Yunnan Investment Group, Kunming, P.R. China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_63,

engineering construction. EPC is defined as the contractors are entrusted by employers to implement the total proceeding and several stages including survey, design, purchase, construction and test run. In this paper, the EPC is the integration of design, purchase and construction (Shui-bo Zhang et al. 2005). There are lots of comprehensive bid evaluation methods at present, Li-ming Liang (Li-ming Liang et al. 2006; Guo-xiang Hu et al. 2003) used AHP to bidding and built the bidding model; De-yu Huang (De-yu Huang and Xin Chen 2005) described qualitative norms and their important degree using fuzzy number according to the characteristic of group decision making and the synthetically sequencing numerical values were calculated; Chen Tao (2005) established the comprehensive evaluation model of bidding the construction adopting principal components analysis.

The subjective methods such as AHP, fuzzy evaluation has lots of human factors affecting the index weights and lack the objectivity, the objective methods has limitations, for example, the principal components analysis cannot explain the real meaning (Ning Mu and Kai-chao Yu 2010). The method of Rough set was used to make up for the lack of the previous study and study the bid evaluation. This paper proceeded as follows: first, the evaluation indexes were determined according to the specific requirements of the project and the goals of the employers, the Attribute Reduction algorithm based on information quantity was used to reduce the evaluation indexes and optimize index system and the reduced attribute were acquired; then the significance of indexes was used to determine the index weights; lastly, the comprehensive evaluation values of the contractors were calculated. This method solves the problems of subjectivity and one-sidedness existing in the traditional method, decreases the amount of computation on the comprehensive evaluation, reduces the subjectivity of experts to a great extent and provides objective and quantitative decision basis for decision makers.

The Theoretical Knowledge of Rough Set

Rough Set was put forward by Zdzislaw Pawlak in the early 1980s to analyze the data tables. The initial data were acquired from measurements or from experts (Jan Komorowski 1998). The rough set has lots advantages in processing the initial data as follows:

1. Synthesis of efficient algorithms for digging the potential information in data;
2. Reduction of data to get a minimal model;
3. Calculation of the significance of data;
4. Processing of both qualitative and quantitative parameters;
5. Reduction of the subjectivity of experts to a great extent;
6. Support of the objective and quantitative decision basis for decision makers (Duntsch 1997).

Information System

Definition 1. An information system $S = (U, A, V, f)$, U is the finite set of objects and defined as the domain; $V = \bigcup_{a \in A} V_a$, V_a is the domain of the attribute a; $f : U \times A \to V$ is an information function providing a value for the attribute of every object, $a \in A, x \in U, f(x, a) \in V_a$.

Equivalence Relation

Each attribute subset $P \subseteq A$ determines an equivalence relation IND(P), the information system $S = (U, A, V, f)$ is defined as knowledge A.

Definition 2. If $(x, y) \in IND(P)$ is equivalent, x is equivalent to y. The equivalence relation IND(P) forms a equivalence partitioning in U, $U/IND(P) = \{X_1, X_2, \ldots X_n, \}$ is the expression form.

The Core and Reduction of the Attribute

Definition 3. An information system $S = (U, A, V, f), a \in A$, if IND(A−{a}) = IND (A), the attribute a is unnecessary in A, or a is necessary in A.

Definition 4. An information system $S = (U, A, V, f)$, the set consisting of all the necessary attributes is the core Core(A) of attribute set A.

Definition 5. An information system $S = (U, A, V, f)$, if $P \subseteq A$:

1. IND(P) = IND(A);
2. P is independent.;
   P is a reduction of A.

The Information Quantity and the Significance of Knowledge

Definition 6. An information system $S = (U, A, V, f)$, $P \subseteq A$, $U/IND(P) = \{X_1, X_2, \ldots, X_n\}$. The definition of information quantity of knowledge P is defined as:

$$I(P) = \sum_{i=1}^{n} \frac{|X_i|}{|U|}\left[1 - \frac{|X_i|}{|U|}\right] = 1 - \frac{1}{|U|^2} \sum_{i=1}^{n} |X_i|^2. \tag{63.1}$$

$|X|$ is the radix of the set X, $\frac{|X_i|}{U}$ is the probability of the equivalence class $|X_i|$ in U.

Definition 7. An information system $S = (U, A, V, f)$, the importance of the attribute a in A is :

$$sig_{A-\{a\}} = I(A) - I(A - \{a\}). \tag{63.2}$$

Definition 8. An information system $S = (U, A, V, f)$, $C \subseteq A$, the importance of arbitrary attribute $a \in A - C$ for attribute set C is defined as follow (Xue-min Zheng 2010; Yi-tan and Lai-sheng 2006):

$$sigC(a) = sig_{C\cup\{a\}-\{a\}} = I(C \cup \{a\}) - I(C). \tag{63.3}$$

The Bid Evaluation Model Based on Rough Set

The Establishment of the Bid Evaluation Indexes

The bid evaluation is a complex and very important work. For a specific project, the reasonable evaluation methods should be taken and the evaluation indexes are determined according to the specific requirements of the project and the goals of the employers. The bid evaluation projects were shown respectively from the commercial affairs, technology and management.

1. Commercial Indexes
   The commercial indexes are to control the employer's engineering cost. Not only the engineering bid but also operation costs in the whole cycle are considered due to the different design options. The higher operation costs, the lower score of the indexes. In addition, the rationality of the bid should also be considered, for example, the whole bid can be decomposed as design, purchase, and construction.
2. Technical Indexes
   The design options are raised according to employer's requirements in bidding document of EPC. The employers take some factors into account to judge the design options, such as the integrity and innovativeness of the design, the advancement of the permanent facilities and equipment, the overall construction etc.
3. Management Indexes
   Under the practicable design options, whether the engineering project can be completed on time, having high quality, safely and environmentally depend on the management level of the contractors. The management level is shown in planned capacity, organizational capability and control ability etc.

In order to make the bid evaluation more practical and manipulable, a set of complete, scientific and comprehensive bid evaluation system must to be built. In this paper, all just are used for explaining this model, nine indexes are chosen including engineering bid, operation cost in the whole cycle, the rationality of the

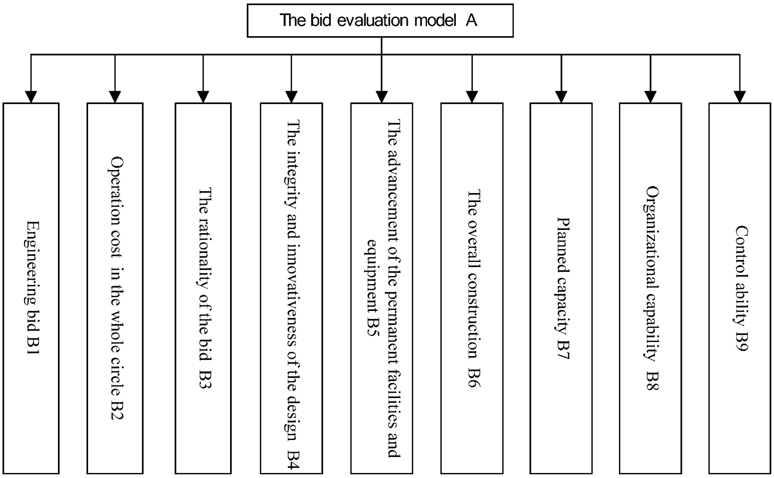


Fig. 63.1 The bid evaluation model

bid, the integrity and innovativeness of the design, the advancement of the permanent facilities and equipment, the overall construction, planned capacity, organizational capability and control ability. The bid evaluation model is as follow in Fig. 63.1:

The Reduction of Evaluation Indexes

The main steps of the algorithm are as follows:

1. The formula (63.1) is used to calculate the information quantity $I(A)$;
2. Firstly, $Core(A) = \emptyset$, the formula (63.2) is adopted to calculate the significance of every $a_i \in A$. If $sig_{A-\{a_i\}}(a_i)$ is not 0, $Core = Core \cup \{a_i\}$, the core of index set A is got and then calculate $I(Core)$. If $I(Core) = I(A)$, the algorithm ends (this $Core$ is the minimum approximate reduction, or go to (3);
3. $C = Core$, the index set $A - C$ can be calculated repeatedly:
   The formula (63.3) can be used to calculate the significance $sig_C(a_i)$ of every attribution $a_i \in A - C$;
   The maximum $sig_C(a_i)$ is got, then $C := C \cup \{a_i\}$;
   If $I(C) = I(A)$, the algorithm ends (C is one of the minimum approximate reduction of A); or go to (1).

The Case Study

To verify the effectiveness of this model based on Rough Set, four contractors were chose to be studied.

Table 63.1 The initial information table

	B1	B2	B3	B4	B5	B6	B7	B8	B9
U1	6	6	7	8	8	8	6	7	7
U2	8	7	7	6	9	8	6	7	6
U3	8	6	6	9	8	9	7	7	7
U4	7	8	6	8	5	7	6	5	7

U1, U2, U3, U4 stood for four contractors

Table 63.2 The discrete information table

	B1	B2	B3	B4	B5	B6	B7	B8	B9
U1	2	2	2	1	1	1	2	2	2
U2	1	2	2	2	1	1	2	2	2
U3	1	2	2	1	1	1	2	2	2
U4	2	1	2	1	3	2	2	3	2

Data Collection

The committee of bid evaluation consists of the representative familiar with the relative business and the experts about technique and economy. Likert 10-level measuring was used to divide the score into 11 levels, 10 meant to be very satisfied with the index, 0 meant to be very dissatisfied with the index (Paddock et al. 2000). Firstly, the initial score were rated by the committee as follows in Table 63.1. Then the initial information sheet were discretized, in the discretization in this paper, 1 stood for 8–9, 2 stood for 6–7, 3 stood for 4–5, therefore, the discrete information table was as shown in Table 63.2.

The Reduction of the Indexes

1. According to the information system, the equivalence relation U/IND(A) = {U1, U2, U3, U4}, I(A) = 12/16;
2. For index set A−{a1}, the equivalence relation U/IND(A−{a1}) = {U1, {U2, U3}, U4}. According to the formula (63.2), $sig_{A-\{a1\}} = I(A) - I(A - \{a1\}) = 2/16$, in the same way, $sig_{A-\{a2\}}(a2) = sig_{A-\{a2\}}(a3) = sig_{A-\{a2\}}(a5) = sig_{A-\{a2\}}(a6) = sig_{A-\{a2\}}(a7) = sig_{A-\{a2\}}(a8) = sig_{A-\{a2\}}(a9) = 0$, $sig_{A-\{a4\}} = 2/16$. So Core(A) = {a1, a4}, I(Core) = 10/16 ≠ I(A).
3. C = Core, the index set A–C can be calculated repeatedly:
   According to the formula (63.3), the significance can be calculated: $sig_C(a2) = sig_C(a5) = sig_C(a6) = sig_C(a8) = 2/16$, $sig_C(a3) = sig_C(a7) = sig_C(a9) = 0$.
   I(a1, a2, a4)= I(a1, a4, a5)= I(a1, a4, a6)= I(a1, a4, a8)= I(A).
   Now {a1, a4, a6} was chosen as the reduced index set.

The Calculation of the Index Weights

The weights of three reduced indexes were calculated and the steps were as follows:

1. The division of the domain U based on the equivalence relation C:U/IND (C) = {U1,U2,U3,U4}; I(C) = 12/16 according to the formula (63.1);
2. The significance of the attribute: $sig_{C-\{a1\}}(a1) = 6/16$, $sig_{C-\{a4\}}(a4) = sig_{C-\{a4\}}(a6) = 2/16$;
3. The weights were normalized, $W_1 = \frac{sig_{C-\{a1\}}(a1)}{sig_{C-\{a1\}}(a1)+sig_{C-\{a4\}}(a4)+sig_{C-\{a6\}}(a6)} = \frac{3}{5}$, $W_{a4} = W_{a6} = \frac{1}{5}$.

The Comprehensive Evaluation Values

The evaluation values of every object were calculated using linear weighted model: U1 = 6.8, U2 = 7.6, U3 = 8.4, U4 = 7.2.

Determining the weights was one of the key issues of bidding, it can be seen from the weights that engineering bid was the most important factor, followed by the integrity and innovativeness of the design and the overall construction. From the results of evaluation values, the highest score was U3, the employers can chose the best contractor from this result.

Conclusion

Because the factors affecting the bidding are very large and the significance of each factor has big difference, the comprehensive and data-driven completely bid evaluation method was put forward based on Rough set. This model was applied into hospital project and proven objectivity and practicality overcoming the problems of the traditional methods, such as subjectivity and partiality. Adopting the attribute reduction shown the comprehensiveness of bid evaluation and simplify the arithmetical complexity, the objectivity of bid evaluation was emphasized and the subjective experience was used in calculating the weights of each factor. All can help finishing the bidding equally, fairly and scientifically and choose the ideal contractor who has high quality, short duration and reasonable cost.

Acknowledgments First and foremost, thanks to the help of the staffs in Integrated Management Department in FAW-GM Hongta Yunnan Automobile Manufacturing Co., Ltd and the staffs and leaders in Yunnan Investment Group, I could know about the bid and finish my paper. What's more, this research has been supported in part by the project of Yunnan province scientific and technological innovation (Project No. 2008AA011).

References

De-yu Huang, Xin Chen (2005) Sequencing analysis of fuzzy comprehensive appraise bids in construction project. Relig Archit 23:175–176 (in Chinese)

Duntsch I (1997) A logic for rough set. Theor Comput Sci 179(1–2):427–436

Guo-xiang Hu, Guo-ping Nie, Zhen-zhi Wu (2003) Application of AHP in engineering project assessment. Anhui Archit 10(4):110–111 (in Chinese)

Jan Komorowski, Lech Polkowski, Andrzej Skowron (1998) Rough sets: a tutorial. In: Pol, Skowron [195], p 1

Li-ming Liang, Li Wu, Rong-hao Xie (2006) Research on application of analytic hierarchy process in engineering project assessment. J Jiangxi Univ Sci Technol 27(1):61–63 (in Chinese)

Ning Mu, Kai-chao Yu (2010) The evaluation research of service capability of the third-party logistics enterprise that facing manufacturing. Mod Manuf Eng 2:32–35 (in Chinese)

Paddock LE, Veloaki J, Chatterton ML et al (2000) Development and validation of a questionnaire to evaluate patient satisfaction with diabetes disease management. Diabetes Care 23 (7):951–956

Shui-bo Zhang, Lei Zhang, Yuan Gao (2005) On the integration of indicators of Bid evaluation under design-build/EPC project delivery approach. J Tianjin Univ (Soc Sci) 7(2):97–101 (in Chinese)

Tao Chen (2005) Comprehensive evaluation model of engineering project assessment based on principal components analysis. J Wuhan Univ (Nat Sci Ed) 51(S2):54–56 (in Chinese)

Xue-min Zheng (2010) Comprehensive evaluation method of multiple indexes based on rough set. Stat Decis 5:37–39, (in Chinese)

Yi-tan Xu, Lai-sheng Wang (2006) Fuzzy comprehensive evaluation model based on rough set theory. In: IEEE International Conference on Cognitive Informatics (ICCI 2006), Beijing, China (in Chinese)

Chapter 64
The Innovative Management of Mobile Phone Design

Ming-Tang Wang, Rain Chen, and Sin-Hung Lin

Abstract This study took three different class items for research, which were (1) Class I: the patent of iPhone which has been authorized by Apple; (2) Class II: The cell phones which have infringed on the design patent of iPhone after judicial judgements; (3) Class III: the cell phones which intentionally pirated iPhone's features but they have not been accused of infringement by Apple yet. There were 18 samples in total in this study, and the researcher asked 30 ordinary consumers who have no work experience in the filed of designing to do the similarity test. The research results were compared with the infringed cases in reality, and Multi-Dimensional Scale (MDS) was used to build up the real range of patent identified by the ordinary consumers at end of the study. The research results showed if the researcher took Class I to Class II as the real range of patent. Although most present Class III samples did not infringe directly on the patent range of iPhone, the judge confirmed that it is an infringement between Class I and Class II range on judging. Class III presented the distances which were very close to Class I, and therefore the possibility of infringement would be extremely high. The results of the study could build a display system which would help the real range of patent to be presented by visualization. The system could also clearly show whether other people's designs have infringed on the real range of patent of ours or not. It could be an important reference of infringement and overall patent management.

M.-T. Wang
Department of Industrial Design, National Kaohsiung Normal University, Kaohsiung, Taiwan, ROC

R. Chen (✉)
Department of Creative Product Design, Southern Taiwan University, Tainan, Taiwan, ROC
e-mail: ocean@mail.stut.edu.tw

S.-H. Lin
Graduate Institute of Digital Content and Animation Design, Southern Taiwan University, Tainan, Taiwan, ROC

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_64,

Keywords Design • Patent • Innovative management • Mobile phone

Introduction

The new generation of cell phone revolution has begun in recent years since the smart phone – iPhone released. Many cell phone manufacturers have used patents as their weapons to accuse other competitors of infringement and to retard their market development on purpose in business competition. This action means that the design patent plays an important role on global technology R&D (research and development) and industrial competitiveness. A lot of scholars are devoted to the research of system innovation design. Zhang's study could assist a company in designing the patent which could block other competitors on business (Zhang 2009). An effective patent range could help companies ask for compensation from others and execute transfers of patent to others (Pressman 1981). Patent analysis and patent range management are effective ways to avoid patent infringements. The two elements could also be the best competition tools for enterprises if a systematic process is adopted to do the analysis of law requests (Liu et al. 2011).

On the other hand, if an enterprise could build up an effective protect range, it could help the company keep other competitors away from the core of the enterprise. As a result, a lot of scholars have eagerly dedicated themselves to related research because of the importance of patent range. For example, some researchers attempt to use a systematic way to bring the concept of design matrix into patent information, patent infringement judgement rules, design around tactics and TRIZ. The applications of these theories could obtain the following advantages: (1) Decreasing the production cost of R&D (research and development), (2) Shortening the time line of launching products, and (3) Diminishing the risk of patent infringement (Hsu et al. 2009). The techniques of patent literature usually include higher technical values. It could provide companies an important reference value by applying statistical analysis, trend analysis, correlation analysis and database assistance to help R&D of a product avoid the patent infringement effectively (Zha and Chen 2010).

The classes of patent could be divided into function patent and form patent. Function patent is named invention patent; form patent is named design patent. Invention patent is easier to identify whether it belongs to the real range of patent or not due to the objective data (ex. Temperature, Pressure). In contrast, design patent is harder to identify whether it belongs to the real range of patent or not due to the subjective judgment of form similarity. The product similarity could be categorized into the board sense and narrow sense according to the scholars' definitions (Taylor and Bearden 2002). The former means the traits between the product and extended product are abstract, such as the relativity of products and the concept of brand (Park et al. 1991). The latter means product trait similarity (Keller and Aaker 1992) and product category similarity (Aaker and Keller 1990; Chen and Chen 2002).

It is anticipated that this study could present the real range of design patent by visualization to examine clearly whether others' designs infringe on the real range of patent of ours or not. Thus, it could be an important reference of infringement and overall patent management.

Methodology

This study attempted to investigate the level of form similarity for each product. The participants were thus required to do the research of real similarity range of shapes for each product. Afterwards, the researcher compared the results of the study with the judicial judgments at the end of this study, in order to show the real range of design patent.

Subjects

As the purpose of protecting design patents is to assure that the general public will not be confused and face any losses by the pirated products, 30 ordinary consumers having no work experience in the field of designing were chosen to be the participants. They were required to fill in a professional questionnaire and to do the similarity comparison among 18 samples.

Samples

The Apple iPhone has been a leading brand of the smart-phone market in the recent years. The great marketing success of iPhone, however, has made other similar cell phones start to copy and imitate. Therefore, the samples of this study could be divided into three classes: (1) Class I: The patent of iPhone which has been authorized by Apple (Code Number: P1–P4); (2) Class II: The cell phones which have infringed on the design patent of iPhone after judicial judgements (Code Number J1–J2); (3) Class III: The cell phones which intentionally pirated iPhone's features but they have not been accused of infringement by Apple yet (Code Number: S1–S12). There were 18 samples in total (Fig. 64.1).

Designing the Questionnaire

The 18 cell phones were confirmed by the researcher as study samples (P1–P4, J1–J2, and S1–S12). These cell phones were examined by the participants to do the similarity level identification. To avoid interference of many judging factors, the aspects of brand, color, size and picture were not involved in the study. In addition, there was not any word information in this test. Likert-scale was utilized to measure the five similarity levels: identical, similar, about the same, a little different, different.

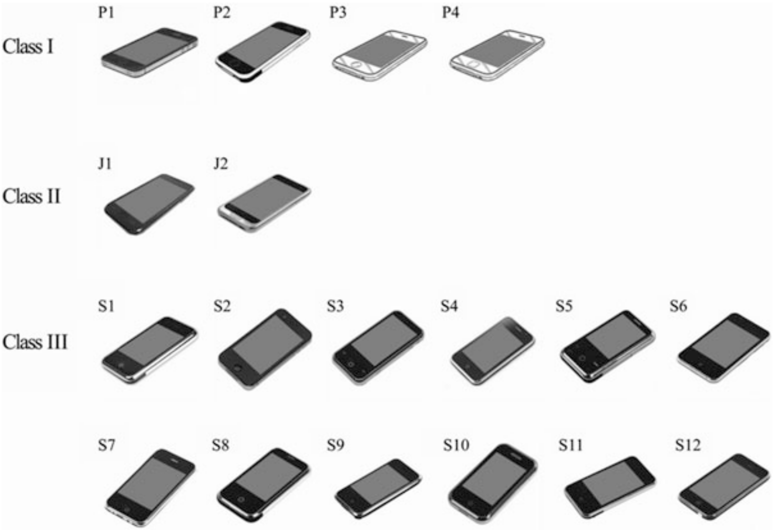


Fig. 64.1 The samples of study

Statistical Methods

There were 18 samples selected by the researcher in this study and the participants were required to compare two cell phones at one time during the test. This study applied Multi-Dimensional Scale (MDS) to construct the sample space in order to know the distribution of Class I, Class II and Class III on two-dimensional space.

Results

This study explored the similarity levels of the form and shape of one product, and visualized the similarity levels based on the ordinary consumers' identification. Among 30 participants, the gender ratio was: 19 males (63% of the total participants), 11 females (37% of the total participants); the age ratio was: 2 participants who are under 20 years old (including 20 years old; 7% of the total participants), 23 participants who are 20–25 years old (77% of the total participants), 4 participants who are 25–30 years old (13% of the total participants), 1 participant who is 30–35 years old (3% of the total participants); the education ratio was: 19 bachelors (63% of the total participants), 11 masters (37% of the total participants). Among 30 participants, 19 of them are males (63%) and 11 of them are females (37%). Two of them are under 21 years old (7%), 23 of them are 20–25 years old (77%), 4 of them are 25–30 years old (13%) and one is 30–35 years old (3%). As for their education level, 19 of them have a bachelor's degree (63%), 11 of them own a master's degree (37%).

Table 64.1 Familiarity test

Items	F	p
Gender	0.19	0.67
Age	0.95	0.45
Education level	1.04	0.41

*Significant level ($p \leq 0.05$), Significant difference

Table 64.2 Class I, Class II, and Class III Test

Items	Testing Variables	F	P
Gender	P3S3	6.81	0.01*
Age	P1S3	5.00	0.03*
Age	P4S1	5.73	0.02*
Age	P3S5	6.53	0.02*
Age	P4J1	3.57	0.03*
Education Level	P2S5	6.89	0.01*
Education Level	P4S3	4.87	0.04*
Education Level	P2J2	4.80	0.04*
Education Level	P4S9	8.77	0.01*
Education Level	P4S7	5.85	0.02*

*Significant level ($p \leq 0.05$), Significant difference

Familiarity Test

This study investigated the familiarity of using iPhone by three different factors, i.e., gender, age, education level, to do the T-test and ANOVA. The results showed that all three factors were not significant. There was no difference among gender, age and education level of using familiarity. The data is shown in Table 64.1.

Class I, Class II and Class III Test

This study applied three factors (gender, age, education level) to do the ANOVA. The results showed that there was significance on some comparisons of the items to the participants. The data is shown in Table 64.1 which only shows the significant items due to the numerous comparing items in this study.

Presenting the Two-Dimensional Space

To show the relationship between the 18 samples and the distance, this study applied Multi-Dimensional Scale (MDS) to construct the sample space. The data in Fig. 64.2 was the confirmed sample space after two cell phones were compared during the test by the participants. Each dot in Fig. 64.2 stands for the similarity among different samples. The nearer distance meant the similarity between the two

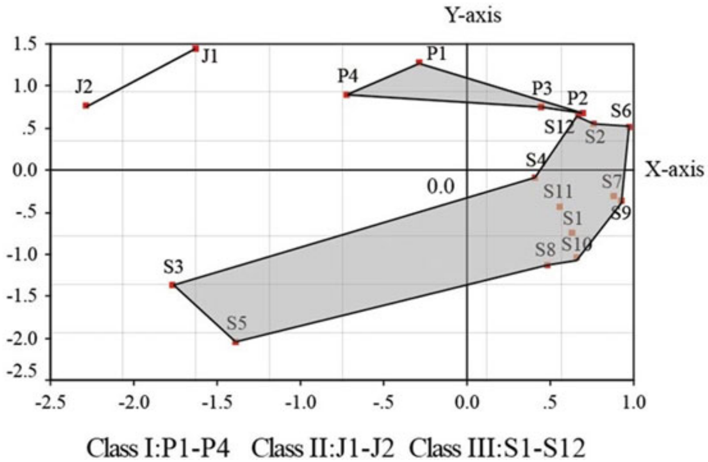


Fig. 64.2 Sample space of mobile phone design

items was more similar to each other. The connected space of P1–P4 was the real range of patent of iPhone designing.

Discussion

The study aimed at 30 ordinary consumers who have no work experience in the filed of designing to do the similarity test. The results showed that there was no difference among gender, age and education level for the familiarity of using iPhone; however, the results showed that there was significant on specific comparisons of the items to the participants.

This study applied Multi-Dimensional Scale (MDS) to construct the sample space. In the samples, P1–P4 were Apple iPhone's patents; J1–J2 were the cell phones which have infringed on the design patent of iPhone confirmed by the court (ChinaMeizu and Samsung); S1–S12 were the China pirated cell phones. Class II (J1–J2) has been verified that the cell phones have infringed on the patents of iPhone design by the judicial judgements. Therefore, people could evaluate the possibility of infringement of Class III (S1–S12) in the future lawsuits by knowing the distance relationship between Class II (J1–J2) and Class I (P1–P4).

Conclusion

The analysis of patent scope is to reduce the possibility of infringement on the rights of other people. It could also be beneficial for companies to use the design around when they are developing the product. In fact, the patent range of invention patents is easier to identify than that of the design patent because the judicial judgment of design patent could be subjective. Thus, the judge would be confused whether the person infringes on the design patent of others.

The study constructed the display system by the ordinary consumers and anticipated using the objective method to change the very subjective patent range of designing. The researcher expected to build an objective data gauge confirmed by the general public on the issue of infringement between any controversial designs. Therefore, the researcher decided to set up a prior process through examining the basic judgment of the general public. The process could be a valued reference before acting any infringement lawsuits in the future.

Acknowledgment This work was partially supported by the National Science Council, Taiwan, under the Grant No. NSC 100-2221-E-017-012 and NSC 100-2221-E-218-049.

References

Aaker DA, Keller DL (1990) Consumer evaluations of brand extension. J Mark Res 54(1):27–41

Chen A, Chen R (2002) Design-related products and services merchandised through e-commerce. J Chin Inst Ind Eng 19(3):19–25

Hsu YL, Hsu PE, Hung YC (2009) Development of a design methodology based on patent and axiomatic design. J Qual 16(3):153–163

Keller KL, Aaker DA (1992) The effect of sequential introduction of brand extensions. J Mark Res 29:35–50

Liu YM, Jiang P, Wang W, Tan RH (2011) Integrating requirements analysis and design around strategy for designing around patents. In: CCIE 2011 – proceedings: 2011 I.E. 2nd international conference on computing, control and industrial engineering, Wuhan, vol 2, pp 320–323

Park CW, Milberg S, Lawson R (1991) Evaluation of brand extensions: the role of product feature similarity and brand concept consistency. J Consum Res 18(2):185–193

Pressman D (1981) Question of law – penetrate a patent's legalese to determine scope of protection. Expert Syst Appl 26(20):486–500

Taylor VA, Bearden WO (2002) The effects of price on brand extension evaluations: the moderating role of extension similarity. J Acad Mark Sci 30(2):131–140

Zha XL, Chen HM (2010) Study on early warning of competitive technical intelligence based on the patent map. J Comput 5(2):274–281

Zhang L (2009) A systematic innovation design method based on patent. In: International technology and innovation conference 2009 (ITIC 2009), Munich, 2009, vol 2009, no. 556, pp CP556

Chapter 65
Probability and Integration Judgment Based Best Selection of Aircraft Conceptual/Preliminary Scheme

Kang-wen Sun and Jun Huang

Abstract The technical feasibility analysis of an aircraft design scheme directly influences the design proposal, which determines whether scheme can satisfy the maximum design requirements or we can continue the detailed design. Conventional design evaluation of a new technical influence is insufficient, because the weight evaluation (analytic hierarchy process, AHP) is usually subjective. This paper proposes a new impact analysis method based on probability theory, and the comprehensive information including the data envelopment analysis (DEA) and the interval number AHP is referred to as a comprehensive empowerment of the appraisal criterion. According to the proposed method, the best selection method of an aircraft conceptual/preliminary scheme based on probability and integration judgment is established. Finally, some examples are presented to demonstrate the validity of the method.

Keywords Probability • Integration judgment • The technical feasibility of aircraft design scheme • Best selection

Introduction

Along with the improving requirements of various applications, modern aircraft design becomes more and more complicated (Jianxi Xie et al. 2004; Wen Xiong 2005). Due to the lack of consideration of the influence degree of a new technology as well as the use of analytic hierarchy process (AHP) of subjective values, the traditional empirical formula and qualitative analysis technology based aircraft conceptual/ preliminary scheme evaluation method hardly meets the design need of the modern aircraft. Probability theory is employed in this paper to analyze feasibility of new technology (DeLaurentis Daniel and Mavris 2002; Kirby 2001; Mavris and

K.-w. Sun (✉) • J. Huang
School of Aeronautic Science and Technology, BeiHang University, Beijing, China
e-mail: sunkw100@buaa.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_65,

Delaurentis 2003), This method needs not to know the influences of these new technology characteristics, and instead enhances the design scheme evaluation of anti-interference ability by using interval number AHP (Jianjun Zhu 2005; Zhen Wang and Mao Liu 2006) and data envelopment analysis (DEA, an objective weight method) (Yemei Wang 2008; Yang Han et al. 2010) combined with the comprehensive empowerment method to improve the weight factor of objective reality.

According to the above technique, this paper presents a best selection method of an aircraft conceptual/preliminary scheme based on probability and integration judgment, which can be applied to the technical feasibility analysis of the multiple design schemes and the best design scheme selection.

The Impact Analysis of New Technology Based on Probability

The development of a new technology is a gradual process. The new technology development can be divided into ten steps, which are shown in Table 65.1. According to one point system's grading principle, each step is endowed with a corresponding grade value. Then, a certain number of experts are invited to evaluate every technical development stage.

The experts finished independently evaluation of the principles in Table 65.1 (Kirby 2001). The decision-making departments get the maturity probability of these new technologies during the application period using the following formula:

$$(P_{WB})_I = \sum_{j=1}^{n} \left(G_j \times \frac{M_j}{M} \times 100\% \right) \tag{65.1}$$

Where G_j denotes the technical completeness grade of the new technology under application stage, M denotes the number of experts, and M_j denotes the number of experts who recognize the application technology in the state of grade G_j.

When the new technology becomes applicable, combining the modeling software simulation with the experimental validation is adopted to get the impact data about the intermediate variables in the design analysis. In addition, in consideration of the development stage of the new technology, the impact data can be expressed by using interval number method. Based on the comprehensive analysis, the integration impact factor of the new technology on the i^{th} design criterion (or target) can be expressed as:

$$P_{JKi} = \left[\sum \left((P_{SY})_{Ii} \cdot (P_{WB})_I \right) + \sum \left((P_{SS})_{Ji} / (P_{WB})_J \right) \right] \tag{65.2}$$

where $(P_{SY})_{Ii}$ denotes the income of the I^{th} new technology brought by the i^{th} criterion, $(P_{SS})_{Ji}$ denotes the loss of the J^{th} new technology brought by the i^{th} criterion, $(P_{WB})_I$ and $(P_{WB})_J$ denote the technical mature probability of the new

Table 65.1 The new technology readiness levels (TRL)

Stage description	Level	Work to do	Grading criteria
Basic research	1	Report and comment on basic scientific/engineering principles	0.1
Feasibility research I	2	Clearly demonstrate the technology concept, application, and potential benefits (select candidate system)	0.2
Feasibility research II	3	Prove the concept of technology analytically and/or experimentally (proof of critical functions or characteristics)	0.3
Technology development I	4	Study the system concept in laboratory (breadboard test)	0.4
Technology development II	5	Validate the system concept and its potential benefits in a controlled circumstance	0.5
System development I	6	Demonstrate system concept prototype in a relevant circumstance	0.6
System development II	7	Validate system prototype and potential benefits in a more broadly circumstance	0.7
Operational verification I	8	Construct and demonstrate actual system in a relevant circumstance, and substantiate its benefits	0.8
Operational verification II	9	Operate the actual system and substantiate its benefits	0.9
Technical maturation	10	Extensive application after various validation and improvement	1

technology in the future operational stage. The Eq. (65.2) carries on division processing to the loss factor, mainly due to the immaturity of the new technology, which brings a bigger loss to the system. Therefore, the policymaker must be discrete when the selection of the new technology may cause a potential lose.

Comprehensive Empowerment Method Based on Integration Judgment

At present, the determination methods of the relative weight factor mainly include the subjective weight method and the objective weight method. The objective weight method based on the actual data of all criteria, employs the mathematical model with various standards to get weight coefficient. But this method however cannot reflect the preference of decision maker. Since the weight coefficient may not be consistent, this will give rise to a discrepancy for the final decision (Zeshui Xu 2004). In subjective weight method, the policymaker chooses criterion weight coefficient according to their fancy, experience and knowledge, or uses a mathematical model to determine the weight coefficient, based on comparative matrix after the binary comparison among all criteria. But the disadvantage of this method will introduce a subjective factor that may exert a strong influence on the result which may depart from object reality (Choo and Wedley 2004). In order to make the final decision more objective and reliable, dual considerations are paid to the fancy of the policymaker in criteria and reduce the arbitrariness in criteria weight determination. Through the interval number AHP, the subjective weight coefficient is obtained, which reflects the policymaker's subjective fancy. Through the DEA we can get the objective weight coefficient, which can reflect the objective relationship between two discretional criteria (or attributes). Finally, by linear weight method one can acquire the evaluation criteria of synthesis weights, namely:

$$w^* = \alpha\bar{\varpi} + (1 - \alpha)\xi \tag{65.3}$$

where w^* is the synthesis weight; $\overline{\varpi}$ is the subjective weight decided by the interval number AHP; ξ is the objective weight decided by the DEA, $\alpha \in [0,1]$ is the subjective fancy coefficient, $(1-\alpha)$ is the objective fancy coefficient, and α usually takes 0.5. To facilitate the problem analysis, it is noteworthy of getting an average value from the analysis result in which the interval number AHP contains. Furthermore, the comprehensive weight that is obtained from the interval number AHP and the DEA should be normalized.

Steps as follow should be implemented to ascertain relative criteria weight number in the aircraft design:

- According to the analysis of the client demand, confirm the objective sets that satisfy the performance index (i.e. the performance index and its number n).
- Based on the demand of client, invite a number of k experts in relative fields to give an evaluation for the performance indexes mentioned above.
- Establish a judgment matrix B_{nxn} based on the results given by experts:

$$B_{n\times n} = \begin{bmatrix} [b_{11}^L, b_{11}^U] & [b_{12}^L, b_{12}^U] & \cdots & \cdots & [b_{1n}^L, b_{1n}^U] \\ [b_{21}^L, b_{21}^U] & [b_{22}^L, b_{22}^U] & \cdots & \cdots & [b_{2n}^L, b_{2n}^U] \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ [b_{n1}^L, b_{n1}^U] & [b_{n1}^L, b_{n1}^U] & \cdots & \cdots & [b_{nn}^L, b_{nn}^U] \end{bmatrix} \tag{65.4}$$

- Analyze the partial uniformity of the interval number judgment matrix B_{nxn} and the uniformity extent. If the interval number judgment matrix B_{nxn} is not partially uniform or its uniformity extent is not strong enough, a modification is needed.
- After the interval number judgment matrix B_{nxn} meets uniformity requirement, obtain the subjective weight number $\overline{\varpi}$ by using the genetic algorithm.
- Calculate the objective weight ξ by using nonlinear programming software, such as Lingo 7.0.
- Solve Eq. (65.3) to get the final comprehensive weight.

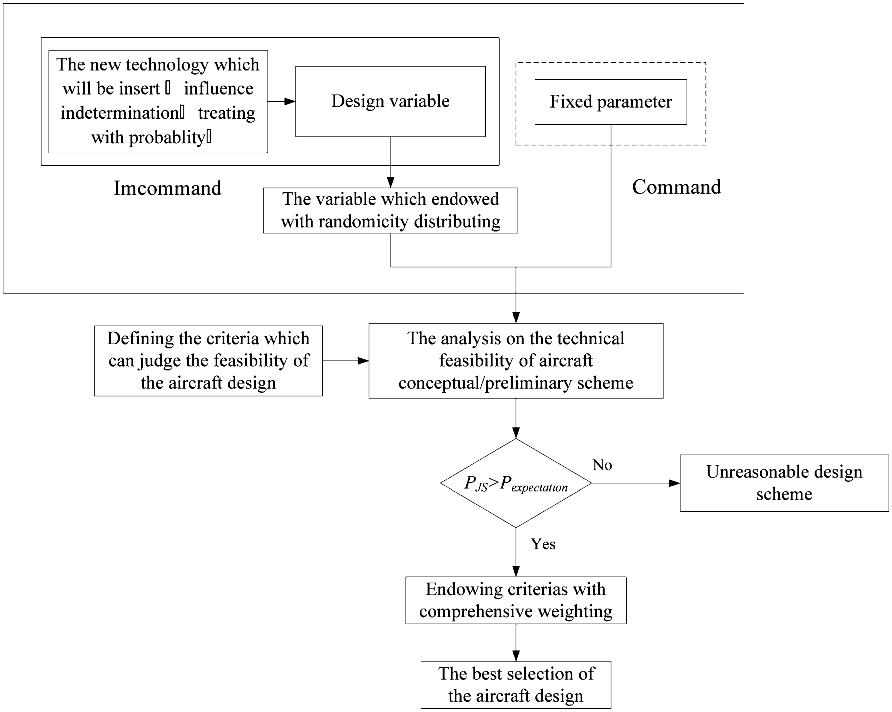


Fig. 65.1 The flow chart of the best selection method of aircraft conceptual/preliminary scheme based on probability and integration judgment

The Best Selection Method of Aircraft Design Scheme

Based on the new technology influence characteristic analysis method combined with the interval number AHP and DEA comprehensive weight method, the best selection method of an aircraft design scheme is constructed, as shown in Fig. 65.1:

- According to the domain of the design variable and the influence of the new technology exerted on the correlated variables shown in Fig. 65.1, the corresponding design variables are designated with a random distribution.
- For a specific aircraft, an accurate model based on the experiential formula (referred to (Raymer 1999) for the related parameters and formula) is selected. The technical feasibility analysis of aircraft conceptual/preliminary scheme is expressed as:

$$P_{JS} = P\{\cap[F_{i\,\min} \le f_i\,(x,y) \cdot P_{JKi} \le F_{i\,\max}]\} \quad (i = 1, 2, \ldots M) \tag{65.5}$$

where P_{JS} denotes the technical feasibility of an aircraft conceptual/ preliminary scheme. The items in square brackets at the right side of Eq. (65.5) denotes the probability of the i$^{\text{th}}$ design criterion actual value and the corresponding design requirements $F_i \in (F_{imin}, F_{imax})$ under the condition of the effective design value, x is the design variable vector, and y is the state variable vector. Generally, when feasible probability is larger than 50%, this design scheme is ideal, and otherwise the design scheme is unreasonable.

- When the feasibility of design scheme meets the general requirements, use the comprehensive weight method in part II to analyze the comprehensive weight of the related design target.
- Based on the preceding analysis, the best selection of the design scheme is obtained by using the equation as follows:

$$P_{JSE} = P\left\{\cap\left[(w_i \cdot M) \cdot F_{i\min} \le f_i(x, y) \cdot P_{JKi} \le \frac{F_{i\max}}{(w_i \cdot M)}\right]\right\} \quad (i = 1, 2, \ldots M) \tag{65.6}$$

Where P_{JSE} denotes the equipollence technical feasibility of the alternative scheme, w_i is the ith design criterion weight number, and M is the appraisal criterion number. The item in square brackets at the right side of Eq. (65.6) denotes the probability of the ith actual design criterion value and the corresponding design requirements $F_i \in ((w_i \cdot M) \cdot F_{imin}, F_{imax}/(w_i \cdot M))$ under the condition of taking the effective design the value. To emphasize the weight number reasonable adjustments of transition coefficient $(w_i \cdot M)$ to the relatively feasible domain of criterion are performed. Evaluation criterion must be satisfied harshly.

One of the alternative schemes that meets the requirement of the specified P_{JSE}, P_{JSE} with highest value is the best solution. If no alternative schemes' P_{JSE} values were larger than 0, the related criterion value must be readjusted to get higher P_{JSE} value. Correspondingly, if several alternative schemes' P_{JSE} values reach 1, the related criterion value should be modified to reduce P_{JSE} value. Thus, all alternative schemes can be distinguished and the truly preferred scheme can be obtained finally.

Instance Analysis and Validation

Select the initial design indexes of a certain aircraft (refer to the third generation aircraft) as shown in Table 65.2, and the domain of relevant design variables are shown in Table 65.3. Some relevant fixed parameters setting can be referred to (Weiji Li 2003).

Let A and B denote two designing departments. They select the new technical program permutation in their own design schemes respectively: A {T1, T2, T3}, B {T4, T5, T6}. And the specification is shown in Table 65.4 (Aditya Utturwar et al. 2002).

Table 65.2 Request of target

Design property	Guide line
Takeoff gross weight (W_{dg})	≤24,000 kg
Takeoff field length (S_{TOFL})	≤500 m
Approach speed (V_{app})	≤70 m/s

Table 65.3 Design variables

Design variable	Min	Max
Wing aspect ratio (A_w)	3	7
Wing area (S_w/m^2)	40	80
Wing sweep ($\Lambda_w/°$)	35	60
Wing maximum thickness-to-chord ratio ($(t/c)_w$)	0.03	0.07
Horizontal tail aspect ratio (A_{HT})	6	9
Horizontal tail area (S_{HT} /m^2)	12	17
Horizontal tail sweep ($\Lambda_{HT}/°$)	30	50
Vertical tail aspect ratio (A_{HT})	6	10
Vertical tail area (S_{VT} $/m^2$)	12	18
Vertical tail sweep ($\Lambda_{VT}/°$)	40	60
Max flying speed (Ma)	2.0	2.5
Thrust-to-weight ratio (T/W)	0.9	1.2
Air density at cruise height ($\rho_c/kg/m^3$)	0.104	0.365

Table 65.4 New technical detailed list

Designing department	Technical symbol	The definition of the technical
A	T1	Active load alleviation on tail
	T2	Integrative antenna systems
	T3	Biologically inspired material systems on fuselage structure
B	T4	Low cost composite manufacturing on tail structure
	T5	Propulsion system health management
	T6	BIOSANT on wing structure

The New Technology Impact Analysis

Assuming the new technology must be applied in 2015, through the synthesis judgment from 30 peer experts, the new technical TRL statistical table is shown in Table 65.5. To facilitate our analysis, the data are fitted referring to the literature (Kirby 2001) based on a different normal distribution. Furthermore, in view of both simulation results- and the relevant test data for validation, the impact on the relevant intermediate parameters caused by the new technology is shown in Table 65.6.

Table 65.5 The new technical TRL statistical table

Grading technical	0.5	0.6	0.7	0.8	0.9	1	PWB
T1	–	4	4	10	9	3	0.81
T2	–	4	8	10	8	–	0.75
T3	3	5	10	10	2	–	0.71
T4	–	–	3	4	14	9	0.9
T5	–	–	2	6	11	11	0.9
T6	1	4	13	10	2	–	0.73

Table 65.6 Technical influence matrix

		New technical group					
% k_i		T1	T2	T3	T4	T5	T6
k_1	Wing weight	–	–	–	–	–	−2
k_2	Fuselage weight	−5	–	−13	–	–	–
k_3	Vertical tail weight	−5	–	–	−20	–	–
k_4	Horizontal tail weight	–	–	–	−20	–	–
k_6	Electrical weight	2	−45	–	–	–	–
k_7	Engine weight	–	–	–	–	5	–
k_8	Zero drag	–	1	–	–	–	–
k_9	Fuel cost	–	–	–	–	−4	–
k_{10}	Thrust-to-weight	–	–	5	–	–	5

Comprehensive Weight Analysis

Assume the interval number judgment matrix of the experts' evaluation is $B_{3\times 3} = \begin{bmatrix} [1,1] & [3,4] & [5,7] \\ [\frac{1}{4},\frac{1}{3}] & [1,1] & [2,3] \\ [\frac{1}{7},\frac{1}{5}] & [\frac{1}{3},\frac{1}{2}] & [1,1] \end{bmatrix}$.

The random deterministic judgment matrix is $A = \begin{bmatrix} 1 & 4 & 7 \\ \frac{1}{4} & 1 & 3 \\ \frac{1}{7} & \frac{1}{3} & 1 \end{bmatrix}$. Then the consistency index can be obtained as $C.I. = \frac{\lambda_{\max} - n}{n-1} = 0.0324$.

By searching the corresponding stochastic consistency index table (as shown in Table 65.7) we know R.I. = 0.52, and therefore the above matrix uniform proportion is CR(A) = 0.0324/0.52 = 0.06 <0.1, which demonstrates that the local uniform degree of the above interval number judgment matrix is satisfactory. In addition, the degree of the N (= 100) judgment matrices generated randomly by aforementioned interval number judgment matrix is $\delta = 68\% > 60\%$, which shows the degree of the interval number judgment matrix is consistent.

Employ GA method and MATLAB 7.0. Assume the population N is 30, the crossover probability P_c is 0.9, mutation probability P_m is 0.001, and the crossover operation parameter α is 0.3. Thus, relative weights of the three performance indices (i.e. W_{dg}, $S_{TO/LFL}$, V_{app}) are $\overline{w_1} = [0.9161, 0.9471]$, $\overline{w_2} = [0.2769, 0.3715]$, and $\overline{w_2} = [0.1252, 0.1620]$, respectively, which can be used to calculate the subjective weights of the three performance indexes, i.e., $\overline{w_1^*} = 0.9316$, $\overline{w_2^*} = 0.3242$, $\overline{w_3^*} = 0.1436$.

Table 65.7 The stochastic consistency index table

n	1	2	3	4	5	6	7	8
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41

Through Lingo7.0, the objective weights of the three performance indices are respectively $\xi_1 = 0.604$, $\xi_2 = 0.257$ and $\xi_3 = 0.139$. Therefore, the comprehensive weights of the three kinds of performance indices are respectively ($a = 0.5$ here) 0.7678, 0.2906, and 0.1413. After normalized processing the comprehensive weights of the three performance indices are $w_1{}^* = 0.6400$, $w_2{}^* = 0.2422$, and $w_3{}^* = 0.1178$, respectively.

Through the above analysis, the feasibility evaluation mathematical model of the design scheme candidates can be expressed as follows:

$$P_{JSE} = P\left(0 \leq W_{dg} \leqslant \frac{23,600}{1.92}, 0 \leqslant S_{TOFL} \leq \frac{500}{0.7266}, 0 \leq V_{app} \leq \frac{65}{0.3534}\right)$$

According to the preceding formula, combining the influence matrix in Table 65.7 with the feasibility analysis program, the following result can be obtained

$$(P_{JSE})_A = 0\%, \ (P_{JSE})_B = 0\%.$$

Consequently, the best selection result is unable to carry on temporarily, and the values of the related constraint criterion must be adjusted.

In view of the above analysis, the weight processing on W_{dg}, makes the constraint excessively strict, and therefore value of the W_{dg} criterion must be adjusted. After the constraint criterion W_{dg} coefficients are relaxed by 1.85, the following formula can be obtained:

$$P_{JSE} = P\left(0 \leq W_{dg} \leq \frac{23600 \times 1.85}{1.92}, 0 \leq S_{TOFL} \leq \frac{500}{0.7266}, 0 \leq V_{app} \leq \frac{65}{0.3534}\right)$$

By recalculating, $(P_{JSE})_A = 0\%$, $(P_{JSE})_B = 16\%$ is obtained. Therefore, according to the application requirements of the users, the technical feasibility of design scheme B is better than that of A, namely, project B is a better solution. Furthermore, according to Eq. (65.5), $(P_{JS})_A = 89.5\%$, $(P_{JS})_B = 97.9\%$, which can also verify that the technical feasibility of design scheme B is better than that of A.

Conclusion

This paper analyzes the degree of a new technology development and its impact on the design scheme using probability theory. And then, a comprehensive weight analysis by combining the subjective weight method (i.e. the interval number AHP) with the objective weight method (i.e. DEA) is proposed. In view of the above two aspects, the best selection method of aircraft conceptual/preliminary scheme based on probability and integration judgment is established. This method fundamentally overcomes the appraisal flaws of the traditional design scheme, such as insufficient consideration on new technical influence, subjective inclination on weight evaluation. And thus precision of the appraisal result is improved.

References

Utturwar AS, Rallabhandi SK, DeLaurentis DA, Mavris DN (2002) A bi-level optimization approach for technology selection. AIAA-2002-5426

Choo EU, Wedley WC (2004) A common framework for deriving preference values from pairwise comparison matrices. Comput Op Res 31:896–908

DeLaurentis DA, Mavris DN (2002) Uncertainty modelling and management in multidisciplinary analysis and synthesis. AIAA-2000-0422

Jianjun Zhu (2005) Research on some problems of the analytic hierarchy process and its application. PhD thesis, Northeastern University [in Chinese]

Jianxi Xie, Bifeng Song, Weiji Li (2004) A research on decision tradeoff of aircraft top-level design. Exploration, Innovation, Communication-China Aviation Institute of Science and Technology Forum on Youth Collection 8(2):23–30 [in Chinese]

Kirby MR (2001) A methodology for technology identification, evaluation, and selection in conceptual and preliminary aircraft design. PhD thesis, Georgia Institute of Technology

Mavris DN, Delaurentis DA (2003) A probabilistic approach for examining aircraft concept feasibility and viability. Aircr Des 3:79–101

Raymer DP (1999) Aircraft design: a conceptual approach, 3rd edn. AIAA Inc., Reston

Weiji Li (2003) Aircraft conceptual design. Northwestern Polytechnical University Press, Xi'an [in Chinese]

Wen Xiong (2005) Multidisciplinary robust design of aircraft conceptual configuration. MA thesis, BeiHang University [in Chinese]

Yang Han, Jinwei Liu, Zeling Peng, Yu Chen (2010) Cost-effectiveness evaluation model of radar jamming shell based on DEA. Ordnance Ind Autom 29(8):10–12 [in Chinese]

Yemei Wang (2008) Study on decision-making method in engineering projects based on DEA and its applications. MA thesis, Nanjing University of Aeronautics and Astronautics [in Chinese]

Zeshui Xu (2004) A note on the subjective and objective integrated approach to determine attribute weights. Eur J Op Res 156:1101–1112

Zhen Wang, Mao Liu (2006) On fire-safety of high-rises with IAHP-based method. J Saf Environ 6 (1):12–15 [in Chinese]

Chapter 66
Electric Power Forecasting in Inner Mongolia by Random Forest

Zhi-jun Wei

Abstract Demand forecasting is the foundation of planning for electricity power. Time, gross national product and population in Inner Mongolia can be viewed as three important factors influencing power demand. Rank correlation coefficients between them and demand are calculated respectively. The results display strong dependence. The function among them is fitted by Random Forest, a matured algorithm in machine learning. Relative errors of three reserved samples are 5.6, −0.4 and 3.6%. All of them are less than 6%. It is showed that Random Forest is suitable for power demand forecasting. Future gross national product and population are predicted by ARMA time series model. Substituting those values into the fitted function, power demand of 2015 in Inner Mongolia is predicted to be 236,768.07 million kilowatt-hours. The predicted value is helpful to planning development strategy.

Keywords Forecasting • Power demand • Random Forest

Introduction

Gone through 60 years from 1947 to the present, Inner Mongolia Electric Power Industry with initial running of isolated small power plants has seen the direct distribution power to one factory by its own grid and later 35, 110, 220 and 500 kV grid. At the beginning of the foundation of the People's Republic of China, only 11 power plants and 14.8 thousands kilowatt capacity were on operation and to 2007 a network of "Four Verticals and Three Transverses", west rose from Alxa and east ended to Xilingol, was formed with 11 converting station of 500 kW and 91 generating stations. The idea of transferring electricity instead of coal was proposed in 1991 by

Z.-j. Wei (✉)
School of Management, Tianjin University, Tianjin, P.R. China
e-mail: nmdlwzj@gmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_66,

constructors, which enhanced the strategy of Coal-to-Electric Transportation. After several years developing, the days of power shortage in Inner Mongolia has gone and electricity was exported to Mongolia and Beijing in 1994 and 1995 respectively with 12.18 billions kilowatt-hours. Since basic and energy industries were put at the primary position in national policies during “the twelfth five-year plan”, the district took power industry as backbone and suggested industry acceleration policies. Power industry, especially western electricity enterprises obtained more privileges on investment, finance, taxes and price, would be the focus of national support in the future, which provided a great chance for developing. It was urgent to make sufficient and scientific plans to figure out the direction for development of electricity estate in Inner Mongolia after past rapid progress for 60 years.

It was difficult to balance electric power, quantity and peak and optimize structure without reliable prediction which was viewed as the foundation of power planning. According to power demand characters, structure and mind, adjusting development schedule and supply mechanics and enhancing economic and reasonability of electricity supply, could make enterprises impregnable (Liao 2008). Forecasting with significant meaning to electric industry and national economic, was helpful to unifying production and market, saving resource and energy and obtaining economic, social and environmental benefits. In a word, prediction had its theoretical and practical values.

The pioneer research of power demand was made out by American scholar Kraft (Eden and Hwang 1984) in 1978 and demand function and prediction were taken into consideration at that time. Until 1980’s mid-long term demand forecasting had been starting to boom with regression analysis, artificial intelligence, exponential smoothing, auto regression moving average (ARMA) and so on (Liao 2008; Eden and Hwang 1984; Liu Guangying and Li Xiang 2010; Yan 2006; Liu Lixiang and Meng Qingpeng 2010). Each method had its own restriction, for example, the prediction precision of artificial intelligence, expert system and artificial neuron network depended on the huge sample and proficient’s’ experience. Here we choose Random Forest (Breiman 2001), a successful machine learning algorithm in practical application.

Random Forest

Random Forest, firstly proposed by Breiman in 2001 (Breiman 2001), grows many regression and decision trees since ensemble learning can improve precision obviously and becomes a popular research focus in the past 10 years. It inherits all advantage of regression and decision tree and greatly improves accuracy of single tree by combination of many trees, which make it to be one of most used algorithm. Each tree can deal with both regression and classification when presented with a set of predictor values.

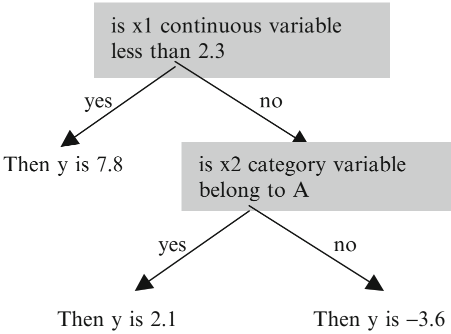


Fig. 66.1 A simple classification and regression tree

A novel CART was constructed for studying in Fig. 66.1, where x1 and x2 were explained as independent variable and y as dependent variable. Variable y and x1 were assumed to be continuous one while variable x2 as category variable. Three leaf nodes gave predicted value of y given their dependent values fell into corresponding leaf. Indeed the final model of tree in Fig. 66.1 was

$$\begin{aligned} y = f(x1, x2) = 7.8I(x1 < 2.3) + 2.1I(x1 \geq 2.3) \cdot I(x2 = A) \\ - 3.6I(x1 \geq 2.3) \cdot I(x2 \neq A), \end{aligned} \tag{66.1}$$

Where $I(\cdot)$ was indicator function with

$$I(x < a) = \begin{cases} 1, & x < a \\ 0, & otherwise \end{cases}.$$

Bagging ensemble method was applied to construct a series of tree-based learners. Each base learner was constructed by different training set of **n** instance which was sampled independently with replacement from the original training set **n** instance. This sample-generating method was also called Bootstrap. The rest of the instances, called out-of-bag data, could be used to estimate prediction error, i.e. OOB error. With Bootstrap sample, each tree was made up by its own algorithm. But in each note of tree the splitting variable was selected from a randomly chosen candidate sets of all independent variables. The best splitting was calculated based on these candidate variables in the training set of Bootstrap. Each tree was grown as large as possible and not pruned which usually was an inevitable step in single tree model.

Many authors (Granitto et al. 2006; Svetnik et al. 2004; Ehrman et al. 2007) had reported that Random Forest produced a highly accurate prediction and classifier without over fitting in many actual data sets and simulations comparing to other traditional method, such as artificial neuron network, support vector machine. It was computationally effective and less sensitive to noise on large data bases with thousands of independent variables without variable deletion. Parallel computing brought its learning progress very fast. In fitting process generated forests could be conserved for future use with arbitrary adding, deleting and inserting.

Random Forest also had many extra tools for analysis. It provided an equation to calculate the importance and the interaction of input variables in the classification and to visualize the relation between the variables and the regression by computing prototype. Proximities between pairs of cases were calculated for clustering, locating outliers, which had strength to view the interior of the data. The abilities of the above could be extended to continuous data, leading to automated clustering, outlier detection and data visualization.

Since the training sets of individual tree were generated by bootstrap replication, there were about 36.8% of bases leaving out as OOB data which provided an unbiased estimation of internal error, strength and correlation. Using its unique methods, missing data with large proportion could be estimated and maintained higher accuracy. Balancing error might be carried out for population unbalanced data sets.

Prediction Results

Sample Exploratory Analysis

Power supply (10,000 kW-h), gross national production GDP (100 million Yuan) and population (10,000) in Inner Mongolia from 1980 to 2009, listed in Fig. 66.2, were collected from “Inner Mongolia statistical yearbook”. It could be seen from Fig. 66.1 that the three indexes were growing with time and the trend of supply and GDP were almost the same. Their scatter points were depicted in line 3 and column 2 in Fig. 66.1 with strong dependence of nearly straight line, and the same as supply and population in line 4 and column 2 in Fig. 66.2.

Kendall rank coefficients, proposed to test covariation without thinking variation amplitude in two-dimensional or higher space, were calculated between three influencing factors like time, GDP and population and power supply respectively. The probabilities of the tests based on Kandll rank coefficients, illustrated in Table 66.1, were all less than 0.05, which revealed the correlation between power supply and three influencing indexes. The three coefficients, closed to one, indicated strong dependence.

Random Forest Prediction

It is the key for forecasting to fit the function between Time, GDP and population, viewed as independent variables and power supply, as dependent one. Random Forests that could directly deal with data with different dimensions without standardization, was done by library random Forest in R language, whose key parameter was *mtry* representing the number of candidate variables in splitting.

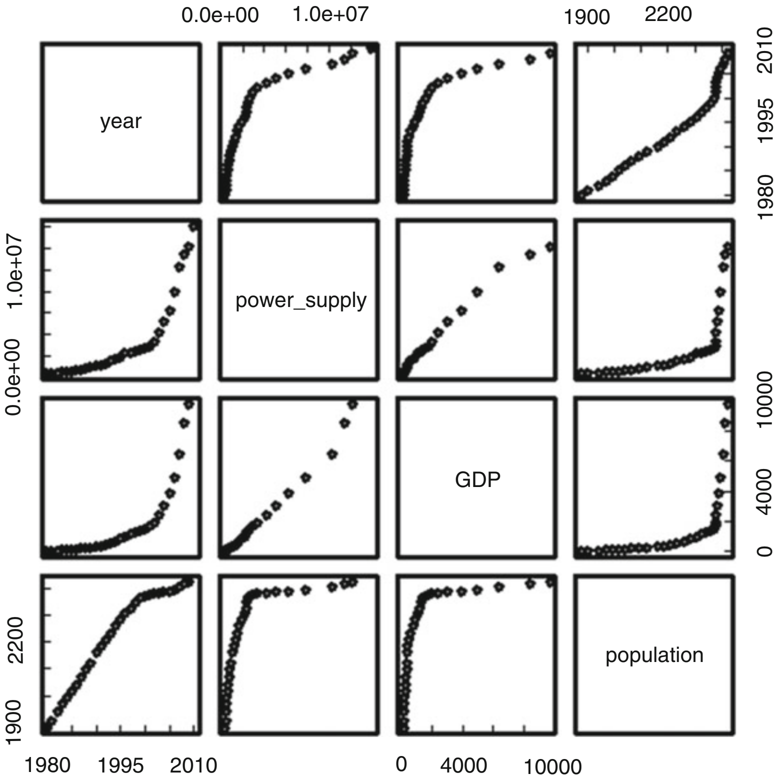


Fig. 66.2 Pair plots of sample from 1980 to 2009 in Inner Mongolia

Table 66.1 Kendll correlation coefficients between power supply and the other three influencing factors

Two indexes	Kendll correlation coefficients	Test Probability
Power supply and time	1.0	2.2×10^{-16}
Power supply and GDP	1.0	1.1×10^{-15}
Power supply and population	1.0	1.1×10^{-15}

Advised value of *mtry* was square root of all variables for classification mode and one third for regression mode. A preferred method was to compute Out-of-bag (OOB) errors for different *mtry* and choose the value of the smallest error, which was depicted in Fig. 66.3 and the optimized *mtry* was three.

The other two important parameters were *ntree* and *nodesize* indicating total number of tree and samples in each terminal node respectively. *Nodesiz* took its default value 500 for over much of trees burdened computation cost with limited precision growth and lower could not ensure each variable's split. Errors of varying

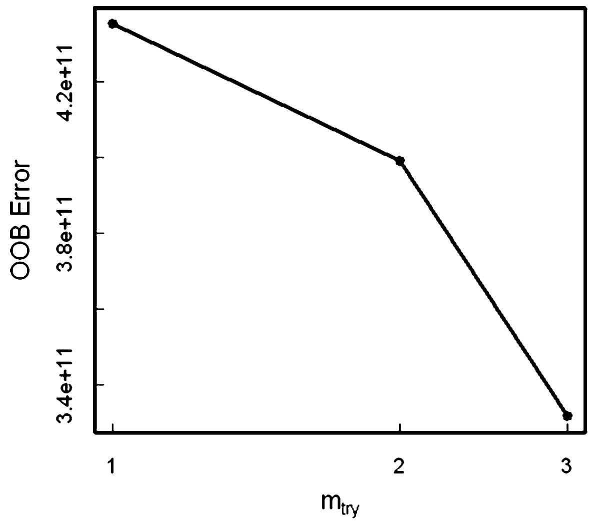


Fig. 66.3 OOB errors under varying values of *mtry*

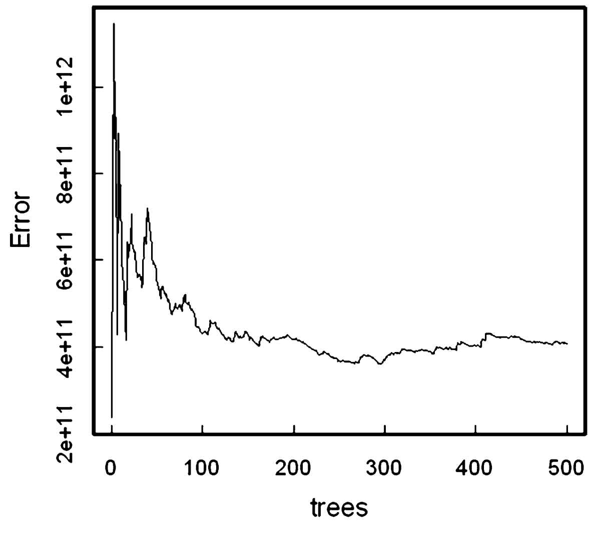


Fig. 66.4 Errors of different tree number *ntree*

trees number was shown in Fig. 66.4, from which it could be seen that larger tree number decreased the fitted error very little if tree number reached 200. If asking for small *nodesize*, big tree was easy to generate with unavoidably pruning and large *nodesize* leaded to tiny tree with fast speed. Usually *nodesize* took 1 for classification and 5 for regression.

Graph is more intuitive for explain. But visualization is utilized only for two or three dimensional space. Functions of a single variable can be represented as a scatter-plot for real-valued variables and bar-plot for categorical ones. Functions of

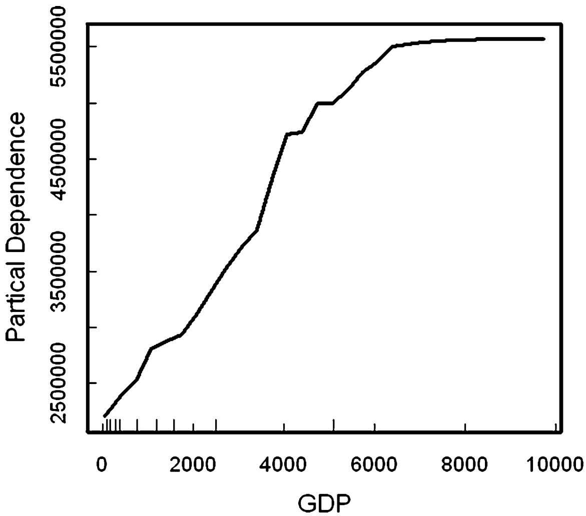


Fig. 66.5 Partial dependence between GDP and power production in Inner Mongolia

two real-valued variables can be pictured using contour or perspective mesh plots. Functions of a categorical variable and another variable (real or categorical) are best summarized by a sequence of ("trellis") plots. Multivariable function is more difficult to view. Partial dependence of the function is supposed to view higher dimension space on selected small subsets of the input variables (Breiman et al. 1984). A series of such plots can often produce helpful clues for understanding.

Figures 66.5 and 66.6 gave the partial dependences between GDP and population and power supply respectively. Comparing their scatter plots (line 3 and 4 column 2 in Fig. 66.2), varying modes were different but with the same overall growing trend. Scatter plot was obtained under the condition that all input variables were fixed, meanwhile, only one variable was constant and the other ones varied and their mean value was the partial dependence. For example, in 1992, power production in Inner Mongolia was 1,316,125 ten thousands kilowatt-hours with 42.168 billions GDP and 22.066 millions population. For fixed 42.168 billions GDP, time changing from 1980 to 2009 and population altering from 18.765 to 24.2207, all values were substituted to the fitted function to gain power productions whose average value formed partial dependence.

To test prediction precision, data in 1982, 1996 and 2004 were reserved for computing relative error which equals quotient with dividend being difference between true value and forecasted one and divisor being true one. The relative errors, limited to 6%, were listed in Table 66.2, which demonstrated high precision and preference of Random Forest in power demand prediction.

Using ARMA model (Box and Jenkis 1978) to forecast future GDP and population and substitute those values and corresponding time to the fitted function, the future electricity demand then came out in Table 66.3.

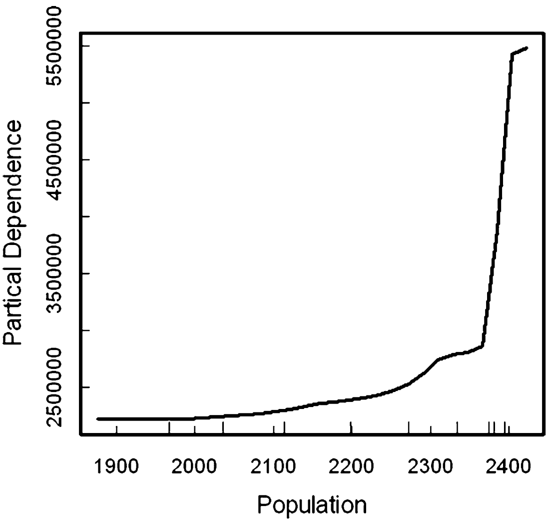


Fig. 66.6 Partial dependence between population and power production in Inner Mongolia

Table 66.2 Relative errors of three reserved data

Year	True power production (ten thousands kilowatt-hours)	Predicted power production (ten thousands kilowatt-hours)	Relative error (%)
1982	443,265	468,024.4	5.6
1996	2,205,692	2,196,499.5	−0.4
2004	5,164,000	5,349,783.7	3.6

Table 66.3 Power demand forecasting from 2010 to 2015

Year	Predicted GDP /(hundred million Yuan)	Population/(ten thousands)	Predicted power demand/(ten thousands kilowatt-hours)
2010	10,126.15	2,432.722	13,389,576
2011	11,253.74	2,445.428	14,917,310
2012	12,399.02	2,456.301	16,708,700
2013	12,988.55	2,464.952	18,756,036
2014	14,021.14	2,474.961	21,071,113
2015	15,095.76	2,487.273	23,676,807

Conclusion

Electricity demand was predicted from three strongly influencing factors like time, gross national production and population in Inner Mongolia by Random Forest fitting their function. Relative errors of three reserved data were 5.6, −0.4 and 3.6%, which indicated our method's advantage. Power demand in 2015 in Inner Mongolia was predicted to be 236,768.07 millions kilowatt-hours by substituting the future GDP and population which was forecasted through ARMA time series to the fitted function.

Acknowledgments The research work of thesis is fully supported by the National Natural Science Foundation of China (Grant NO. 10772132) and the Doctoral Foundation of Ministry of Education of China (Grant No. 20070056063).

References

Box GP, Jenkis GM (1978) Time series analysis: forecasting and control. Wiley Press, San Francisco, pp 390–408

Breiman L (2001) Random forests. Mach Learn 45(1):5–32

Breiman L, Fredman J, Olshen R et al (1984) Classification and regression trees. Chapman & Hall, New York, pp 278–290

Eden SH, Hwang BK (1984) The relationship between energy and GNP: further results. Energy Econ 6:186–190

Ehrman TM, Barlow DJ, Hylands PJ (2007) Virtual screening of Chinese herbs with random forest. J Chem Inf Model 47(2):264–278

Granitto PM, Furlanello C, Biasioli F et al (2006) Recursive feature elimination with random forest for PTR-MS analysis of agroindustrial products. Chemom Intell Lab Syst 83(2):83–90

Liao Wenwei (2008) Electricity demand forecasts in the "11th Five-Year Plan,". Master dissertation, Technological Economics and Management, Chongqing University, Chongqing, China

Liu Guangying, Li Xiang (2010) SVM-based models for forecasting electricity demand in China. Manufac Autom 32(3):160–162

Liu Lixiang, Meng Qingpeng (2010) Prediction of urban power demand considering the factors of population economy and environment. J Hebei Eng Tech Coll 1:30–32

Svetnik V, Liaw A, Tong C, Wang T (2004) In: Roli F, Windeatt T (eds) Application of Breiman's random forest to modeling structure-activity relationships of pharmaceutical molecules, MCS, 2004. Springer, Berlin/Heidelberg, pp 334–343

Yan Dechun (2006) Electricity demand forecasts from 2006 to 2010 in Changzhou. Master dissertation, Business Administration, Nanjing University of Science and Technology, Nanjing, China

Chapter 67
Study on Forecast of Tianjin Construction Cost Indices Based on ARIMA Model

Fei-peng Li and Hong-li Wang

Abstract Present status of research on construction cost indices was discussed and the methods of cost indices were analyzed. Based on multiplicative model of economic data time series, the cost index was decomposed into seasonal factor, trend-cycle factor and irregular component. The ARIMA model was established to fit the data of the construction cost indices of Tianjin from 2007 to 2011 and the fitting and predicting result shows that performance of the ARIMA model was satisfied.

Keywords Cost indices • Time series • ARIMA • Forecast

Introduction

Construction cost indices are kind of composite quantitative indices which reflect the influence of price and volume change in labor, raw materials and machinery on construction cost. Construction engineering cost indices are empirical application of economic indices in construction engineering. It plays an important role in construction cost management. For example, it provides an important basis for project valuation and control and price trend prediction and also a reference for cost engineers to estimate and budget project investment and determine tender offer. It is of practical significance and feasibility in China to combine representative construction cost information and indices to form a cost foundation which can partly solve static problems of existent project cost information and establish an appropriate cost management model Suitable for China's construction market. In addition,

F.-p. Li (✉)
School of Management, Tianjin University, Tianjin 300072, China
e-mail: Feipeng@tju.edu.cn

H.-l. Wang
Research Institute of Architectural Design and Urban Planning, Tianjin University, Tianjin 300072, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_67,

construction cost indices can also be applied for statistics work, policy formulation and market participants (including contractors, owners and investors) to gain directive information.

The United Kingdom is the first country to implement construction cost management and by far has established a sound system and far-reaching influence in the world. In Britain construction cost information is released by government, professional groups and business units. Department of Trade and Industry in the UK is responsible for collecting information on labor cost, materials and machinery price and volume and estimating and regulating each cost index. Professional groups such as Royal Institution of Chartered Surveyors (RICS) set up a platform on which various kinds of price and cost indices are collected and released. In addition quantity surveyor association, engineering consulting company and contractors also release relevant cost information. In America construction cost indices are released by consulting company and news press, and one of the mostly-adopted indices is Engineering News-record (ENR). ENR consists of labor cost, timber, cement and steel indices and is divided into housing cost index and construction cost index. The Japan will survey construction cost change via reports half a year, modify general administrative fees and site budgets every 3 year and construction project budgetary estimate quota every 5 year.

In Hong Kong, construction cost information is usually released in the form of index and there are two main types, namely cost index and price index, which is formulated by cost and price trend respectively. Government and business groups release their own cost indices separately. Some indices released by government are commonly used in Hong Kong, including quantity survey composite cost indices, labor cost indices and material price indices. The most influential cost indices in Hong Kong are from Architectural Services Department and two nongovernmental quantity survey associations. Architectural Services Department's quarterly tender price index is mainly used to adjust construction cost data and measure new project tender price.

Due to separate industrial and regional management, Chinese mainland hasn't established a national unified construction cost indices system. Different management leads to different levels of cost indices in each region and a lack of information collection standard. Tianjin is one of the few regions that have sound construction cost index system. The system covers a wide area, ranging from primary material to secondary material, from construction to installation and municipal engineering. Indices are categorized into monomial indices and composite indices. Certain researches on the formulation and its practical application of construction cost indices have been done by domestic scholars (Zhang Cuiqing 2010; Wu Xuewei 2009; Chenwei 2009; Wangjing 2005). For example, Daode Zhang (2009) adopted grey model to analyze highway construction cost indices; however this method couldn't be applied widely. Literature 6 uses chaotic time series analysis for prediction and its result proves that the determination of parameters of grey model is largely vulnerable to subjective factor Wang Chunfeng (2007).

In this paper the ARIMA model was established to fit the data of the construction cost indices of Tianjin from 2007 to 2011 and the fitting and predicting result shows that the short-term prediction performance of the ARIMA model was satisfied and it is a reliable method.

Construction Cost Indices Decomposition

Construction engineering cost indices belong to quality composite index and it is best to calculate it via composition analysis, for it can not only reflect changing direction and degree of the research target but also use the difference between numerator and denominator to directly reflect actual economic effect (Hong Ke 2003).

The decomposition of cost indices is to separate each factor so that their fluctuation could be clearly observed. Tianjin construction engineering cost indices are monthly data and could be decomposed into trend factor, cycle factor, seasonal factor and irregular factor according to time series decomposition theory. Owing to limited observations it is hard to distinguish trend from cycle. Therefore trend factor and cycle factor are combined into trend-cycle factor. Seasonable factor reflects periodic change of construction cost in the same time of different year and it's a regular fluctuation repeatedly shown by time series revolving around trend and cycle. It is affected by natural factors such as climate factors and cultural factors. Irregular factor shows random change and outlier influence and other irregular influence including non seasonal climate, natural disaster and some unfair sales campaigns.

Therefore in this paper time series are decomposed into seasonal factor, trend factor and irregular factor and X12 method is adopted to adjust seasonal factor with Eviews. CI_IR represents irregular factor, CI_TC is trend-cycle factor and CI_SF is seasonal factor and CI_SA is final result after excluding seasonal factors, their relation is as follows:

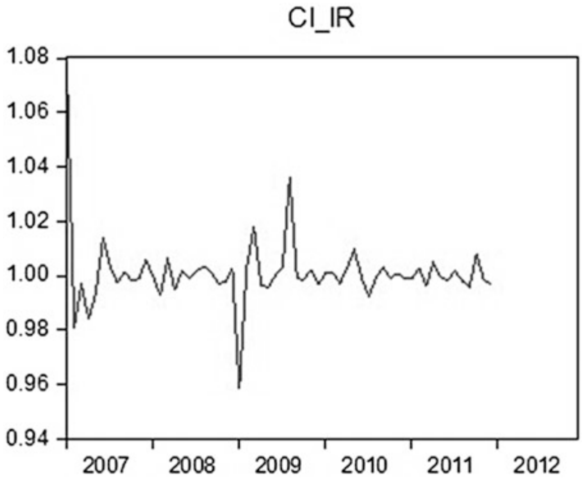
$$CI = CI\_IR \times CI\_TC \times CI\_SA$$

Graphs 67.1, 67.2, 67.3, and 67.4 are results of time series decomposition of Tianjin construction cost. From these graphs it is easily noticeable that economic cycle and trend is influential as Olympic Games and global financial crisis have affected Chinese fixed asset investment in 2008 and 2009. And in second and third quarter of every year owing to mild climate construction projects are on the rise. It clearly shows that cost indices are subject to seasonal fluctuation.

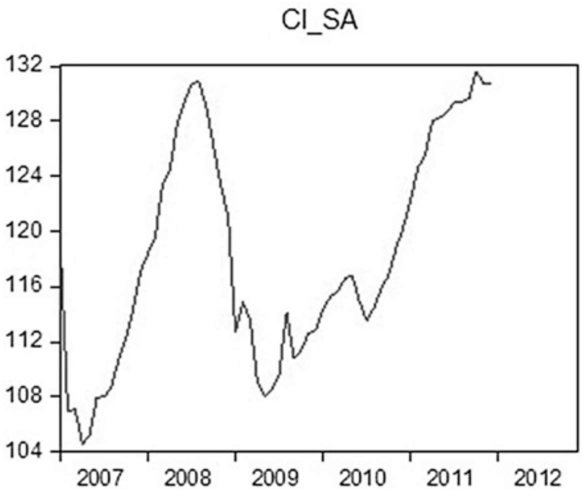
Arima Model Establishment and Forecast

Data Preprocess

According to the analysis above, Tianjin construction engineering cost indices have a strong variation trend and present a 12-month-cycle seasonal fluctuation. Time series is nonstationary. Take first-order difference of the original series



Graph 67.1 CI irregular fluctuation



Graph 67.2 CI final result excluding seasonal factor

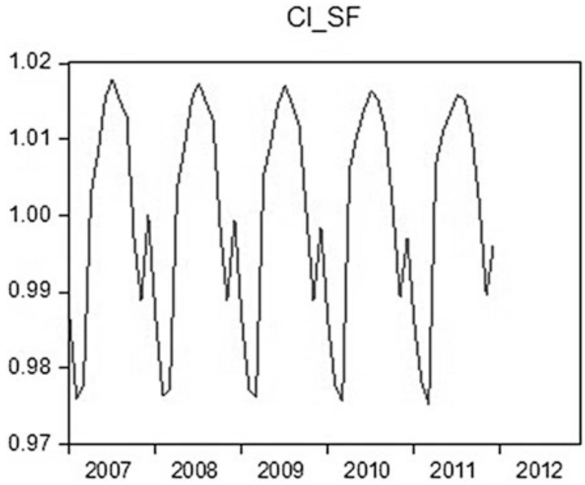
and get difference series D(ci). The tendency of D(ci) is approximately eliminated and its autocorrelation and partial autocorrelation analysis is presented in Graph 67.5.

ADF test shows that D(ci) is stationary series with unit root so ARIMA is fitted for prediction.

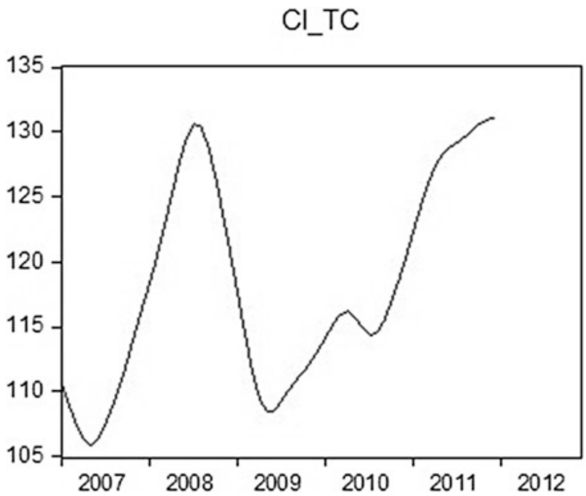
Model Selection and Estimation

After first-order difference and season difference, the ARIMA(p, d, q) (P, D, Q) s model is selected. Judging from partial autocorrelogram, $p = 1$or $p = 3$ is appropriate and autocorrelogram shows that $q = 1$or $q = 3$ is appropriate. There

Graph 67.3 CI seasonal fluctuation

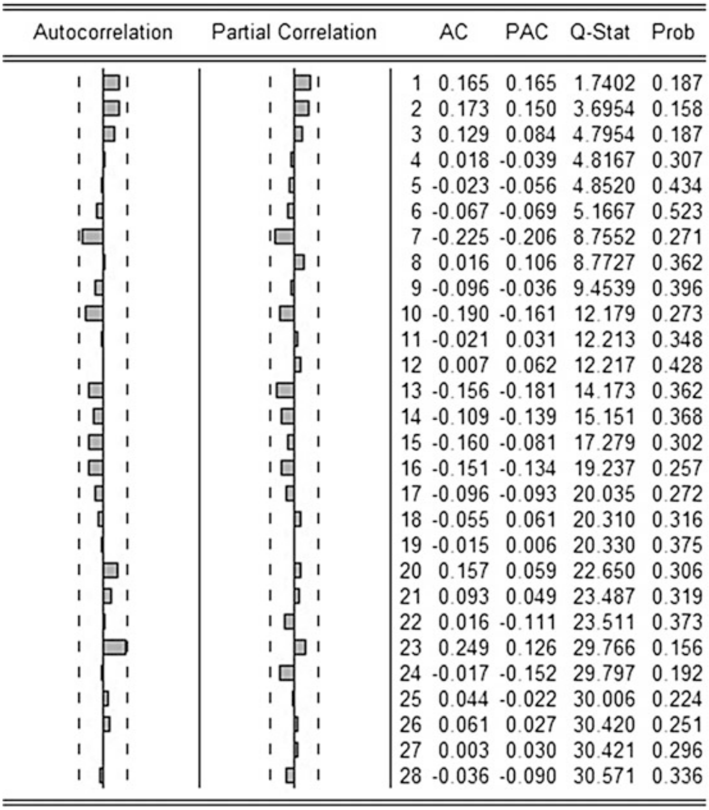


Graph 67.4 CI trend-cycle fluctuation



are many (p, q) groups to choose from. Since data series have evident seasonal character, P = 1, Q = 1, D = 1. Eviews is used for predicting model and adjustment is made according to coefficient significance and at last three models are selected and listed in Tables 67.1, 67.2, and 67.3.

1. ARIMA (1,1,3)(1,1,1)12 Model (Model I)
   Estimation result is shown in Table 67.1:
2. ARIMA(0,1,1)$(1,1,1)^{12}$ Model (Model II)
   Estimation result is shown in Table 67.2.
3. ARIMA(1,1,0)(1,1,1)12 Model (Model III)
   Estimation result is shown in Table 67.3.



	AC	PAC	Q-Stat	Prob
1	0.165	0.165	1.7402	0.187
2	0.173	0.150	3.6954	0.158
3	0.129	0.084	4.7954	0.187
4	0.018	-0.039	4.8167	0.307
5	-0.023	-0.056	4.8520	0.434
6	-0.067	-0.069	5.1667	0.523
7	-0.225	-0.206	8.7552	0.271
8	0.016	0.106	8.7727	0.362
9	-0.096	-0.036	9.4539	0.396
10	-0.190	-0.161	12.179	0.273
11	-0.021	0.031	12.213	0.348
12	0.007	0.062	12.217	0.428
13	-0.156	-0.181	14.173	0.362
14	-0.109	-0.139	15.151	0.368
15	-0.160	-0.081	17.279	0.302
16	-0.151	-0.134	19.237	0.257
17	-0.096	-0.093	20.035	0.272
18	-0.055	0.061	20.310	0.316
19	-0.015	0.006	20.330	0.375
20	0.157	0.059	22.650	0.306
21	0.093	0.049	23.487	0.319
22	0.016	-0.111	23.511	0.373
23	0.249	0.126	29.766	0.156
24	-0.017	-0.152	29.797	0.192
25	0.044	-0.022	30.006	0.224
26	0.061	0.027	30.420	0.251
27	0.003	0.030	30.421	0.296
28	-0.036	-0.090	30.571	0.336

Graph 67.5 D(ci) autocorrelation-partial correlation

Table 67.1 Model I estimation result

Variable	Coefficient	Std. error	t-statistic	Prob.
AR(1)	0.491568	0.166314	2.955666	0.0058
SAR(12)	−0.333484	0.098808	−3.375063	0.0019
MA(3)	0.148394	0.097936	1.51521	0.1395
SMA(12)	0.930734	0.031813	29.25665	0.0000

Residual test result is shown in Graph 67.6

Table 67.2 Model II estimation result

Variable	Coefficient	Std. error	t-statistic	Prob.
AR(12)	−0.320937	0.095293	−3.36791	0.0019
MA(1)	0.239309	0.089357	2.678136	0.0113
SMA(12)	0.90032	0.032863	27.39655	0.0000

Residual test result is shown in Graph 67.7

Table 67.3 Model III estimation result

Variable	Coefficient	Std. error	t-statistic	Prob.
AR(1)	0.48814	0.158886	3.072268	0.0042
SAR(12)	−0.28865	0.096224	−2.999779	0.0051
SMA(12)	0.932296	0.030402	30.66585	0.0000

Residual test result is shown in Graph 67.8

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.029	0.029	0.0331	
		2	0.026	0.025	0.0597	
		3	0.161	0.160	1.1354	
		4	0.027	0.018	1.1656	
		5	0.051	0.044	1.2819	0.258
		6	-0.136	-0.170	2.1270	0.345
		7	-0.192	-0.205	3.8670	0.276
		8	-0.007	-0.015	3.8693	0.424
		9	-0.166	-0.120	5.2696	0.384
		10	-0.116	-0.044	5.9791	0.426
		11	-0.138	-0.112	7.0160	0.427
		12	-0.056	-0.010	7.1940	0.516
		13	0.062	0.052	7.4193	0.594
		14	0.017	0.047	7.4367	0.684
		15	-0.136	-0.167	8.6423	0.655
		16	-0.003	-0.103	8.6431	0.733

Graph 67.6 Model 1 residual test result

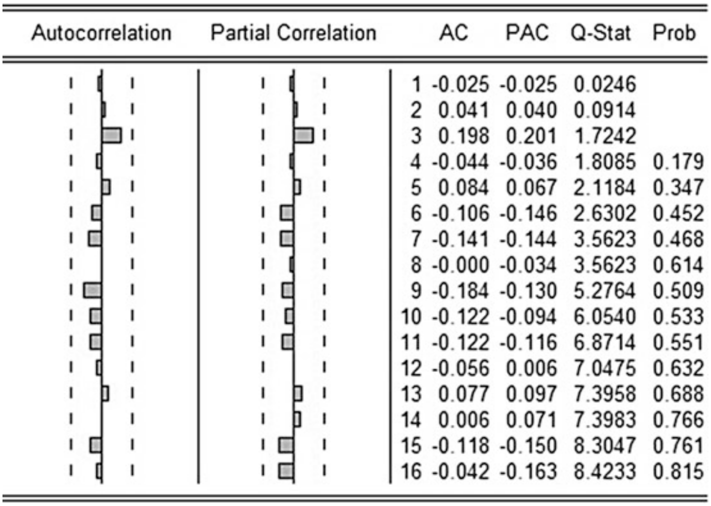
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.217	0.217	1.8889	
		2	0.090	0.045	2.2213	
		3	0.178	0.157	3.5646	
		4	0.086	0.017	3.8906	0.049
		5	0.124	0.094	4.5863	0.101
		6	-0.102	-0.188	5.0660	0.167
		7	-0.199	-0.184	6.9745	0.137
		8	-0.062	-0.022	7.1632	0.209
		9	-0.230	-0.193	9.8845	0.130
		10	-0.136	0.005	10.866	0.145
		11	-0.167	-0.083	12.413	0.134
		12	-0.022	0.156	12.441	0.190
		13	0.039	0.041	12.533	0.251
		14	-0.103	-0.069	13.195	0.281
		15	-0.075	-0.106	13.562	0.330
		16	-0.023	-0.102	13.600	0.403

Graph 67.7 Model II residual test result

After calculation, correlation coefficient in three models fall into random interval and each residual series are interdependent and they are white noise series. The model fitting is satisfied.

Model Selection and Evaluation

Three models' test results are summarized in Table 67.4. Compared with the first two models, model III's AIC and SC value is comparatively smaller and its concomitant probability of residual series white noise test(p-Q value)is the largest,



Graph 67.8 Model III residual test result

Table 67.4 Test result summary sheet

(p,q)	A−R^2	AIC	SC	p−Q	MAPE
(1,3)	0.73198	3.9533	4.1292	0.733	0.988
(0,1)	0.70000	4.0125	4.1431	0.403	1.077
(1,0)	0.7283	3.9421	4.0740	0.815	1.013

accompanied with a relatively higher accuracy(MAPE). Even though model III's sample determination coefficient is not as good as the first model, of which the coefficient is not significant, it is still better than the second one. Therefore the third model ARIMA (1,1,0) $(1,1,1)^{12}$ fits best and its expansion form is as follows:

$$(1+0.28855B^{12})\,(1-0.48814B)\,(1-B)\,(1-B^{12})\,CI=(1-0.932296B^{12})u_t$$

Model Forecast

This paper uses ARIMA (1,1,0) $(1,1,1)^{12}$ to forecast Tianjin construction cost indices and the result is shown in Table 67.5:

Table 67.5 Forecast of Tianjin construction cost indices

Obs	Fitted	Error (%)
2011M01	120.6976	0.20
2011M02	122.1436	0.21
2011M03	122.8514	0.33
2011M04	128.826	−0.06
2011M05	129.8898	0.15
2011M06	129.1657	−0.91
2011M07	130.8923	−0.45
2011M08	131.6241	0.20
2011M09	132.5365	1.17
2011M10	131.0292	−0.63
2011M11	130.6352	0.99
2011M12	129.3123	−0.66
2012M01	129.8975	0.02
2012M02	129.7832	0.38

Conclusion

Through analyzing construction cost indices of Tianjin from 2007 to 2011, this paper draws conclusions that construction engineering cost indices have obvious seasonal fluctuation trend and ARIMA model is suitable for construction cost indices forecast as the fitting and predicting result of this model is accurate and satisfied.

References

Chenwei (2009) Research on forecast of construction engineering cost indices [D]. Chongqing University, Chongqing

Daode Zhang (2009) Prediction and analysis of highway construction indicies [J]. China Price, 6:38–40

Long Huidian, Zhang Haiyan (2007) ARIMA-based forecast of Guangzhou commercial housing price [J]. Bus Res 7(363):211–213

Wang Chunfeng, Songwei (2007) Application of chaotic time series analysis method in GDP forecast [J]. J Tianjin Univ (Social Science edition) 2(9):137–139

Wangjing, Tianpeng (2005) Application of wavelet neural network in real estate price index forecast [J]. Comput Simul 7(22):96–98

Wu Xuewei (2009) Research on residential engineering cost indicators and indices [D]. Chongqing University, Chongqing

Yangnan, Xing Licong (2006) Application of Gray-Markov model in housing price forecast [J]. Stat Inf Forum 5(21):52–55

You Meifang, Huangmin, Chengli (2009) Empirical study on commercial housing price index predication in Sichuan Province based on ARIMA model [J]. China Price 6:38–40

Zhang Cuiqing (2010) Applied research on construction cost indicators and indices [J]. Eng Constr 4(24):556–558

Chapter 68
The Prediction of Tianjin West Railway Station's Passenger Flow Based on Stochastic Gradient

Su-qing Li, Hong-li Wang, Zhao-hui Meng, and Shi-lei Yao

Abstract Predict the future passenger flow of a railway station, which can provide an important reference for decision-making on scales of building a station and the management after the completion of the construction. According to the population changes of Tianjin in recent years, we have predicted Tianjin West Railway Station's passenger flow in future using Stochastic Gradient. The study found that the passenger flow of the station will grow significantly. The station will transmit the passengers mainly by rail-transport and vehicles like busses, taxis as an auxiliary. In addition, the south square will transmit more passengers than the north square.

Keywords Passenger Flow • Stochastic Gradient • Population

Introduction

Passenger flow is usually know as the flow of people, refers to the number of passengers through a section of the route in a certain time. It is an essential data in the construction and management of large shopping centers, airport, railway station and other public places. If the station scale is too small, it will be difficult when operating the passengers, if the station scale is too large, it will result in waste and resources idle in the financial, human and material. In addition, to predict the flow of people in future will bring the convenience of management, when setting in the entry and exit ports, subways, buses, taxis and private cars' operation area.

In recent years, the rapid economic development of Tianjin and the rise of Binhai New Area, make the city's passenger traffic and logistics of a rapid growth in size. So,

S.-q. Li • H.-l. Wang (✉) • Z.-h. Meng
School of Management, Tianjin University, Tianjin 300072, China
e-mail: wanghl@tju.edu.cn

S.-l. Yao
School of Mechanical Engineering, Tianjin University, Tianjin 300072, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_68,

the infrastructure that has more powerful, logistics and operational capabilities is needed. While Tianjin Railway station (East station) gradually reached the limit of the ability to operate. Therefore, improving the function capability of Tianjin West Rail Station has a positive role in promoting the development of the whole city.

Tianjin West Rail Station covers an area of 680,000 m^2, the main structure of the ground two floors and underground of three layers. Beijing-Tianjin urban express, Beijing-Shanghai, jin-qin and jin-bao four high-speed railways will intersect here, subway, bus, rail, rental and the long distance bus will achieve “zero transfer”. The rebuild station will become a large-scale integrated hub and the passenger distribution center to connect the North and the South.

There are many methods to predict the passenger flow. Some of them are so simple that the error is unacceptable, while others like Chaotic Time Series and Gray Prediction require the data is stable. Yu Jun-mei and Yang Yi (2008) predicted the passenger flow of bus station using Support Vector Regression. (Guo Peng and Xu Ruihua (2006) studied system dynamics of cities rail transit passenger flow, and analyzed the impact factors of it. Sun Qi-feng et al. (2008) predicted the passenger flow of highway tourism using BP Neural Network. Yang Ming-gui and Yang Xiao-xia (2010) predicted inbound tourism passenger flow in ChongQing using Gray Prediction Model. While Tianjin West Railway Station was reconstructed in large Scales in 2009–2011, many high-speed rails and subways will go through the West Station. So, large errors will occur when the methods above is used. Up to now, nobody has ever predicted the railway station’s passenger flow using advanced Machine Learning Method, like Stochastic Gradient. In this article, we will use Stochastic Gradient to predict Tianjin West Railway Station’s passenger flow. In order to verify the accuracy of this method, we reserved the last 2 years data as test data. Then, we will predict Tianjin West Railway Station’s annual, daily and peak-hour’s passenger flow in 2020 and 2030.

Stochastic Gradient

The Stochastic Gradient Boosting algorithm (Zhou Pu et al. 2010) based on regression tree has good performance, which takes into account the advantages of the regression tree while avoids many of the shortcomings of the single tree (Zhang Jiang-tao and Liu Yan-jun 2010). It is discontinuous when use single regression tree. Using multiple linear combinations of the regression tree can avoid the discontinuity of a single tree (Ding Feng et al. 2003). Therefore, the predictive performance has greatly improvement to a single tree. Meanwhile, a single tree exist unstable faults. The Stochastic Gradient Boosting (Yu Li et al. 2007; Zhao xiao-quan et al. 2009), described as the first section of this chapter, continuously uses multi-tree, which averages the error of each tree and improves stability in the statistical sense. Lastly, using single tree exist difficulties such as difficult segmentation. While Stochastic Gradient Boosting decreases this difficulty and improve stability of model. So Stochastic Gradient Boosting has a wide range of applications.

Randomness is measured by the scale factor k, where $k = \widetilde{N}/N$. When k decreases, the difference between this cycle and the previous cycle becomes great, which means that select different subset of the sample with higher probability (Wang Hong-li et al. 2008). Thereby, the randomness of the whole algorithm is increased. Meanwhile, when k decreases, the computational cost of the algorithm is reduced, the proportion of which is k. But, if k is too small, the generated regression tree will take on a bigger partial value. Studies have shown that the performance of the algorithm can reach a better balance when k is equal to 0.5.

In this article, the algorithm is accomplished by gbm package in R language. Before operate on the data, there are two quantities needed to be determined, which are the best delay time and the best embedding dimension. There are many ways to calculate these two quantities. Now, we will briefly introduce a common method.

Let N be the number of samples, $\bar{x}$ as the mean of the sequence, x_i is the i th sample. So, in the following expression:

$$R_{xx} = \frac{1}{N}\sum_{i=1}^{N-\tau}(x_i - \bar{x})(x_{i+\tau} + \bar{x}) \tag{68.1}$$

When R_{xx} reach the initial value $1 - \frac{1}{e}$ with the change of τ, this τ the best delay time.

The method of calculating the best embedding dimension is Cao's method.

$$a_{(i,d)} = \frac{\left\|X_i(d+1) - X_{n(i,d)}(d+1)\right\|}{\left\|X_i(d) - X_{n(i,d)}(d)\right\|} \tag{68.2}$$

$X_{n(i,d)}(d+1)$ is the nearest point with $X_i(d+1)$ in d-dimension space. The mean of function $a_{(i,d)}$ is:

$$E(d) = \frac{1}{N - d\tau}\sum_{i=1}^{N-d\tau} a_{(i,d)} \tag{68.3}$$

Define:

$$E'(d) = E(d+1)/E(d) \tag{68.4}$$

When $E'(d)$ does not change with d, d is the best embedding dimension.

Prediction Results

Learning from statistical data of Tianjin and other cities' experiences, this statistical rule is obtained: passenger flow of the Railway Station in a city is about twice as the population of it. Therefore, the prediction of West Railway Station's future passenger flow can be converted to the prediction of future population in Tianjin.

Table 68.1 The population of Tianjin in recent years (1983–2009)

Years	Population (million)	Years	Population (million)
1983	7.85	1997	9.53
1984	7.95	1998	9.57
1985	8.04	1999	9.59
1986	8.15	2000	10.01
1987	8.29	2001	10.04
1988	8.39	2002	10.07
1989	8.52	2003	10.13
1990	8.84	2004	10.23
1991	9.09	2005	10.43
1992	9.20	2006	10.75
1993	9.28	2007	11.15
1994	9.35	2008	11.76
1995	9.42	2009	12.02
1996	9.48		

Then, Stochastic Gradient algorithm is used to predict the population of Tianjin from 2020 to 2030. Take the population of Tianjin from 1983 to 2009 as calculate data. Reserve the data of 2010 and 2011 as the test data which is used to verify the accuracy of this algorithm (Table 68.1).

After computing, it is obtained that the total calculated population of Tianjin is 12.23 million while actual population is 12.93 million in 2010. In 2011, the population is 13.15 and 13.55 million respectively. So this algorithm has a high accuracy.

It is calculated that the total population of Tianjin is 15.91 million in 2020, while in 2030 the number will be 19.02 million. Therefore, considering the statistical regularity about the passenger flow and the total population obtained previously, it can be predicted that the traffic is about 311.82 million in 2020 and 38.04 million in 2030.

According to the statistical planning materials of Tianjin West Railway Station, as well as the development and trends of districts and countries in Tianjin, the traffic of the West Station will account for 45% of the total traffic in Tianjin, while the East Station will account for 55%. In 2030, the percentage will be 60 and 40% respectively. Therefore, it is predicted that passenger traffic volume annually will be 14.32 million, passenger traffic volume daily will be 39.232 thousand, peak-hour passenger volume will be 4.119 thousand (peak-hour passenger volume is obtained by daily amount multiplied by the peak-hour coefficient). In 2030, passenger traffic volume annually of Tianjin West Railway Station will be 22.82 million with passenger traffic volume daily 62.52 thousand and peak-hour passenger volume 65.65 thousand.

In future, rail traffic will take 50% sending volume, regular bus will take 30%, while taxi, social vehicle and other modes of transportation will take 20%. This means that, in 2020, rail traffic will send 7.16 million passengers per year, regular bus will send 4.3 million passengers per year and others will send 2.88 million

Table 68.2 Tianjin west railway station's passenger flow in 2020 and 2030

Years		2020	2030
Tianjin west railway station	All day	40,701	64,819
	Peak-hour	4,588	6,884
Beijing-Tianjin urban express	All day	11,107	16,631
	Peak-hour	1,166	1,663
Ordinary high- speed rail	All day	3,206	3,800
	Peak-hour	609	722
Beijing-Shanghai high-speed rail	All day	8,194	13,383
	Peak-hour	1,003	1,458
Jin-Qin	All day	12,954	22,642
	Peak-hour	1,296	2,220
Jin-Bao	All day	5,329	8,363
	Peak-hour	514	820

Unit: person/day, person/hour

passengers per year. In 2030, the number of sending passenger will be 11.41, 6.85 and 4.56 million respectively.

Tianjin West Railway Station sends passengers through the South and North squares. It can be determined by the convenience of the two squares that the passenger volume in south and north squares are 62 and 38% respectively. So, in 2020, passenger traffic volume annually in south square will be 8.88 million while north square 5.44 million. In 2030, the volume will be 14.15 and 8.67 million respectively.

The following is the prediction of the Third Railway Survey and Design Institute to Tianjin West Railway Station relevant data:

In 2020, Tianjin West Railway Station will send 14.68 million passengers in a year. In 2030, it will send 23.67 million passengers in a year (Tables 68.2 and 68.3).

Conclusion

In this article, we predict the passenger flow of Tianjin West Rail Station annually, daily, as well as the peak-hour in 2020 and 2030 with Stochastic Gradient. Predict the passenger volume of rail traffic, regular bus and vehicles like taxi, social respectively divided by the modes of transportation. Predict the passenger volume of the North and South squares in Tianjin West Rail Station divided by the location. Obtain the following conclusion.

1. The passenger volume of Tianjin West Rail Station will be 14.32 million in 2020. Meanwhile, the number will be 22.82 million in 2030. Therefore, Tianjin West rail Station will play a very important role in the operation of the passenger flow in future. The traffic in the scale is enormous. It means that Tianjin West Rail Station will become an important transport hub. With matching facilities, it can meet the needs of the operation of massive passenger flow.

Table 68.3 Passenger flow of each traffic modes

Years			2020	2030
Beijing-Tianjin urban express				
On the ground	South square	All day	2,803	4,124
		Peak-hour	233	308
	North square	All day	1,718	2,528
		Peak-hour	233	291
Rail traffic		All day	6,585	9,979
		Peak-hour	699	1,064
Ordinary high-speed rail				
On the ground	South square	All day	1,014	1,202
		Peak-hour	193	228
	North square	All day	621	736
		Peak-hour	118	140
Rail traffic		All day	1,571	1,862
		Peak-hour	298	354
Beijing-Shanghai high-speed rail				
On the ground	South square	All day	2,951	3,650
		Peak-hour	310	364
	North square	All day	1,589	2,238
		Peak-hour	201	278
Rail traffic		All day	4,015	7,495
		Peak-hour	491	817
Jin-Qin				
On the ground	South square	All day	4,096	6,167
		Peak-hour	402	577
	North square	All day	2,511	3,786
		Peak-hour	259	400
Rail traffic		All day	6,348	12,680
		Peak-hour	635	1,243
Jin-Bao				
On the ground	South square	All day	1,323	2,281
		Peak-hour	103	205
	North square	All day	810	1,398
		Peak-hour	103	123
Rail traffic		All day	3,106	4,684
		Peak-hour	308	492

Unit: person/day, person/hour

2. The study found that the passenger flow of the station will grow significantly. The station will transmit the passengers mainly by rail-transport and vehicles like busses, taxis as an auxiliary, which is also fully considered when reconstructing the West Station. Three subway lines and the Xiqing Sinking Tunnel will go through the station. On the square, the bus depot and long-distance station were established. And the first layer underground is equipped with a taxi parking, the second layer underground is equipped with social car parking. Therefore, Tianjin West Railway Station will be able to effectively achieve the passenger sending.

3. The traffic data of the North and South square shows that the traffic of these two squares will be significantly improved in a decade or two. Compared with the North Plaza, the South Square will undertake more traffic. Geographically, the north of the Tianjin West Railway Station is close to the Ziya River, while south of the station is wide. Therefore, the South Plaza has conditions to accommodate more vehicles. In addition, Tianjin West Railway Station is located in the northwest of Tianjin. To the convenience degree for visitors getting to the north and South Square, the South Square is more convenient than the North Square. From the analysis of the economic development situation of China's various regions, the Yangtze River Delta region, the Pearl River Delta region and the Central Plains region's economic development relatively strong, while the economy of northeast area is still in the promotion period. Therefore, passenger flow density of the South Square is higher than that of the North plaza. So it is a reasonable choice that the South Plaza undertakes more passenger traffic.

References

Ding Feng, Xiao de-yun, Ding Tao (2003) Multi-innovation stochastic gradient identification method. Control Theory Appl 20(6):870–874

Guo Peng, Xu Ruihua (2006) Study on the growth of passenger flow in urban rail transit based on system dynamics. Urban Rapid Rail Transit 19(6):38–41

Sun Qi-feng, Zhou Xu, Sun Xiao-feng (2008) High way travel passenger volume forecast based on improved B{ neural net work. J Shandong Univ Technol (Natural Science Edition) 22 (6):75–79

Wang Hong-li, Han Hong-chen, Li Sheng-peng et al (2008) Stochastic gradient regression analysis of city municipal and domestic water consumption. J Tianjin Univ (Soc Sci) 10(3):225–227

Yang Ming-gui, Yang Xiao-xia (2010) Prediction for inbound tourism flow of Chongqing based on grey prediction model. J Southwest China Norm Univ (Natural Science Edition) 35 (3):260–263

Yu Jun-mei, Yang Yi (2008) Real time passenger volume forecasting in bus stops based on SVR. J Yantai Vocat Coll 14(1):79–83

Yu Li, Ding Feng, Zhang Jia-bo (2007) Convergence of multi-innovation stochastic gradient identification method. Sci Technol Eng 7(21):5475–5479

Zhang Jiang-tao, Liu Yan-jun (2010) Auxilliary model based multi-innovation stochastic gradient identification algorithm for multivariable system. Comput Meas Control 18(6):1424–1427

Zhao xiao-quan, Li Hui-ming, Yu Chao et al (2009) Influence of stochastic gradient estimation on blind equalization algorithm. J Tong ji Univ (Natural Science Edition) 37(9):1236–1240

Zhou Pu, Wang Xiao-lin, Ma Yan-xing et al (2010) Analysis on residual error for adaptive optical system based on stochastic parallel gradient control algorithm. Acta Opt Sin 30(3):613–617

Chapter 69
The Research on the Enterprise Competitiveness Evaluation Based on Fuzzy Multiple Index and Topsis Approach—Take the Financial Service Outsourcing Industry as an Example

Chen Shen and Li-ming Zhao

Abstract Based on fuzzy multiple index and Top sis approach, this paper analyzes and compares the competitiveness evaluation of the financial service outsourcing companies. It sets up the model frame and index system of financial service outsourcing companies, and analyzes various factors of three typical domestic financial service outsourcing companies. By using fuzzy multiple index and Top sis approach, it calculates the weight coefficient of each respective factor and the competitiveness ranking of the companies. This paper has a very important guiding significance on the financial service outsourcing companies' looking to improve their competitiveness.

Keywords Financial service outsourcing • Fuzzy multiple index • Information top sis • Competitiveness

Nowadays there are plenty of financial service outsourcing companies in China, most of which present a short of core competitive advantage, deliverability, operation ability and risk-control ability, etc. Chinese financial service outsourcing market is on its emerging stage, therefore those companies who speed up their self-development, will become first-movers in the market (Wu 2009; Xu and Jiao 2008).

Prior researches on financial service outsourcing companies were confined in current situation and operation model analysis, while paid little attention on competitiveness evaluation and competitive enhancement strategies. Meanwhile quantitative mathematical methodology was seldom employed (Zhou 2007; Mikhaii 2002). This paper is aimed at analyzing financial service outsourcing companies in microeconomic perspective from company level. It is assumed that a company's competitiveness is the comparative advantage of the company to configure and integrate its internal resources and external environments under competitive

C. Shen (✉) • L.-m. Zhao
College of Management and Economics, Tianjin University, Tianjin 300072, China
e-mail: gm@citic-os.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_69,

market environment, so as to seize the market, create values, satisfy its customers, dynamically adapt to environment changes and develop sustainably.

In this concern, identify the ways that influence a financial service outsourcing company's competitiveness, and discover the determinant factors and the relevant strategies are vital important to enhance its competitiveness, as well as to accelerate the development of domestic financial service outsourcing industry.

The Establishment of Competitive Evaluation Model of Financial Service Outsourcing Companies

Competitiveness Evaluation Index System

There are a variety of sources that influence a company's competitiveness, based on which the influencing factors are organized and the competitiveness evaluation index system is built. Due to the complexity of these influencing factors, the evaluation process of a financial service outsourcing company should focus on indicators that not only reflect the company's competitive situation accurately, but also obtain the reliable evaluative information easily, in order to ensure data availability and effectiveness (Hou and Yuan 2009). The indicators are shown in Fig. 69.1.

1. Company's basic quality and growth ability: it is a very important factor for any company to operate independently and develop and grow.
2. Company scale: it reflects the overall scale of a financial service outsourcing company.
3. Capability of management board: the reflection of a financial service outsourcing company's competitiveness is eventually achieved by the management board and its teams.
4. Quality of service: financial service outsourcing companies' mission is to serve financial institutions. Service differentiation attributes an important factor to the competitiveness of financial service outsourcing industry.

The Competitiveness Evaluation Methods of Financial Service Outsourcing Companies

Popular methods to analyze and evaluate a company's competitiveness include Analytic Hierarchy Process, fuzzy comprehensive evaluation method and expert scoring method.

The common drawback is some charge parameters such as membership function have to be assumed in advance, which has certain effects on evaluation and sorting

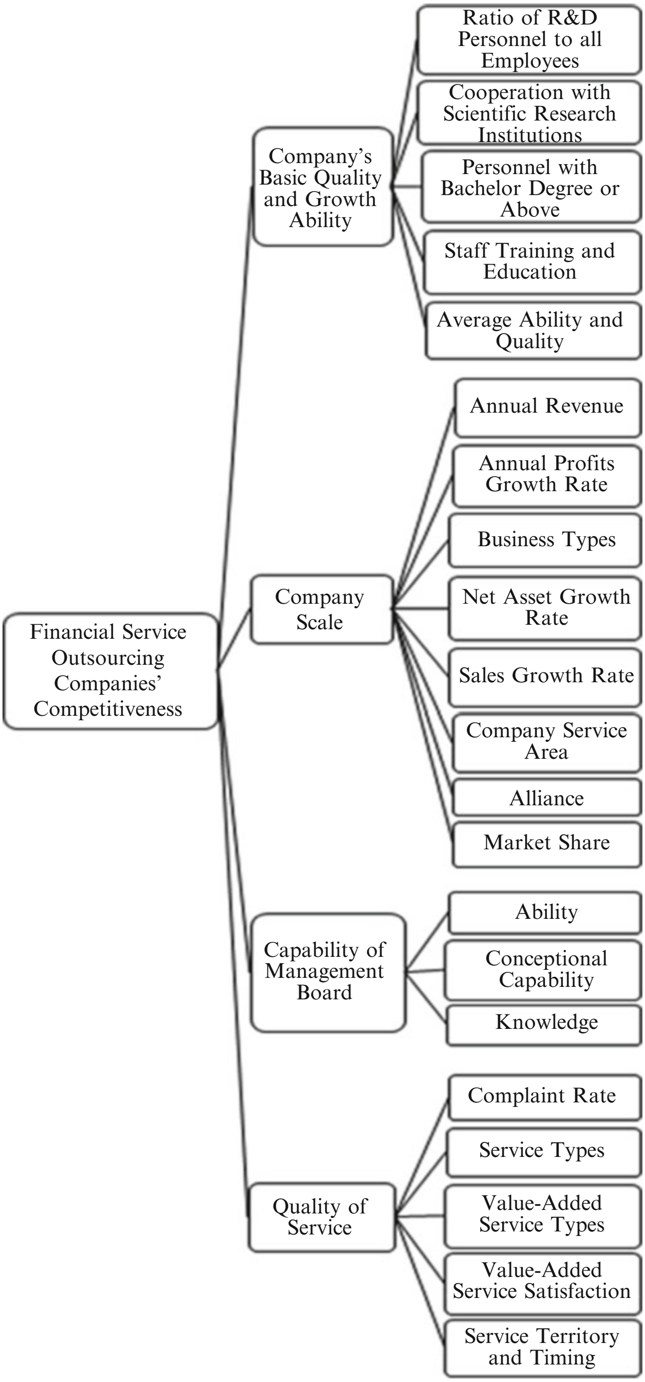


Fig. 69.1 Index system of financial service outsourcing companies' competitiveness

outcomes, which is vulnerable to subjective factors (Mikhaii 2002; Hou and Yuan 2009). To overcome this shortcoming, and considering the actual situation of financial service outsourcing industry, as well as indicators' feasibility and information incompleteness, this paper employs fuzzy multiple index and Top sis approach in order to overcome the subjectivity of weight assignment and get a more accurate evaluation result (Chen 2001a, b).

In such competitiveness evaluation method, the financial service outsourcing companies to be evaluated are assumed as $S = \{S_1, S_2, \cdots S_m\}$, the users who take part in the evaluating process are assumed to be $D = \{D_1, D_2, \ldots D_l\}$, and evaluation indices are $C = \{C_1, C_2, \ldots C_n\}$. Within the evaluation process, the information quoted includes: index weight vector $\varpi = \{\varpi_1, \varpi_2, \ldots \varpi_n\}$ and judgment matrix $\tilde{X} = \left[\tilde{X}_{xj}\right]_{m \times n}$, among which ϖ_j is the weight of C_j, and $\tilde{X}_{xj}$ is the competitiveness evaluation value of financial service outsourcing company i derived from C_j. In particular, ϖ_j and $\tilde{X}_{xj}$ are consist of natural language variables comment set that were designed by experts in advance, then they are valued by natural language variables format, and converted into the correspondent triangular fuzzy numbers to be calculated.

Empirical Research

In order to analyze the determinants and distribution patterns of domestic financial service outsourcing industry's competitiveness, this paper selects three representative outsourcing companies—Digital China, ChinaSoft Group, and HiSoft—based on their scales and strengths from a wide range of financial service outsourcing companies so as to ensure data availability and object representative.

Data Collection and Standardization

First is to inquire and acquire the specific data of each index of the three financial service outsourcing companies from different channels. Among them, companies' revenues, growth rates, complaint rates and the like are obtained from their public 2010 business data; technique capability and learning capability are gained from interviews of five intermediate staff or above in each company; and indicators such as capability of management board, market share and quality of service are derived from the scores marked by industry experts and calculated as average level.

Conversion of Language Variable Index Weights and Index Evaluation Value

The index weights and index evaluation value acquired from natural language variables format are then converted into correspondent triangular fuzzy numbers, where the triangular fuzzy numbers' index evaluation value comes out.

Calculation of Evaluation Index Clear Type Number Normalization Weights

Using relevant formulae and data from language variables correlated to index weights, triangular fuzzy number index weights related to customer groups evaluation are calculated, then the clear type number normalization weights of each index are derived.

Calculation of Clear Number Index Value

Using data from language variables related to index value, and through the clarity of normalized weighting formula, the clear evaluation value matrix $X = (X_{ij})_{m\times n}$, $\forall i, j$ is then defined as presented in Table 69.1.

The Establishment of Dimensionless Standardized Evaluation Matrix

Dimensionless standardized evaluation matrix $R = (r_{ij})_{m\times n}$ is obtained from the matrix $X = (X_{ij})_{m\times n}, \forall i, j$.

Calculation of Weighted Standardized Evaluation Matrix

Using normalized index weight vector and data from standardized evaluation matrix, via the formula $V = (V_{ij})_{m\times n} = (\omega_j r_{ij})_{m\times n}, \forall i, j$, weighted standardized evaluation matrix is gained. Within this formula, ω_j is the weight of index j, and r_{ij} is the dimensionless element.

Table 69.1 Competitiveness evaluation index and normalization weights of the three financial service outsourcing companies

Primary index and weights	Secondary index	Secondary index weights
Company's Basic Quality and Growth Ability 0.2765	Ratio of R&D personnel to all employees	0.0593
	Cooperation with scientific research institutions	0.0512
	Personnel with bachelor degree or above	0.0562
	Staff training and education	0.0557
	Average ability and quality	0.0541
Company Scale 0.3600	Annual revenue	0.0579
	Annual profits growth rate	0.0555
	Business types	0.0282
	Net asset growth rate	0.0529
	Sales growth rate	0.0540
	Company service area	0.0203
	Alliance	0.0496
	Market share	0.0415
Capability of management Board 0.168	Ability	0.0547
	Conceptional capability	0.0607
	Knowledge	0.0535
Quality of Service 0.1945	Complaint rate	0.0518
	Service types	0.0309
	Value-added service types	0.0362
	Value added service satisfaction	0.0307
	Service territory and timing	0.0449

Calculation of the Relative Closeness Degree of the Three Financial Service Outsourcing Companies' Competitiveness

Using weighted standardized evaluation matrix, through the formulae

$$\begin{aligned} V^{+} &= \left\{ \left(\max\ V_{ij}\ | j \in J \right), \left(\min\ V_{ij}\ | j \in J' \right), \quad i = 1, 2, \ldots m \right\} \\ &= \left\{ V_1^{+}, V_2^{+}, \ldots, V_n^{+} \right\} \end{aligned}$$

and

$$\begin{aligned} V^{-} &= \left\{ \left(\min\ V_{ij}\ | j \in J \right), \left(\max\ V_{ij}\ | j \in J' \right), \quad i = 1, 2, \ldots m \right\} \\ &= \left\{ V_1^{-}, V_2^{-}, \ldots, V_n^{-} \right\} \end{aligned}$$

the positive and negative ideal point V^{+} and V^{-} are calculated. Within these formulae,

$J = \{j = 1, 2, \ldots, n\}$, j is benefit index set;
$J' = \{j = 1, 2, \ldots, n\}$, j is cost index set.
Furthermore, the formulae

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^+\right)^2} \quad (i = 1, 2, \ldots m)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2} \quad (i = 1, 2, \ldots m)$$

help to define the distance of the positive and negative ideal point, $V_i{}^+$ and $V_i{}^-$, of the three financial service outsourcing companies' competitiveness.

Finally, the formula

$$C_j^+ = \frac{S_i^-}{S_i^+ + S_i^-} \quad (i = 1, 2, \ldots m)$$

is employed to calculate the relative closeness degree of the companies' competitiveness:

$$C_1{}^+ = 0.5823; \quad C_2{}^+ = 0.5601; \quad C_3{}^+ = 0.5218;$$

Ranking of the Three Financial Service Outsourcing Companies' Competitiveness

The competitiveness of the evaluated financial service outsourcing companies is ranked according to the numerical size C_i^+. That means, the higher the C_i^+, the greater competitiveness of the outsourcing company(Tang 1998). Therefore $S_1 \succ S_2 \succ S_3$. As calculated, Digital China has the greatest competitiveness among the three sampling financial service outsourcing companies.

Conclusion

Based on the empirical research presented above, financial service outsourcing companies should enhance their competitiveness from the following aspects:

Integrate Resources, Expand Company Scale and Improve Company Performance

Scale growth is regard as a company's short-term goal, or as a means and transition period for the company to achieve its ultimate goal. The advantage of scale growth is that, it could improve the company's economic efficiencies, including lower the production costs, transportation costs and increase the productivity. Meanwhile, scale growth could also enhance the competitiveness of the company (Baum and Korn 1999).

Attach Importance to Human Resource Management, and Enhance the Overall Staff Quality

Taking measures to train employees purposeful and systematically, so that they could continuously upgrade their knowledge, develop their skills and improve their motivations, attitudes and behaviors. As a result, the company is able to adapt to new requirements, therefore improve organization efficiency and fulfill organization goals (Jaya Chandran et al. 1999).

Strengthen the Service Awareness and Improve Customer Satisfaction

Superior service quality and customer satisfaction are determinant factors of financial service outsourcing companies' competitiveness, and strengthen the service awareness and improve customer satisfaction are the key to enhance competitiveness.

References

Baum JAC, Korn HJ (1999) Dynamics of dyadic competitive interaction [J]. Strateg Manag J 20 (3):251–278

Chen SM (2001a) *Fuzzy group decision making for evaluating the rate of aggregative risk in* software development [J]. Fuzzy Set Syst I18:75–88

Chen CT (2001b) Appling linguistic decision—making method to deal with service quality evaluation problems [J]. Int J Uncertain Fuzziness Knowl Based Syst 200(9):103–114

Hou Y, Yuan W (2009) Virtual enterprise partner selection based on fuzzy hierarchy comprehensive evaluation method [J]. Mech Eng Autom (4):60–62

Jaya Chandran S, Gimeno J, Varadarajan PR (1999) The theory of multimarket competition: a synthesis and implications for marketing strategy [J]. J Mark 63(6):49–66

Mikhaii OV (2002) Fuzzy analytical approach to partnership selection in formation of virtual enterprises [J]. Omega 30(5):393–401

Tang G (1998) Evaluation and expansion of TOPSIS approach [J]. Zhejiang Stat 27(2):12–14 (Chinese)

Wu L (2009) A summarized research of service outsourcing industry [J]. J Xi'an Electron Sci Univ 9(2):35–41 (Chinese)

Xu X, Jiao Y (2008) SWOT analysis of Chinese development of financial service BPO business [J]. Serv Trade 4(1):57–60 (Chinese)

Zhou H (2007) Financial service outsourcing model: risk and control [J]. Mod Manag Sci 8(10):90–97 (Chinese)

Chapter 70
A Study on the Voice Features of CCTV Newscasters Based on Factorial Design

Ying-chun Ye, Jian-guo Li, and Cong-yu Wu

Abstract In this study sections of voice of newscasters who broadcast news in different CCTV news programs are extracted and studied to obtain data of the two voice features: pitch and fluctuation. Experimental design is conducted to discover how such influencing factors as type of news and gender of newscaster underlie the voice features pattern of CCTV newscasters.

Keywords News • CCTV • Newscasters • Average frequency • Standard deviation of frequency • Factorial design

Introduction

By the year of 2010, the penetration rate of television set in China had reached 97%, indicating the hugeness of television audience in the country. Among all the broadcast companies, CCTV is the most official, widely-intended and international TV authority in China (Xunhong 2002). It's especially predominant in the department of news broadcasting programs. As is known to all, newscasters have to go through extremely cutthroat screening process before they enter CCTV. The perfect voice of newscasters of CCTV is no doubt one of the reasons that their news programs are well-received (Guiwu Gao 2007).

News programs in CCTV represent various fields or type, ranging from sports to finance. The technical voice features of newscasters such as pitch and fluctuation of

Y.-c. Ye • J.-g. Li (✉) • C.-y. Wu
College of Management and Economics, Tianjin University, Tianjin 300072, China
e-mail: yeyingchun@vip.sina.com; ljg886@hotmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_70,

different programs should be different accordingly (Guiwu Gao and Li Wang 2010). What is more, gender of newscaster is also an important cause of different voice features. In this paper, both these two factors, type of news program and gender of newscaster, are analyzed and demonstrated to discuss their influence on the voice features of CCTV newscasters (Zhong Li 2009).

Methodology

In order to study the voice features of CCTV newscasters and theirs influencing factors, the authors divide this study by two parts: (a) collection of voice data; (b) analysis of the data collected. Particular computer tools are employed in both parts of the study. Methodologies involved are detailed below respectively (Shiqiu Jia 2006).

Voice Data Collection

To enhance represent of this study, the authors select four renowned news programs from four CCTV channels aired during prime time as subjects, which are (Table 70.1).

All of the programs selected are classical and official, especially News Simulcast, first shown in 1978. News Simulcast and Economic News Broadcast are broadcast by male and female newscasters together while China News and Sports News by one single newscaster (Haorao Xu 2007).

From China Network Television (CNTV, the online website of CCTV) we find the online videos of the news programs and then have them downloaded as local video documents with downloading tools. The video documents are further converted to audio documents using format-converting tools. Then we import these audio documents of the news programs selected as subjects into Cool Edit Pro, digital audio software. In this way, wave patterns of newscasters' voice are generated and related audio data are procured (Qiushuo 2010).

By the audio software we can read the average frequency and standard deviation of frequency of the voice sections in the audio documents collected. Average frequency represents pitch while standard deviation of frequency represents fluctuation (Wen 2010). In this study, we randomly take the frequency data of 21

Table 70.1 News programs studied

Channel	Program	Type	Time
CCTV-1	"Xinwen Lianbo" News Simulcast	Comprehensive	19:00–19:30
CCTV-2	"Jingji Xinwen Lianbo" Economic News Broadcast	Financial	21:00–21:45
CCTV-4	"Zhongguo Xinwen" China News	International	Multiple times a day
CCTV-5	"Tiyu Xinwen" Sports News	Sports	17:25–17:55

sequential points (making 20 intervals in between neighboring points) with interval distance 0.36 s and make one replication of this in voice sections representing each combination of the factors. Average frequency (pitch) and standard deviation of frequency (fluctuation) under each combination of the factors can be calculated with the frequency data obtained (Fei 2010; Zhuqing 2009).

Statistical Analysis

Design of Experiment is the core methodology we adopt in this part. We have two factors to study, type of news and gender of newscaster. The factor type of news has four levels, which are comprehensive, financial, international and sports. The factor gender of newscaster apparently has two levels, male and female. Input the data collected from the above step into the worksheet of Minitab (Statistical software) following each combination of factor levels. Software Minitab can then conduct factorial design and we are able to identify the main and interactive influence of the two factors on the voice features we measured.

Results

The result of average frequency and standard deviation of frequency calculated from the voice data are presented in Table 70.2 below, sequenced by each combination of factors including replication (Table 70.3).

Table 70.2 Summary of data obtained

Sequence	Type of news	Gender of newscaster	Average frequency/Hz	Standard deviation of frequency/Hz
1	Comprehensive	Male	75.220	90.252
2	Comprehensive	Female	77.709	88.777
3	Financial	Male	33.129	29.079
4	Financial	Female	88.735	104.944
5	International	Male	52.825	23.186
6	International	Female	77.810	78.091
7	Sports	Male	70.821	110.004
8	Sports	Female	385.243	648.712
9	Comprehensive	Male	68.450	98.274
10	Comprehensive	Female	71.669	53.564
11	Financial	Male	38.552	23.702
12	Financial	Female	98.833	118.125
13	International	Male	46.846	28.905
14	International	Female	89.190	110.635
15	Sports	Male	75.413	145.979
16	Sports	Female	237.535	699.376

Below are the results of factorial design generated by Minitab

Table 70.3 Factors and levels

Factor	Type	No. of levels	Values of levels
Type of news	Fixed	4	Comprehensive, financial, international, sports
Gender of newscaster	Fixed	2	Female, male

Analysis of Variance for Average Frequency, Using Adjusted SS (Sum of Squares) for Tests (Table 70.4)

Table 70.4 ANOVA for average frequency

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Type of news	3	46,290	46,290	15,430	11.11	0.003
Gender of newscaster	1	27,678	27,678	27,678	19.93	0.002
Type of news*Gender of newscaster	3	33,594	33,594	11,198	8.06	0.008
Error	8	11,109	11,109	1,389		
Total	15	118,671				

* Interaction effect about Type of news & Gender of newscaster

Analysis of Variance for Standard Deviation of Frequency, Using Adjusted SS for Tests (Table 70.5)

Table 70.5 ANOVA for standard deviation of frequency

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Type of news	3	328,503	328,503	109,501	271.22	0.000
Gender of newscaster	1	114,387	114,387	114,387	283.32	0.000
Type of news*Gender of newscaster	3	196,237	196,237	65,412	162.02	0.000
Error	8	3,230	3,230	404		
Total	15	642,356				

* Interaction effect about Type of news & Gender of newscaster

Conclusions

Average Frequency

Both the factors type of news and gender of newscaster and their interaction are significant under significance level 0.05 yet not significant under 0.001. Both the factors and their interaction have strong influence on the average frequency level, i.e. pitch, of the CCTV newscasters' voice.

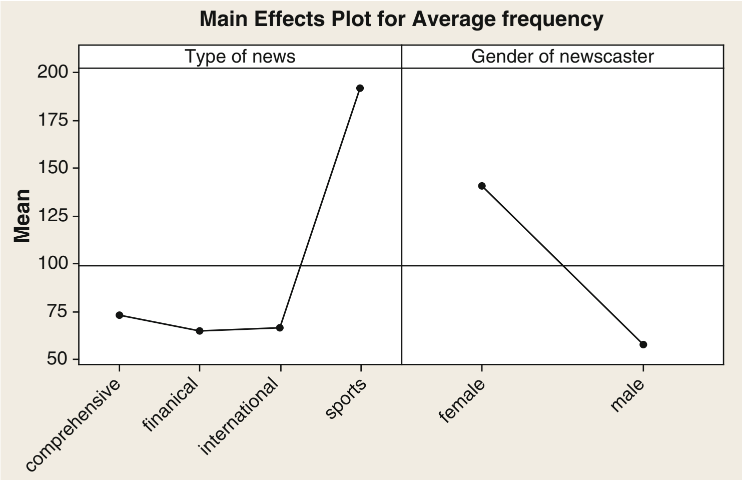


Fig. 70.1 Main effects plot for average frequency

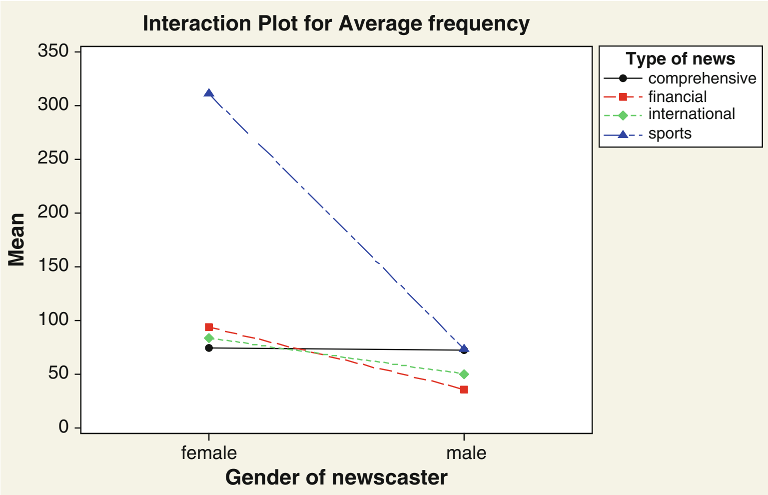


Fig. 70.2 Interaction plot for average frequency

Figures 70.1 and 70.2 are, respectively, average frequency's main effects plot and interaction plot. It shows in Fig. 70.1 that average frequencies in financial and international news are quite low and close, with comprehensive news slightly higher than them and sports news remarkably higher than the other three. The right part of Fig. 70.1 is self-explanatory because females naturally have higher voice than males. According to Fig. 70.2, type of news does not affect the average

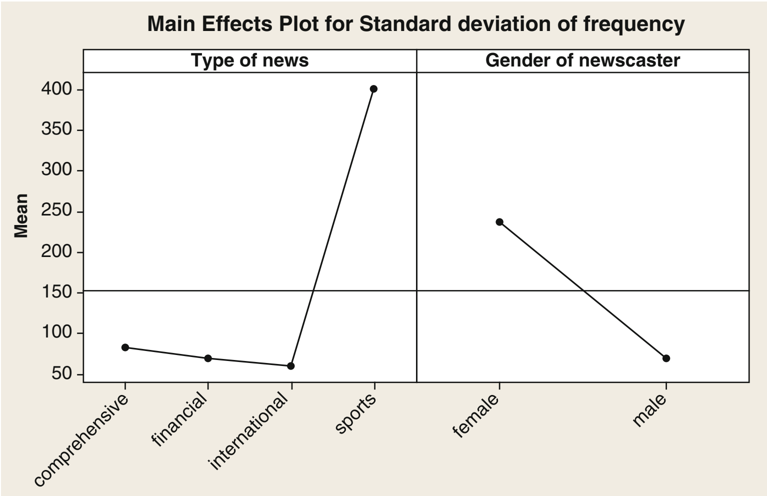


Fig. 70.3 Main effects plot for standard deviation of frequency

frequency of male newscasters very much; however, in sports news program, female newscasters show far higher pitch than their female colleagues in other news programs.

Standard Deviation of Frequency

Both the factors and their interaction are significant under significance level 0.001, indicating that they all have very strong impact on the standard deviation of frequency, i.e. fluctuation, of the CCTV newscasters' voice.

Figures 70.3 and 70.4 are, respectively, the main effects plot and interaction plot of standard deviation of frequency. Newscasters in sports news program have significantly greater standard deviation of frequency than those who broadcast news of other types. Female newscasters have significantly greater voice fluctuation than males. Moreover, in sports news program, female newscasters show far greater voice fluctuation than their female colleagues in news program of other types.

Note: This topic is "Four the first batch" Key task in Chinese Communist Party Propaganda Department of the Central Committee.

Project title: The research of evaluation and management system on announcer anchorperson.

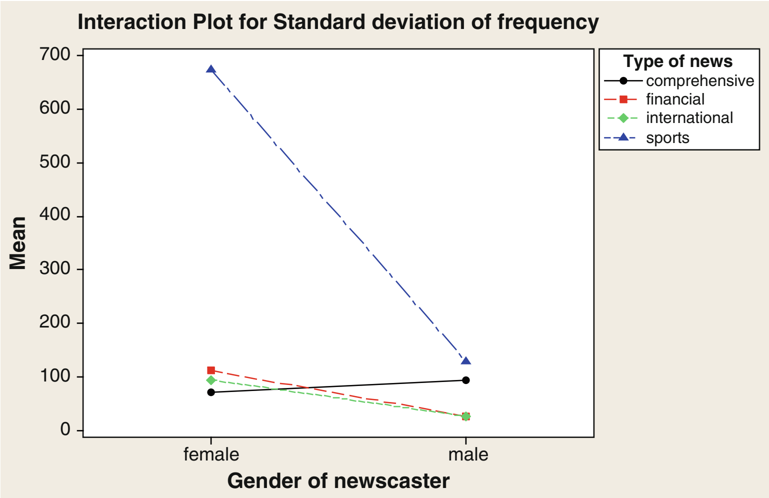


Fig. 70.4 Interaction plot for standard deviation of frequency

References

Fei Yong (2010) Resach on opera and TV, College Chinese opera in Shanghai

Guiwu Gao (2007) A comparative study of Chinese and American TV anchors' group characteristics. Int J 12:63–66

Guiwu Gao, Li Wang (2010) Brand management of United States TV newscasters. TV Res 2:19–21

Haorao Xu (2007) Design of evaluation index systems for TV newscasters. TV Res 4:8

Qiushuo Wang (2010) Construction of evaluation systems for TV newscasters under multimedia environment. News knowledge 1:84–86

Shiqiu Jia (2006) Evaluation mechanics of management innovation for TV newscasters. Young J 22:63

Wen Jun (2010) Research on key technologies for tracking news video stories. Graduate School of National University of Defense Technology, Changsha

Xunhong Zhang (2002) A comparative study of Chinese and American TV newscasters. Zhengzhou University, Zhengzhou, pp 7–8

Zhong Li (2009) Professional quality of newscasters and TV hosts. News Window 5:99

Zhuqing Shi (2009) TV art in the age of mass media. Liaoning University, Shenyang

Chapter 71
Application of LS-SVM by GA for Reducing Cross-Sensitivity of Sensors

Wen-bin Zhang, Jing-ling Chen, Chun-guang Suo, and Wen-sheng Gui

Abstract Least square support vector machine (LS-SVM) is widely used in the regression analysis, but the prediction accuracy greatly depends on the parameters selection. In this paper, Simple Genetic Algorithm is applied to optimize the LS-SVM parameters; correspondingly, the prediction accuracy is improved. Sensors are always sensitive to several parameters, and this phenomenon is called cross-sensitivity which restricts the application of sensors in engineering. In order to reduce cross-sensitivity, the model of multi-sensor system measurement is established in this paper. For solving the nonlinear problems in the model, LS-SVM is used to establish the inverse model. It proves that the method has a high forecasting precision. It is beneficial to the application of sensors.

Keywords Multi-sensorsystem • Nonlinear system • Simple genetic algorithm • LS-SVM

W.-b. Zhang (✉)
Department of Mechanical and Electrical Engineering, Kunming University of Science and Technology, Kunming 650093, China

Postdoctoral Workstation of Yunnan Power Grid Corporation, Kunming 650093, China
e-mail: zwbscg@126.com

J.-l. Chen • W.-s. Gui
Department of Mechanical and Electrical Engineering, Kunming University of Science and Technology, Kunming 650093, China

C.-g. Suo
School of Science, Kunming University of Science and Technology, Kunming 650093, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_71,

Introduction

Interest has been growing in the use of multiple sensors to increase the capabilities of intelligent systems. The issues involved in integrating multiple sensors into the operation of a system are presented in the context of the type of information these sensors can uniquely provide.

Sensors are usually sensitive to several parameters in the testing system. This phenomenon is called cross-sensitivity. For example, with the help of Bragg grating equation we know that the cross-sensitivity of strain and temperature is the key problem of FBG sensors. When using the sensor, it is difficult to distinguish the change of the output caused by the strain or the temperature separately. How to reduce the cross-sensitivity is the hot topic of the application of FBG sensors. It restricts the development of the sensor (Xu et al. 1994).

With the importance of sensors in Automated Testing and Control system, the research for reducing the cross-sensitivity is very popular. The domestic and foreign researchers all make great efforts to suppress the cross-sensitivity of the sensors. For instance, since 1993, the solutions proposed to reduce the cross-sensitivity are based on three kinds of thoughts roughly: first, double wavelength matrix calculation method; Second, double parameters matrix calculation method; Third, strain (temperature) compensation method. But, solving this problem by hardware either makes sensors system more complex and costly or causes high measuring error by material, changes of light source, precision of adding impurities in fiber. On the basis of sufficient study and comparison of a variety of methods for reducing cross-sensitivity of sensors, a data fusion method based on software is proposed for eliminating the affection of non-objection parameters (Luo et al. 1998). This method will no longer rely excessively on sensor's selectivity and it doesn't change the sensor's manufacturing process, but effectively reduces the cross-sensitivity of the sensors. It can weak the affection of non-objection parameters to measurement and enhance the affection of objection parameter to measurement. Finally, it can improve the measurement precision, stability and reliability of sensors (Luo and Key 1989; Suykens et al. 2000, 2002).

In this paper, we concisely review the basic principles of LS-SVM for regression. SVM is a new study method which developed from the statistics theory and structural risk minimization principle. Experimental results indicate that the SVM can solute the problems, such as small samples, nonlinear, high dimension, and local minimum and so on. It has comprehensive applications in pattern recognition, signal processing and function approximation already.

We can see that LS-SVM is formulation of the principles of SVM, which involves quality instead of inequality constraints. Furthermore, LS-SVM uses the least squares loss function instead of thee-insensitive loss function. In this way, the solution follows from a linear KKT system. Therefore it is easier to optimize and the computing time is short. At the same time, the dual problem of LS-SVM corresponds to solve a linear KKT system which is a square system with a global and possibly unique solution if the matrix has full rank.

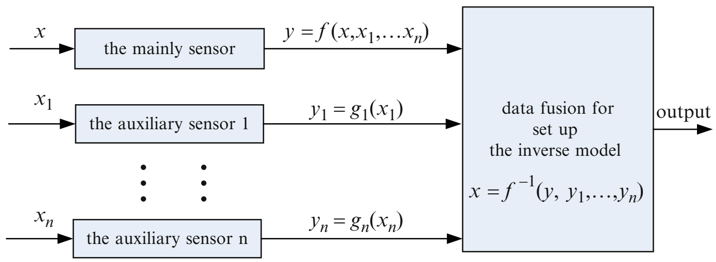


Fig. 71.1 Multi-sensor system measurement model

Therefore, the intelligent sensor system simulation model is set up. Use the method of LS-SVM to set up the inverse model (Suykens 2003) and use Simple Genetic Algorithm to optimize the parameters of LS-SVM.

Multiple Sensors System Simulation Model

Generally, the sensors are influenced by multiple parameters; the expression of input/output of sensors is as follow (Suykens et al. 2001; Hackett and Shah 1990):

$$y = f(x, x_1, \ldots, x_n) \tag{71.1}$$

Where x is an objection parameter; $x_1, \ldots x_n$ are non-objection parameters; y is the output of sensor.

In order to restrain the cross-sensitivity of sensor and improve the static characteristics, an intelligent sensor system model is set up. The model is consisted of the mainly sensor (the sensor which measures the objection parameter) and the auxiliary sensors (the sensors which measure the non-objection parameters. See Fig. 71.1).

Inputs of the model are the outputs of the mainly sensor and the auxiliary sensors. Using the intelligence software for data fusion in PC, set up the inverse model by the output of the mainly sensor and the auxiliary sensors and the mainly sensor's objection parameter.

$$x = f^{-1}(y, y_1, \ldots, y_n) \tag{71.2}$$

Set Up the Inverse Model by Using the Method of LS-SVM

In order to get the outputs which are obtained under the influence of reducing non-objection parameters, in this paper, setting up an inverse model by using the intelligent software. At present the neural network technology is widely applied in data fusion, but the neural network must have been trained by a lot of samle data, only then it can have strong generalization performance, in addition, it is easy to fall into local minima and over fitting (Hall and Llinas 1997; Suykens and Vandewalle 1999).

It has good generalization capacity, and has been the research hotspot in the machine learning field after neural network. Different with neural network, SVM bases on the principle of structural risk minimization, which realized the compromise of given data between approximation accuracy and approximation function complexity. Through choice nesting function subset, and compromised consideration of the experience risk and confidence interval, it chooses the minimum structural risk and then gets the best real risk boundary.

LS-SVM is proposed by Suykens. LS-SVM uses quadratic loss function, which changes quadratic programming problem in SVM into linear equation group resolving. It reduced computing complexity, but still with the high accuracy, and increased the solving speed, and it is more suitable for the cross-sensitivity. But the LS-SVM parameters impact prediction accuracy seriously, therefore, this paper uses genetic algorithm to solve the parameter choice problem of SVM model during forecasting process. Genetic algorithm uses selection, crossover and mutation operation to search the model parameter global optimal solution, with the optimized parameters. LS-SVM increased the forecasting accuracy.

Extensive empirical comparisons show that LS-SVM obtains good performance on various regression problems, but two obvious limitations still exist. First, the training procedure of LS-SVM amounts to solving a set of linear equations. Although the training problem is, in principle, solvable, in practice, it is intractable for a large data set by the classical techniques, Gaussian elimination, because their computational complexity usually scales cubically with the size of training samples. Second, the solution of LS-SVM lacks the sparseness and, hence, the test speed is significantly slower than other learning algorithms such as support vector machine and neural networks.

The algorithm of function approximation based on LS-SVM regression algorithm is described as follows. In a regression problem, we are given a training set of samples $D = \{(x_i, y_i)\}_{i=1}^{l}.\, x_i \in X \subseteq R^n$ is the input vector, and $y_i \in R^m$ is the output data of corresponding goal. The problem of linear regression is that seeking the linear function f is to model data:

$$f(x_i) = \omega^T \varphi(x_i) + b \tag{71.3}$$

Where the input data are projected to a higher dimensional feature space. The nonlinear mapping function $\varphi(\bullet)$ maps the input space to a so-called higher dimension feature space whose dimension can be infinite. The term $\boldsymbol{b}$ is a bias term. ω is a $l \times m$ matrix. The optimization problem can be described as:

$$minJ(\omega, e) = 0.5\omega^T \omega + 0.5\gamma \sum_{i=1}^{l} \sum_{j=1}^{m} e_{ij}^2 \tag{71.4}$$

γ is a positive real constant and should be considered as a tuning parameter in the algorithm. According to optimization function (71.4), it defines Lagrange function as:

$$L(\omega, b, e, \alpha) = J(\omega, e) - \sum_{i=1}^{l} \sum_{j=1}^{m} \alpha_{ij} \{\omega_{ij}^T \varphi(x_i) + b_{ij} + e_{ij} - y_{ij}\} \tag{71.5}$$

With Lagrange multipliers α_{ij}. It is well-known from the *Karush-Kuhn-Tucher* optimization theory that the solution can be expressed as a linear system of equations:

$$\begin{pmatrix} 0 & I^T \\ I & \left[\varphi(x_p)^T \varphi(x_i)_{l\times l}^T\right] \end{pmatrix} \begin{pmatrix} b \\ A \end{pmatrix} = \begin{pmatrix} 0_{l\times m} \\ Y \end{pmatrix} \tag{71.6}$$

Where $p, i = 1, 2, \ldots, l$, $A = (\alpha_1, \alpha_2, \ldots, \alpha_m)$, $\alpha_j = (\alpha_{j1}, \alpha_{j2}, \ldots, \alpha_{jl})$, $Y = (y_1, y_2, \ldots, y_m)$, $y_j = (y_{j1}, y_{j2}, \ldots, y_{jl})$, $I = (1, \ldots, 1)$, $i = 1, 2, \ldots, l, j = 1, 2, \ldots, m)$.

$\boldsymbol{A}^*$and $\boldsymbol{b}^*$ are the optimized parameters consequently,

$$y_j(x) = \sum_{i=1}^{l} \alpha_{ij}^* K(x, x_i) + b_{ij}^* \tag{71.7}$$

$j = 1, 2, \ldots, m)$. According to Mercer's theory, any positive-definite kernel function can be expressed as the inner produce of two vectors in some feature space and, therefore, can be used in LS-SVM. Among all the kernel functions, Gaussian kernel is the most popular choice. We have used a Gaussian kernel for LS-SVM

$$K(X_i, X_j) = \exp\left(-\frac{\|X_i - X_j\|}{\sigma^2}\right) \tag{71.8}$$

The concept of Genetic Algorithms (GA), first formalized by Holland (1975) and extended to functional optimization by De Jong (1975), involves the use of optimization search strategies patterned after the Darwinian notion of natural selection and evolution. During a GA optimization, a set of trial solutions is chosen and "evolves" toward an optimal solution under the "selective pressure" of the object function.

GA optimizers are robust, stochastic search methods modeled on the concepts of natural selection and evolution. GA optimizers efficiently search for and locate global maxima in high dimension, multimodal function domains in a near optimal manner. GA is a direct search method which does not depend on the concrete problem. It can use the existing information to search the data string, which need to improve quality. Similar to the natural evolution, through the effect to the gene in chromosome, genetic algorithm searches the better chromosome to solve problem. Similar to the nature, genetic algorithm knows nothing about solution question. It only needs appraisal to every chromosome produced by algorithm. And it changes the chromosome based on the adaptation value, and makes better adaptability chromosomes have more propagation opportunities than the worse. Simple genetic algorithm (SGA) only uses three simple genetic operators, such as selection operator, cross over operator and mutation operator. Its genetic evolution is simple operation, easy understand, and it also is the rudiment and foundation to other genetic algorithm. Simple genetic algorithm mainly consists of elements, as follows: chromosome coding, individual fitness evaluation, genetic operator (selection operator, crossover operator and mutation operator), and genetic parameter setting and so on. The problem solving process utilized simple genetic algorithm. The main feature of genetic algorithm is that it carries on structural object directly, and it has better ability of global optimization. Genetic algorithm used the probability optimization method, which adjusts search direction adaptively without fixed regulation. It starts form initial population which is randomly generated or specify created. Then according to an operation rule (select, duplicate, crossover, mutation and so on),it uses iterative calculation, according to the individual adaptation value, it retained the improved variety and guides searching process approach to optimal solution.

Used SGA and LS-SVM to reduce cross-sensitivity we establish nonlinear model between input and output. Both γ and σ are optimized in paper through using SGA in the model of LS-SVM. The parameter controls the penalty degree to the sample, which surpassed the error, and the parameter σ is the kernel function parameter. Research showed that the parameters greatly affect the prediction accuracy, so to seek the best combination about γ and σ is the problem about optimization model parameter choice.

Experiment and Analysis

For solving the nonlinear problems in the model, multiple-input multiple-output least square support vector machine is used to establish the inverse model. Using the Simple Genetic Algorithm to optimize the parameters of LS-SVM, finally, it can eliminate the sensors' output influence caused by non-objection parameters.

Therefore, simulation model of the intelligent sensor system is set up. Utilizing the method of least square support vector machine to set up the inverse model and using simple Genetic Algorithm to optimize the parameters of LS-SVM.

The percentages of the left hemisphere resistance and the total value of the two slide rheostats (u_1 and u_2) are inputs of the system. The outputs of the system (y_1 and y_2) are the voltage value of multi meters 1 and 2. We can get 64 groups of simulation data. Among them the serial numbers 1–48 are training set, 49–64 are predicted set. The inputs signals u_1 and u_2 are cross-sensitivity by analyzing the model. For example, regression for u_1 using output data is affected by u_2, and vice versa (Fig. 71.2).

The following tables part of the experimental data through the simulation (see Table 71.1). Firstly, preprocess the input/output data by (71.9).

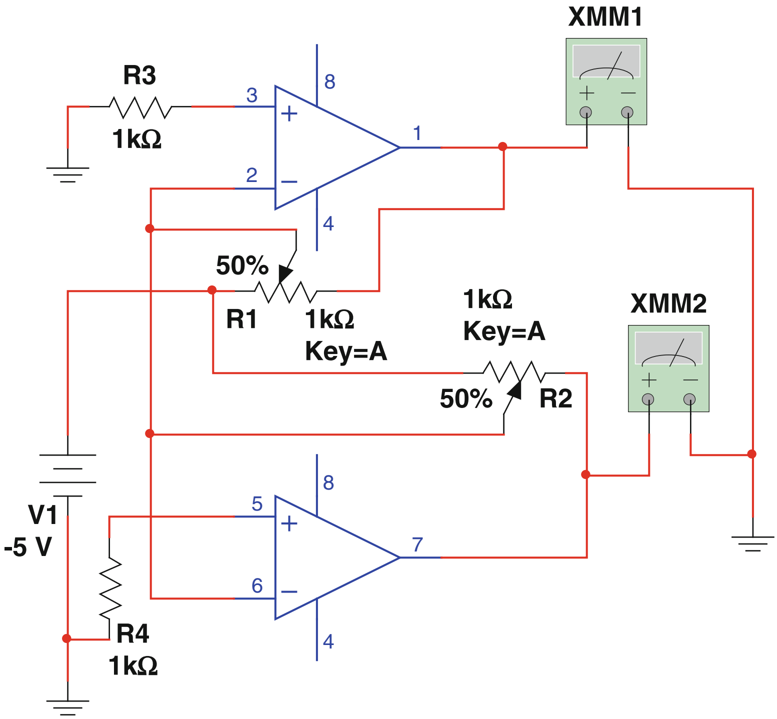


Fig. 71.2 Circuit simulation model of two-input two-outputs

Table 71.1 Simulation data of model for training and predicting

Number	u_1	u_2	y_1	y_2
1	5	15	5.812	3.855
2	5	20	6.739	4.966
...	...	...	...	...
8	5	35	9.22	7.926
9	10	15	3.023	2.016
10	10	20	3.511	2.601
...	...	...	...	...
16	10	35	4.842	4.185
...	...	...	...	...
57	40	15	0.874	0.612
58	40	20	1.016	0.790
...	...	...	...	...
64	40	35	1.426	1.294

$$\bar{x}_i = \frac{x_i - x_{min}}{x_{min} - x_{max}} \tag{71.9}$$

Where x_i is the sample data. x_{max} is the maximum of sample data and x_{min} is the minimum of sample data. $\bar{x}_i$ is the preprocessing data. In order to more close to the

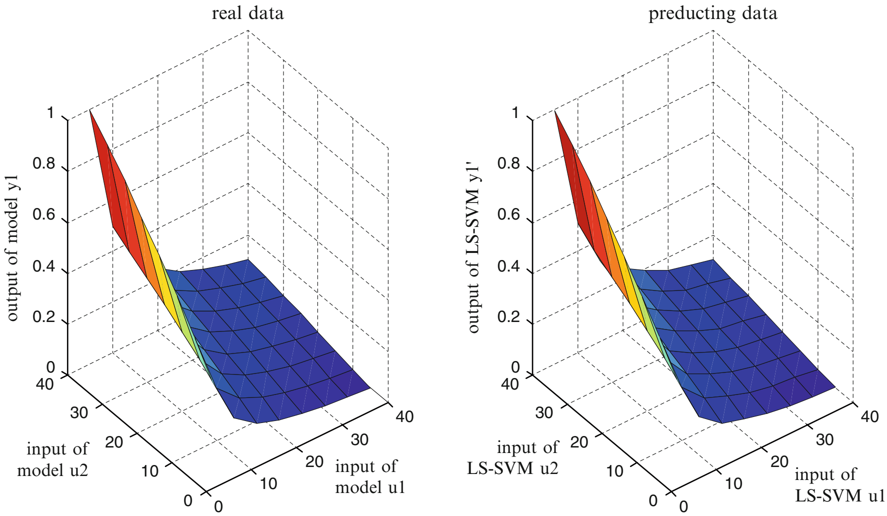


Fig. 71.3 The comparison of the real data and the predicted data for regression

physical truth, superimpose white noise with mean value of 0, standard deviation of 0.03 based on the preprocessing data.

According to the sensors system model, optimize the parameters by Simple Genetic Algorithm. Set the population size for 50, evolution generation for 100, penalty factor for 0.1, calculating fitting value by 15-traverse crosscheck, threshold value of sharing function for 10. From the SGA we can see that after the 50 generation the parameters converging to the global optimal solution probable.

To build the multiple sensors model, the proper parameters γ and σ^2 choosing of LS-SVM regression is very important. In this paper, we take advantage of the Root Mean Square Error (RMSE) minimization in the testing samples as the criterion. If the LS-SVM regression matches this criterion, the parameters are fixed as the sensing parameters. As a result, the parameters of LS-SVM regression are chosen $\sigma^2 = 12467.9$, $\gamma = 5.170$. The prediction results of LS-SVM estimator for training data and the prediction results of LS-SVM estimator for testing data are shown in Fig. 71.3. Figure 71.4 is the relative error of the predicted data.

$$\mathrm{Error} = (\mathrm{b} - \mathrm{a})/\mathrm{a}^* 100\,\% \tag{71.10}$$

Where Error is relative error, *a* is a real data, *b* is a predicted data.

This suggests that the method of support vector regression can get very good predictive effect in the case of small sample data (See Fig. 71.3).

From Fig. 71.4 we know that the maximal relative error of predicted data is less than 2%, so the result is satisfactory.

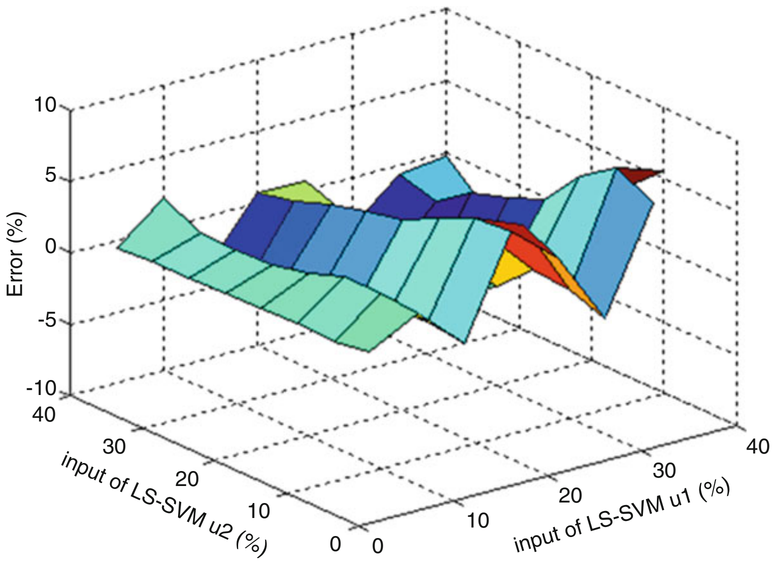


Fig. 71.4 The relative error of the predicting data

Conclusion

Through analyzing the regression of simulation data, LS-SVM is suit for modeling for the data. It also achieves predicted results that are relatively accurate in the case of existing noise. This research uses LS-SVM to reduce the affection of cross-sensitivity to nonlinear multi-sensor signals. The simulation result is satisfactory. It demonstrates that the method has a high forecasting precision. Results show that the method is effective. LS-SVM is prior especially for large scale problem, because of its procedure is high efficiency and its performance is eminent compared with SVM.

Result shows that the cross-sensitivity of sensor is restrained and the stability and precision of the sensor are increased. The proposal is suit for measuring of sensors at high precision. Measurement sensitivity and stability of the whole sensor system have a large enhancement, so the sensor system can get high measurement accuracy under the condition of changing greatly of non-objection parameter. The outputs of the sensor system without cross-sensitivity are more abundant and optimized, and operative modes of sensors are more transparent and open. So that it has great advantages in system maintaining, choosing control strategies and ensuring system reliability.

It improves the prediction accuracy of regression analysis by using genetic algorithm optimize LS-SVM parameters. It proves that the LS-SVM has a high forecasting precision, increasing the security and stability of sensors operation.

Acknowledgments This work was supported by Extracurricular academic technology innovation fund under grant No. 2012YB059, Yunnan Province National Science Foundation under grant No.2010CZ037 and No. 2010CZ015.

References

De Jong K (1975) An analysis of the behavior of a class of genetic adaptive systems. Ph.D. dissertation, Department of Computer Science, University of Michigan, Ann Arbor, MI

Hackett JK, Shah M (1990) Multi-sensor fusion: a perspective. In: Robotics and automation, 1990. Proceedings of the 1990 I.E. International Conference on Cincinnati, May 1990, vol 2, pp 1324–1330

Hall DL, Llinas J (1997) An introduction to multisensor data fusion. Proc IEEE 85(1):6–23

Holland JH (1975) Adaptation in natural and artifical systems. Ann Arbor: The University of Michigan

Luo RC, Key MG (1989) Multisensor integration and fusion in intelligent systems. IEEE Trans Syst Man Cybern 19(5):901–931

Luo RC, Lin M, Scherp PC (1998) Dynamic multisensor data fusion system for intelligent Robots. IEEE J Robot Autom 4(4):386–396

Suykens JAK (2003) Least squares support vector machines for classification and nonlinear modeling. Netw World 10(1):29–47

Suykens JAK, Vandewalle J (1999) Least squares support vector machine classifiers. Neural Process Lett 9(3):293–300

Suykens JAK, Lukas L, Vandewalle J (2000) Sparse approximation using least squares support vector machines. In: Circuits and systems, 2000. Proceedings of the ISCAS 2000 Geneva. The 2000 I.E. International Symposium on 2000, Geneva, Switzerland, May 2000, vol 2, pp 757–760

Suykens JAK, Gestel TV, Brabanter JD (2001) Least squares support vector machines. Word Scientific, Singapore, pp 1–10

Suykens JAK, Brabanter JD, Lukas L (2002) Weighted least squares support vector machines-robustness and spared approximation. Neurocomputing 48(1):85–105

Xu MG, Archambault JL, Reekie L, Dakin JP (1994) Discrimination between strain and temperature effects using dual-wavelength fibre grating sensors. Electron Lett 30(13):1085–1087

Chapter 72
Infrared Application in Smart Home System—Based on Intelligent Air Conditioning Design

Jia-hui Song and Song-fan Hou

Abstract In order to regulates mart home system without manual intervention, a kind of infrared device and a wireless transmission device has been designed. Its main function is to execute terminal air conditioning through automatic switch and temperature control. The device combines infrared human testing with wireless transceiver module. It choose AT89C51 to meet the control requirement as the core, use the pyroelectric infrared sensor, and send wireless signals by PT2262/2272 wireless transceiver module. If the infrared module detects that somebody entered, the air conditioning will receive the wireless signal and start to work. Moreover, if the number reaches one certain level, you will see temperature fall. When all the people leave, it will automatically shut down. Because this system can work automatically, it can satisfy the intellectualization and humanity of the smart home system. The experimental result demonstrates that this system can operate reliably.

Keywords Air conditioning • PIRS • Smart home • Wireless

Introduction

With the development of the society and the improvement of people's live standard, smart home gradually becomes the inevitable trend of future home life (Su Kuo-Lan et al. 2009). The intellectualization and humanity of smart home system is becoming more and more important. There have been many achievements in automatic induction lighting control, security system and so on, but further studies are still necessary.

Research Innovation Fund for College Students of Beijing University of Posts and Telecommunications design.

J.-h. Song (✉) • S.-f. Hou
Department of Information and Communication Engineering, Beijing University of Posts and Telecommunications, Beijing, China
e-mail: songjiahui@bupt.edu.cn; housongfan@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_72,

In order to reduce the manual intervention to smart home system and help people enjoy the comforts of life furthermore, we designed an automatic system to control home appliances such as the air conditioning.

Without using the infrared tube technology and camera-based human identification technology which are widely used, this system is making bold attempts on pyroelectric infrared sensors (PIRS) (Zhang Xiu-zhen et al. 2000). Combining the PIRS with microcontroller, ultimately the system can automatically turn on the air conditioning when somebody come in; automatically lower the temperature to a suitable degree when the number of people reaches a certain level; automatically shut down when people all leave. The intelligent improvement to the smart home air conditioning is the main feature of this system, which brings people more home feeling and makes family life smarter (Da-You Liu and Bo Yang 2004).

System Design

The smart air conditioning is made up of three module, infrared human testing module, wireless transmission module and terminal control module. The following is a brief description of the overall system Studying on PIRSRE 200B (Cheng Wei-dong and Dong Yong-gui 2008), we found that the sensor can identify the mobile sequence of infrared objects (Fig. 72.1). Taking human body as an example, that is: If the human body passes the sensor from left to right, its output is similar to the sinusoidal signal. If the human body passes from right to left, then its output is similar to the anti-sine signal (as is shown in Fig. 72.2) (Li Juan et al. 2010). Based on this principle, we can design a circuit to implement the judgment of the personnel pass in and out. First, we send the signal collected by PIRS to a two-amplifier circuit made by operation amplifier LM324 (Yang Bo and Chen You-xian 2008). Second, the two-signal-comparator translates the signal from the analog signal into a digital signal. Third, AT89C51 receives the digital signal to trigger the microcontroller's interruption. At the same time, interruption program control specified pin to output level (Ai Hong et al. 2007). This level can be used to control wireless transmitter module to send the signal and realize digital tube count display. Then, wireless receiver module can receive the matching signal within a certain range. Again, use the interruption program to send output level. Infrared emission tube is connected by the level to transmit specified pulse signals. Final, the signal controls the air conditioning switch or adjust temperature.

Hardware Design

Infrared Human Testing Module

Because the output signal frequency of PIRS is kind of low, according to its output character, the preamplifier circuit should extract useful weak signal from multiple noise jamming. That is, preamplifier circuit should have the feature of low noise,

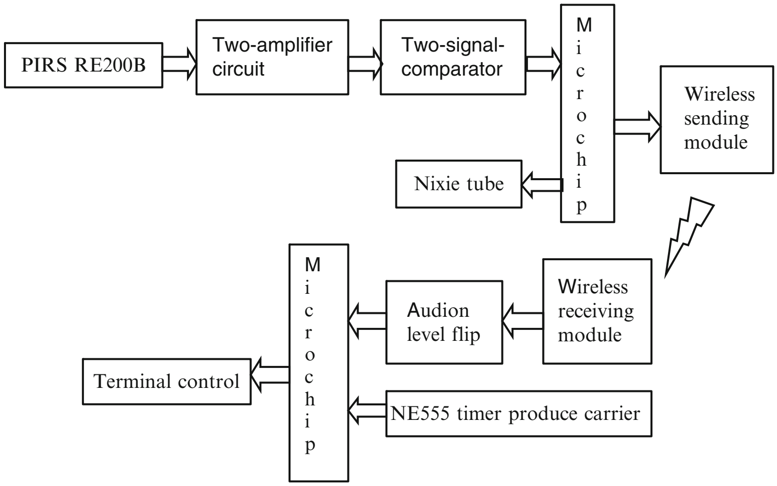
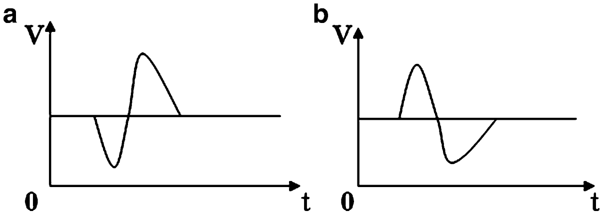


Fig. 72.1 System block diagram module

Fig. 72.2 The output signal of PIRS (**a**) sinusoidal signal and (**b**) anti-sine signal



high gain, low frequency characteristic and outstanding anti-jamming capability. Therefore, the pre-amp of infrared human testing module circuit is built on band-pass filter and two-high-gain-amplifier (Xiao Xing-da and Li Ji-fang 2005). Through debugging and test running, we get a 15.83 Hz bandwidth, and the overall gain is 66 dB. The system can completely realize system function designed.

The back-end of infrared human testing module circuit is based on LM358 operational amplifier to build a dual voltage comparator as shown in Fig. 72.3. The voltage comparator runs normally. Because the threshold can set the range of the largest amplitude fluctuations to 1 V and the positive level output from PIRS is a bit higher than the negative one, so the method finally sets its high-low threshold, +0.5 V and −0.3 V. That means if the output level of the amplifier is above +0.5 V or below −0.3 V, the voltage comparator generates a low level to show the detection of human moving signal. Through trial and error, the infrared human testing module can effectively recognize the order of human movement (Liu Shu-qi and Shi Guo-liang 2005).

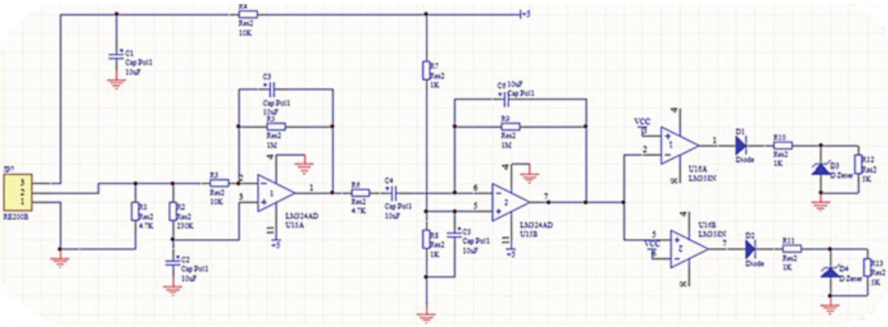


Fig. 72.3 Infrared human testing module

Wireless Transmission Module

In the wireless transmission module section of this experiment, we choose PT2262/PT2272 codec chip. The reason to choose these two chips is that they feature low power consumption, high noise immunity and wide range of operating voltage. PT2262 encodes the signal into code word that contains address, data and sync bits. While PT2272 receives signals, the decoded address bits are compared with the address set, and then PT2272 drives VT output pin and the data output pin to high voltage. When the PT2272 doesn't receive a high level of voltage, it is out of power, therefore the 315 MHz high frequency radiating circuit will not work. On the contrary, PT2272 works when there is a high level of voltage and the 17th output pin outputs modulated serial-data signals. During the high level of the output pin, the circuit starts oscillation and transmits iso-amplitude signals. Above all, the high frequency transmitting circuit is controlled from the digital signal by the output pin of PT2262 and thus it can complete ASK (amplitude shift keying) which is equivalent to a 100 % modulation amplitude.

Terminal Control Module

The terminal control module is composed of the AT89C51 microcontroller, the NE555, 12 MHz crystal, transistors, and various types of adaptive capacitor and resistance. Its main achievement is the actual control of air-conditioning. The wireless module which is equipped in the terminal control system module receives the ON/OFF signal and then input slow level of voltage to the two interruptions of Micro programmed Control Unit (MCU), INTO and INTI. Microcontroller makes the TXD port output the infrared encoding by software programmed when the INTO or INTI port receive a low-level voltage. At the same time, the microcontroller triggers the NE555 timer to produce a 38 KHz carrier. As a modulating signal, the coded signal

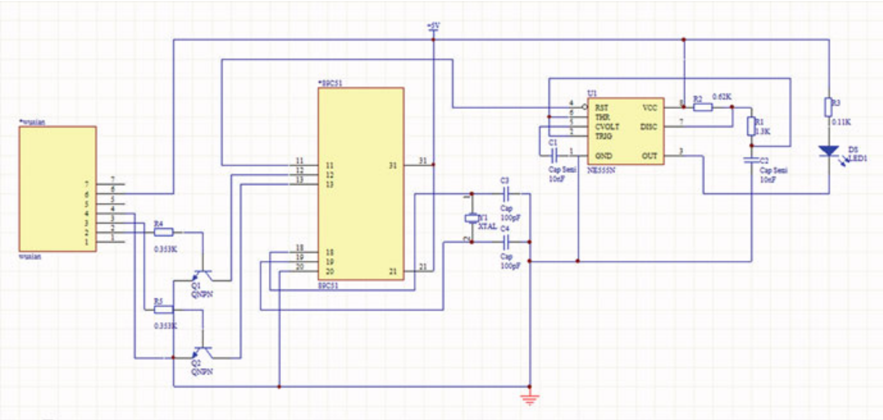


Fig. 72.4 Terminal control module

is added to the38 KHz carrier. Finally, the infrared remote control encoding is sent by an infrared emission tube to control the air conditioning (Fig. 72.4).

Software Design

The system controls the total module by dealing AT89C51 as the core. The following briefly discusses the software design process of the system modules.

As the infrared human testing module should both detect the body in and detect the body out, it is needed that the two interruptions of AT89C51 microcontroller, INTO and INTI, are turned on and that external interruption is set to falling edge trigger model. Turning on the total interruption after system initialization, the system is in a stand by state and the digital displays a fixed value. The detection circuit receives a signal when someone comes in, and triggers the corresponding MCU external interruption an INTO. At this time, because the corresponding external interruption is allowed, the microcontroller is in response to external interruption and starts to handle external interruption, and the program is transferred to the external interruption service routine. In the external interruption service routine, the MCU first shut off the total interruption, then the digital displays value plus 1 (Note: this must be added to eliminate the shaking procedure), and then determine changes of the digital control value. If the value changes from 0 to 1, the corresponding pin level reverses, and the wireless transmitter module sends a high level of voltage. Similarly, when the person leaves, the handling process is same as shown above. The program flow chart is shown in Fig. 72.5 (Li Juan et al. 2010; Zeng Xie-hua et al. 2008).

The air-conditioning infrared remote control encoding which is debugged in test is 35 bits. At the beginning, the 9 ms low-level and 4.5 ms high-level are as the boot code. ‘1’ and ‘0’ are parameters that represent the high and low level of a

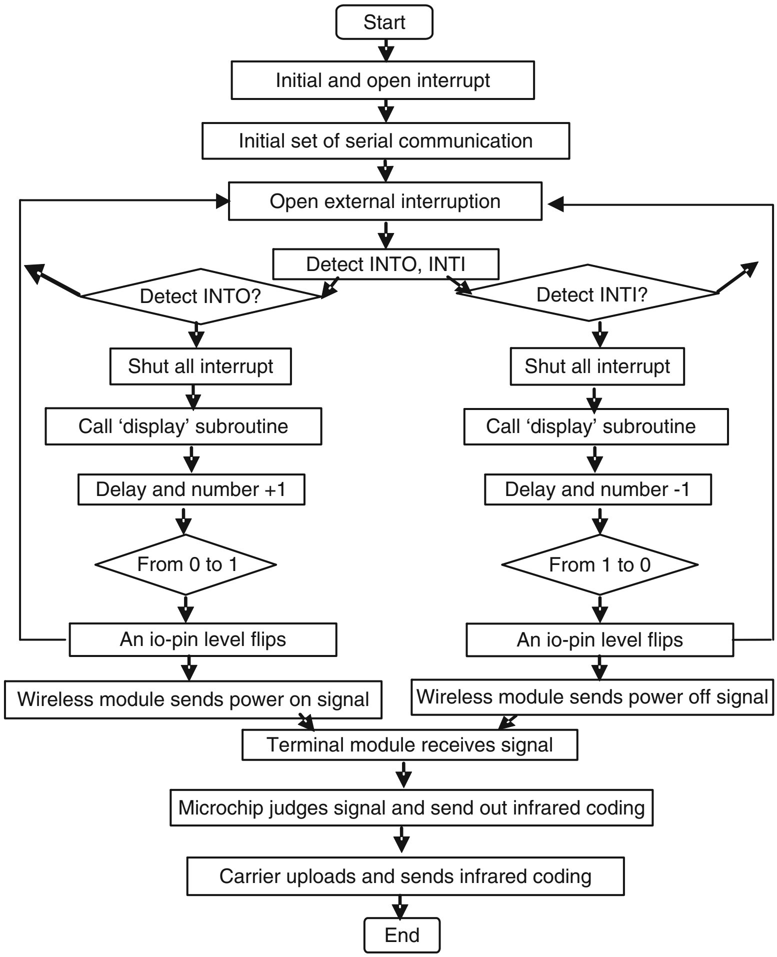


Fig. 72.5 System software flow chart

single-chip receiver port. In accordance with the formats of infrared encoding, we design the delay function with different length of time, then we use the interruption to achieve the encoding and thus the whole system can trigger and send the air-conditioning infrared remote control encoding.

Discussion

The overall test of the system is more successful. Because the infrared human testing module is relatively complex, the following describes test results of this module.

We use a two way oscilloscope to measure the maximum voltage amplitude before amplification and after amplification. Its amplitude on the oscilloscope is approximately 10 mV before amplification and about 1.2 V after amplification. The magnification is about 120 times. The voltage comparator is stable and less susceptible to outside influence. Besides, the external signals which can reach the threshold value can cause change in the output voltage, and the accuracy rate was almost 100%.

If the class of sinusoidal signals is used when people enter and anti-sine is used when people leave, the accuracy rate is higher for the former than the latter. The maximum transmission distance is 8 m for the test of the wireless transmission model, which is enough for indoor use in the case of low-power. When the angle control is within 30° and the distance control less than 5 m, the system turned on or off the air conditioning with 100% error-free.

Conclusion

Infrared new applications in the smart home system can effectively achieve human detection by PIRS, and thereby use the wireless transmission to control the terminal air conditioning. Proven by extensive test, this system is simple, practical, and low cost. it also constitutes reasonable and simplifies the manual control of the home system. Turning the circuit shown in the article to an integrated plate, the whole system is small and flexible placement. The advantages of this system lie in its low power consumption and versatility. The system is excellent to meet the requirements of the smart home system, in line with the designed. The user-friendly design will bring a better home experience.

Acknowledgment This work has been supported by "Research Innovation Fund for College Students of Beijing University of Posts and Telecommunications".

References

Ai Hong, Wang Jie, Sun Shuo (2007) Monitoring and measuring system vehicles based on pyroelectirc infrared sensor. Presented at Instrument Technique and Sensor, pp 46–48 (Chinese)

Cheng Wei-dong, Dong Yong-gui (2008) Dectcion of human body motion features using pyroelectric infrared sensor. Presented at Chinese Journal of Scientific Instrument, pp 1020–1023 (Chinese)

Da-You Liu, Bo Yang (2004) Smart home research. Presented at the Machine Learning and Cybernetics, CA

Li Juan, Yang Lu, Zhang Yan-hua (2010) The design of counting equipment based on infrared sensor. Presented at Shanxi Electronic Technique, pp 23–24 (Chinese)

Liu Shu-qi, Shi Guo-liang (2005) Alarm system with pyroelectric infrared sensors. Presented at International Electronic Elements, pp18–20 (Chinese)

Su Kuo-Lan, Chin Song-Hang, Shiau Sheng-Ven, Guo Jr-Hung (2009) Developing a module-based security system for an intelligent home. Art Life Robot 14(2):242–246

Xiao Xing-da, Li Ji-fang (2005) Vehicle flux detector based on pyroelectirc infrared sensor. Presented at Laser & Infrared, pp 93–95 (Chinese)

Yang Bo, Chen You-xian (2008) Principle and application of pyroelectric. Presented at Instrumentation Technology, pp 66–68 (Chinese)

Zeng Xie-hua, Yang Pu-guo, Ma Zhi-cheng, Wang Yang (2008) Design of counting device based on infrared pyroelectirc sensor. Presented at Journal of Kunming Metallurgy College, pp 48–52 (Chinese)

Zhang Xiu-zhen, Dai Fu-sheng, Mao Xing-peng (2000) Application of pyroelectric infrared transducer to the vehicle counting system. Presented at Journal of Transducer Technology, pp 47–49 (Chinese)

Chapter 73
Discussion on Psychological Wisdom Service of Table Tennis Players Based on Internet of Things

Xin-he Gong, Pei-liang Ling, and Li-juan Yu

Abstract It is preliminary studied on the system framework of psychological wisdom service systems of table tennis players based on the exploration of psychological wisdom service of table tennis players; this paper aims to provide individuation, real-time interactive and intelligence services.

Keywords Internet of things • Intelligent • Psychological wisdom service • Table tennis players

Introduction

Internet of Things is seen as a new wave of information technology development in the world after that of the computer and Internet once again. The idea of Internet of Things was first presented by Bill Gates in 1995 in the book "The Road Ahead" (Hang Li and Hou-jin Chen 2011). International Telecommunication Union (ITU) used the concept of Internet of Things in "The ITU Internet report 2005: Internet of Things" when the meeting of World Summit of Information Society (WSIS) was holding in Tunisia in November 17, 2005 (Bao-yun Wang 2009; International Telecommunication Union ITU Internet reports 2005). In March 2010, Premier Jia-bao Wen first put Internet of Things into the government work report, and it made the development of Internet of Things with strategic significance of country. November 18, 2011, China's ministry of industry and information issued "The Twelfth Five-Year Plan of Internet of Things", which points out the developing

X.-h. Gong (✉) • P.-l. Ling
Mechanical Engineering College, Tongji University, Shanghai, China
e-mail: gongxh@tongji.edu.cn

L.-j. Yu
College of Engineering, Shanghai Ocean University, Shanghai, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_73,

guiding ideology, principles and goals of Internet of Things (Peng Wang 2009; Jun Zhao 2010; He-quan Wu 2010).

Internet of Things is a network that can connect any goods through information technology and equipment such as radio frequency identification (RFID), infrared sensors, global positioning system (GPS), laser scanner sensor, etc. and exchange of information and communication according to the agreement of the contract, in order to realize intelligent identification, location, tracking and monitoring and management (Hang Li and Hou-jin Chen 2011). Internet of Things has been paid more and more extensive attention to the perception, internet and intelligence at any time, any place for any object (Peng Yu 2011).

It provides a strong support for the platform construction of Internet of Things by the rapid development of the computer industry and the popularity of the Internet technology (Huan-sheng Ning et al. 2006), and it also provides an opportunity to the psychological decision-making for table tennis players from the previous traditional model to management and services of intelligence and information.

Psychological Wisdom Service of Table Tennis Players

It is different for each player to ensure its personality characteristics, the level of skill and tactics, adjustment ability to spot situation, psychological quality and psychological advantage. How to adapt to the complex game and win the game at last? How to establish and adjust emergency psychological system in the process of game when players meet some situation of emergency? How to keep the adjustment in time and effectively when the players often have adjusted himself in glued state or blocked stalemate in the process of game? How to have an orienting adjustment of psychology and behavior in the specific game? These are problems need to be solved instantly (Gong et al. 2008).

Psychological adjustment effect depends on the scientific, personalized level of method and the ways to adjustment. Former psychological adjustment of players mostly based on experience of them and they usually have specific aim to train the skills of emotional controlling. Even if there are some decisions-making, which have been finished in the *Local Area Network* (*LAN*), can't satisfy the needs of the development of table tennis sports (http://roll.sohu.com/20120203/n333646895.shtml).

The psychological wisdom service of table tennis players is the service model of smart city with the characteristics of perception, internet and intelligence (Zuo-yi Liu and Shao-fu Du 2008; Shang-liang et al. 2010; Jian-lian Wei and Qing-hua Zhu 2007; Pei-lin Wang 2008; De-ren Li et al. 2011). Because of the numerous system elements and the strong interaction among elements, it often shows the characteristics of random, nonlinear, complex association; at the same time, the player's psychology and behavior always change in the process and it is so difficult to forecast that the psychological wisdom service of table tennis players is dynamic and complex.

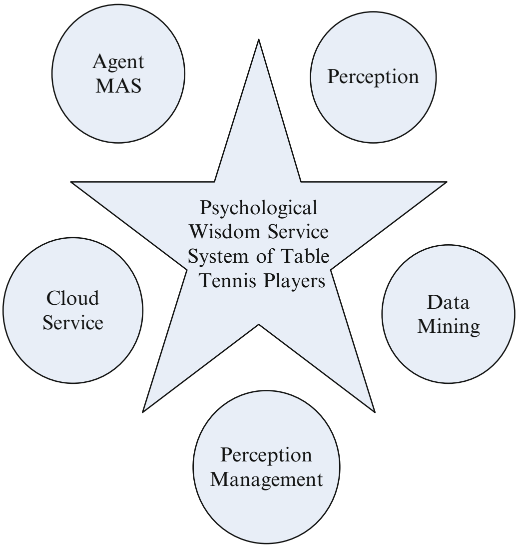


Fig. 73.1 Psychological intelligent service of table tennis players

In the psychological wisdom service of table tennis players based on *Internet of Things*, coaches and experts make realistic strategies and techniques plans taken by their competitors with specific requirements about techniques and tactics to players according to the characteristics and status of players and the features of competitors. Without the restrictions of time and place, players can make preparation and train for competition in accordance with the requirements and objectives. The constitution of table tennis players, coaches, support staff and technology make a service system that can create great value. By the intelligent interaction, it will achieve the goal of realizing and improving the state and performance of players, and it will also realize the aim of psychological service of table tennis players to be timely, real-time, ready, interactive, and personalized. Technology such as *Internet of Things* should be applied in the above situations.

Intelligent

The systematic intelligence plays an especially important role in this system which has a lot of variables, complex structure and changeable dynamic process. It mainly includes five subsystems as following (Fig. 73.1):

1. Psychological data perception and achievement of table tennis players based on *Internet of things*;
2. The sharing intelligence resource of table tennis players not only including mass data storage, screening and intelligent filtering processing, but also knowledge database, regulation database and model database;

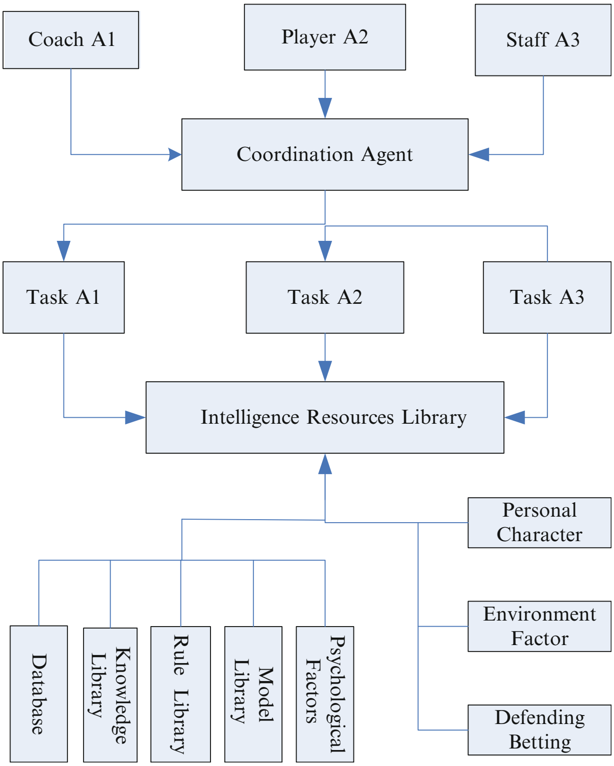


Fig. 73.2 Psychological intelligent service system of table tennis players

3. The psychological perception analysis and knowledge management system of table tennis players based on multiagent; it can operate standardization, intelligent identification and management through analyses data deeply;
4. Psychological intelligent service and adaptation of table tennis players;
5. Cloud service. The users (coaches, scientific researchers, players) store and check the data through Internet and do analyzing and decision-making. It is a mode gradually moving towards the users self service (Fig. 73.2).

The intelligent technology plays a very important role in this system and it mainly includes four modules of technology:

Multi terminal information system: It can expand the perception scope of table tennis players and improve the ability of the psychological perception by gathering information with multi terminal.

The integration technology of heterogeneous network: Because of the different user's goal, there are many kinds of heterogeneous network; it can achieve information of real-time, mobile and sharing of table tennis players through the seamless access.

Sensing equipment standardization of communication protocol: taking all kinds of role in service system as agents which have autonomous behavior and collect each other into an individual network. Through the theory of Agent and MAS, it can maintain all kinds of standards, norms, and planning etc. and degrade the confliction and contradiction.

It is important to research the guarantee of providing safe information and augment of safety of database under the support of modern technology.

System Factors

Viewing from the standpoint of service science, the psychological wisdom service system of table tennis players is a kind of socializing technology system; it mainly includes the factors as following:

Service target: players, coaches and assistants etc.

Service goal: it can transfer the knowledge and skill to player through the design, establish and application of psychological intelligent service system, provide the individual and various psychological intelligent service through understanding the characteristics and status of table tennis players and at last realize the individual psychological adaptation of player.

Service input: the data and information related to player's psychology in the game.

Service output: providing the intelligent decision-making and individual adaptive scheme.

Service process: providing the psychological intelligent service in the course of player's learning, training and game.

Service to participants: coaches, players, assistants (the researchers and psychological doctors) etc.

Sports supporting: the technology of intelligent information.

Resources management: the database of intelligent resources.

Service environment: all kinds of standard, criterion, regulation and policies with the relation of table tennis project.

The System Framework of Psychological Wisdom Service Systems of Table Tennis Players

The system framework of psychological wisdom service systems of table tennis players mainly includes the psychological wisdom service system of table tennis players and *Internet of Things* system of table tennis players (Fig. 73.3).

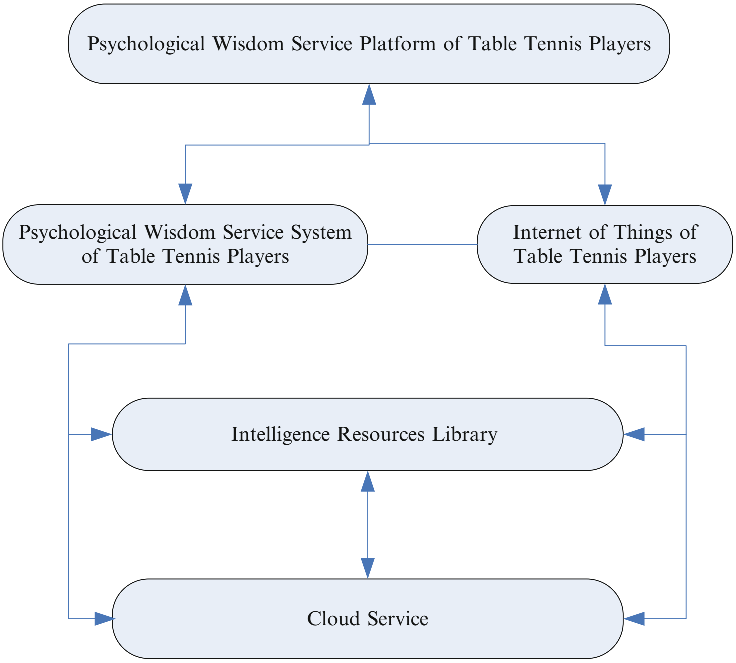


Fig. 73.3 The framework of psychological wisdom service systems of table tennis players

The Psychological-Wisdom Service System of Table Tennis Players

It can collect, obtain a lot of effective data and information from game through a variety of sensors and intelligent technology, find out the potential information by the technology of data mining, set up the corresponding strategy system to analysis the psychological characteristics and status of players accurately, and realize the real-time decision-making beyond the decision-making offline through the service online and search service etc. Based on these, it can realize the scientific, intelligent psychological service to table tennis players and provide creative and individual service at last, which are instantaneity, intelligence, safety and interaction (Fig. 73.4).

Internet of Things System of Table Tennis Players

Internet of Things system of table tennis players: integrating *Internet of Things* technology to the whole process of training and especially important games, set up a service platform of dynamics and real-time through extensive connection to solve the problems of psychological monitor and match tracking of table tennis players, ensure the system operation safely and dependable.

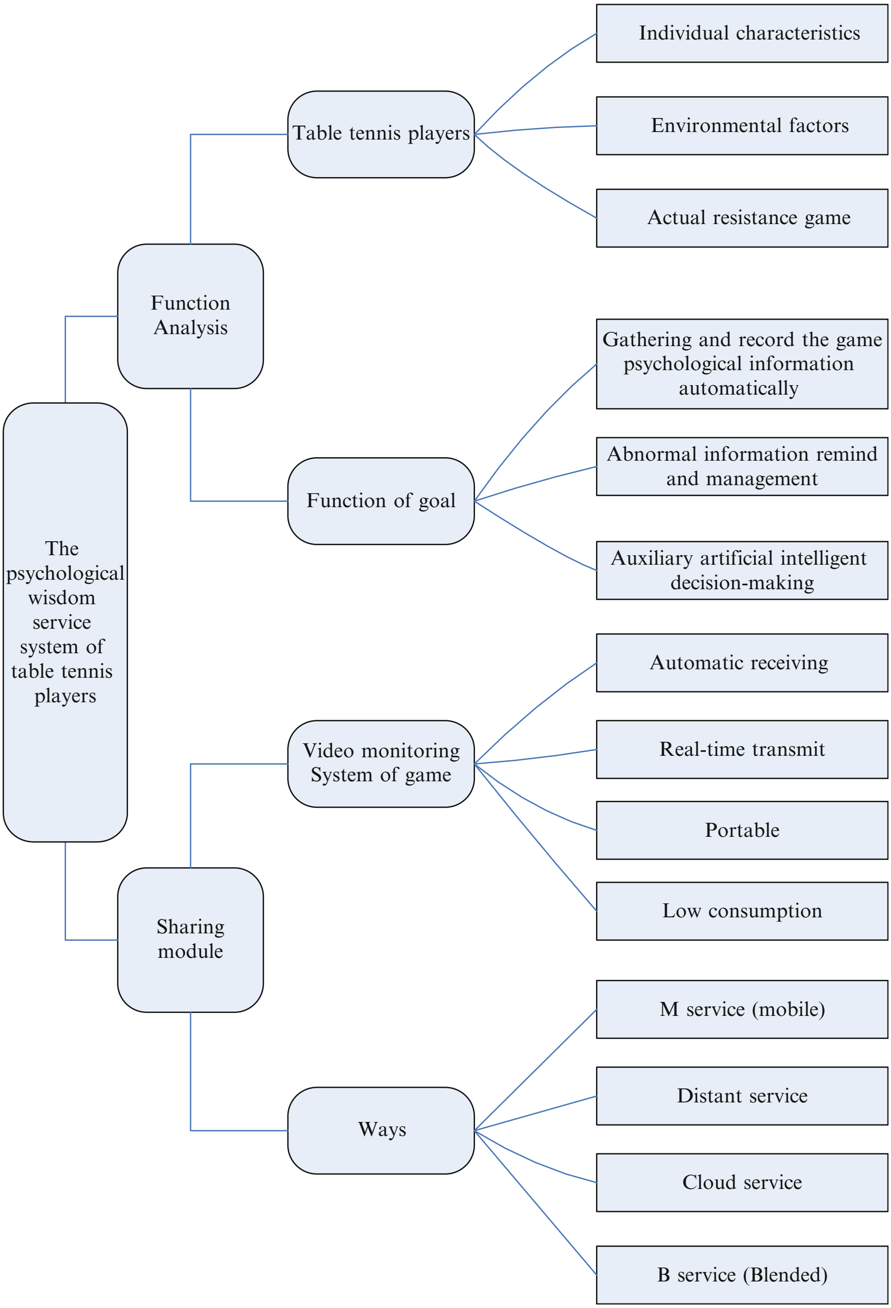


Fig. 73.4 The psychological wisdom service system of table tennis players

The systematic structure of *Internet of Things* of table tennis players includes the level of perception, network and application. Using the technology of *Internet of Things* especially the technology of *RFID* to identify the ID of players and percept or understand the objective phenomena with the relation of psychology of players; and set up the network of sensing to collect the information by lots of automatic, intelligent and remote sensors; promote the method of data mining by *GPS* and *GIS* to percept transmit and deal all the information of player's psychology, physiology and physical agility to make all kinds of function true, such as real-time monitoring, intelligent analysis and judgment, man-machine intelligent dialogue etc. in order to realize perception, identification, management and make decision by its self.

Perception level: set up portable wireless adaptive network monitor terminal to collect and store the matching and training information of psychology, especially such as the information of face, sound and behaviors, and other related physiology information, such as temperature, heart rate and blood pressure etc. by the technology of *RFID*, *GPS*, Video identification, infrared and laser, sensor, intelligent card and two-dimension code.

Network level: applying the integration of heterogeneous network technology, data security technology and other modern network technology, the communication technology, control technology to information center of player, internet, network management and cloud computing.

Application level: through the remote, real-time diagnosis, ensure timely a corresponding countermeasures or alternatives, provide specific guidance for table tennis players, and finally make it true to provide psychological wisdom service for players.

With the development of player's psychological wisdom service platform, it realizes the sharing of intelligence resources and breaks through the restrictions of information islands; at the same time, make it true to mobile services and real-time decision-making through the coordination treatment, automatic feedback and intelligent control.

Conclusion

With the development and application of the large-scale *Internet of Things*, the human community will go forward from information technology to the wisdom. It is preliminary studied on the system framework of psychological wisdom service systems of table tennis players based on the exploration of psychological wisdom service of table tennis players; this research can provide the basic system and ways to individuation, real-time interactive, intelligence services. It also provides an effective way to realize table tennis players' psychological wisdom service. Being a very complex system, the study on the table tennis players' psychological wisdom service based on *Internet of Things* should be deepen and widen from the statistics of players' activities.

Acknowledgment We thank all of the people who give us some helpful ideas to this research.

References

Bao-yun Wang (2009) Review on internet of things (in Chinese). J Electron Meas Inst 23(12):1–7

De-ren Li, Zhen-feng Shao, Xiao-min Yang (2011) From the digital city to the wisdom city of theory and practice (in Chinese). Geospat Inf 9(6):1–5

Hang Li, Hou-jin Chen (2011) Key technology and application prospect of internet of things (in Chinese). Forum Sci Technol China 2011(1):81–85

He-quan Wu (2010) Review on internet of things: application and challenges (in Chinese). J Chongq Univ Posts Telecomm (Natural Science Edition) 22(5):526–531

http://roll.sohu.com/20120203/n333646895.shtml (in Chinese)

Huan-sheng Ning, Yu Zhang, Fang-li Liu, Wen-ming Liu, Shen-feng Qu (2006) Research on China internet of things services and management (in Chinese). Acta Electron Sin 34 (12A):2514–2519

International Telecommunication Union. ITU Internet report 2005: the Internet of things. The meeting of World Summit of Information Society (WSIS)

Jian-lian Wei, Qing-hua Zhu (2007) The research categories and methods of SSME. China information systems research: theories and applications (book style), pp 539–544

Jun Zhao (2010) Developing the cloud platform supporting the operations of the internet of things (in Chinese). Telecomm Sci 26(6):48–52

Pei-lin Wang (2008) The discussion of the research on service science (in Chinese). Libr J 27 (3):2–7

Peng Wang (2009) Cloud computing (book style). Posts & Telecom Press, Beijing, pp 35–52

Peng Yu (2011) Development of the internet of things and its orientation in industrial applications (in Chinese). Process Autom Instrum 32(1):1–12

Shang-liang Liu, Hui-zhang Shen, Feng Li, Cong Zhang (2010) Research review of service science (in Chinese). Sci Sci Manage S.& T 5(6):85–89

Xin-he Gong, Pei-liang Ling, Xian-ming Meng, Tao Wen, An-min Li and Li-juan Yu (2008) Analysis on psychological system of table tennis players based on date mining. In: Proceedings of the 1st joint international pre-Olympic conference of sports science and sports engineering (book style), vol I: computer science in sports. IEEE Press, Piscataway, pp 126–131

Zuo-yi Liu, Shao-fu Du (2008) Services science, management and engineering: an emerging research field (in Chinese). Chin J Manage 5(4):607–615

Chapter 74
Applied Research and Development of New Smart Clothing Material

Ming Yang and Jing Sun

Abstract With the rapid development of clothing industry, enterprises enlarged the market space. As new high-tech fiber, smart clothing has become more and more popular among industrially developed countries, some experts regard smart fabric and smart clothing as the future of fiber clothing industry.

Keywords Smart clothing material • High-tech • Clothing industry

Introduction

Smart clothing is the combination of new fabric material and electronic technology, some well-known clothing companies, calculator giants, electrical equipment manufacturers have began to research and develop smart clothing controlled by computers (Hao Xinmin and Yang Yuan 2010). The market of smart clothing is expanding. Some large clothing manufactures overseas have stepped into this market. Madura clothing company in India introduced Icetouch series shirts. These shirts can reduce 5°C of body surface (Hao Xinmin and Yang Yuan 2010). Compared with other functional clothing, smart clothing is surely with higher price, however this will not affect its market potential.

Chinese research and development of smart clothing is still at the beginning, compared with other developed countries, there are still large gaps. Environmental protection, ecology, intelligentize and digitalize fiber clothing have become the global subject of twenty-first century, smart clothing will be for sure one of the competitive focus point of this century. If China wants to accomplish the change from big clothing country to clothing power, to occupy a place in smart clothing research is very important, the research and development of smart clothing rely on not only

M. Yang (✉) • J. Sun
Institute of Art and Fashion, Tianjin Polytechnic University, Tianjin, China
e-mail: ym19871127@126.com; sunjing@tjtu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_74,

clothing enterprises, but also need the cooperation of chemistry company, optics company, fabric company and electronic equipment manufacturing.

Smart Clothing Material Should Highlight 'Unique' in Developing Function, Fashion, Health and Low Carbon as the Main Subjects

Functional Requirement

As the second skin, clothing in selecting material pays attention on comfortableness and functionality, which should have external environment perception and internal change reaction. When the temperature changes, the phase-change material in fiber will have reversible phase change, absorbs heat or releases heat, when temperature is higher than phase-change material melting point, it will turn from solid to liquid, meantime absorbs the heat, while when the temperature is lower than phase-change material melting point, it will turn from liquid to solid, and releases heat (Hu Jinlian 2006).

Healthy Experience

Nowadays, people pay more attention on life quality, and emphasize more on green. Lately the United States fabrics association stated that in the past 10 years, this industry has spent one billion dollars on environmental protection. There is a company called DIXI Cotton Hill like this in Tennessee, which uses cotton weaving produced by organic fertilizer, and natural dye to dyeing. Meantime the clothing civilization of producing biofibre by technology is rising around the global, which has formed the strict and quantitative standards of PH, color fastness, residual formaldehyde, halogenated dyeing carrier, special odor, and flame retardance.

Low Carbon Needs

Low carbon has become the subject of development economy of all kinds of countries, clothing industry is no exception. Smart clothing material will use all kinds of renewable resources of extraction fiber to do the research through the energy transformation produced by electronic technology. Such as Michael Redhill research group of Philippine (Gong Jixin 2004). It changes the current status of smart clothing has to come into play through electric wire, to supply

Table 74.1 Smart clothing function

Function	Intension
Perception	Perceiving outer world and its surroundings
Feedback	Contrasting with information, provide for control system
Information identification and accumulation	Accumulating all kinds of information
Response	Reacting timely accordingly to the change of external and internal environment
Autodiagnosis	Analyzing current and the past situation, have self diagnosis and correction
Self healing	Making appropriate response to external change of material system through a optimistic way

power with 9 V battery may finally produce electric power from the heat of human body.

Fashionable Tendency

Smart clothing not only has high-tech function of clothing, but also contains various fashion elements. Such as Phillips invented smart clothing, which is to put stereo speaker into the collar of jacket. When turn down the collar, people around can also hear the music, while when the collar is up, only people who wear it can hear the music (Ye Xiumin 2004). More and more clothing and electronic companies developed smart clothing together, to put fashion element into high-tech clothing and be popular has become a certain tendency, which will bring endlessly business opportunity and develop activity to clothing industry.

Methodology

Smart Clothing Material Concept

Smart material concept is first proposed by an American professor called Craig Rogers. In 1989, a Japanese called Gao Mujunyi developed this concept, and defined it as a new material which has perceiving, responding and function found ability of environment (Wang Xuejiao 2002). Smart material refers to the material which has system that can imitate life and function of perceiving and driving (see Table 74.1).

Smart clothing material is an overall development, new fiber material derived from fiber consumer goods, its smart fabric running through fiber, clothing, electronic, chemistry, biology and iatrology (Shan 2005). Due to the diversity and

Table 74.2 Clothing application of shape memory PU material

Material	Application	Characteristic
Shape memory polyurethane emulsion	Textile finishing of cotton, fiber, silk	Anti-wrinkle, iron free, heat preservation, setting
Shape memory polyurethane membrane	Sportswear, military combat uniform, climbing wear	Gas separation, heat preservation, waterproof, breathable
Shape memory polyurethane fiber	Collar, bellyband, lining, underwear	Adjust the shame and size at will, deformation recovery after heat, with small stress and big deformation
Shape memory polyurethane foam	Shoulder pad	Deformation recovery through temperature

technology of the material, it can remedy the damage of human body caused by bad environment, in order to provide better protection.

Smart Clothing Material Classification

1. *Shape memory material*: Shape memory material can percept the stimulation of environment change (such as temperature, stress, magnetism, dissolvent), and affect this change, to adjust its mechanical parameters (such as shape, location, strain), therefore made it recover to preset material. Shame memory PU material has temperature memory, it is also of wide range, light weight, handing ease, deformation variety and easy to re-deformation, is one of the fastest developed memory polymer materials (see Table 74.2).
2. *Waterproof breathable material*: Waterproof breathable material also called proofed breathable fabric, foreign “breathable fabric” refers to water with certain pressure, rain with certain kinetic energy, or snow, dew, frost out of the clothing, cannot transmit or soak fabric. While sweat can transmit to outside in the form of steam, without accumulating or con den sating on the surface or between fabric, in order to make people feel cool and warm, thus achieve the unity of waterproof, heat dissipation, comfortableness of fabric.
   Waterproof breathable materials usually used in uniforms, work clothes and outdoor sports. In addition, the application of waterproof breathable materials in common clothing is increasing, such as raincoat, wind coat, jacket, sportswear, tourism suits, leather clothing, gloves and hat (Yi Jikai and Hou Yuanbin 1999).
3. *Thermal control material*: Thermal control material is the high-tech fiber material that can sense the change of outer temperature automatically and adjust the temperature intelligently. It improves the clothing comfortableness as the major objective, can also absorb, store, re-distribute and release heat. When the surroundings temperature is low, it can heighten clothing temperature automatically,

while when the temperature is high, it can lower clothing temperature, which made clothing temperature at a comfortable range (Lin Min and Ding Jinhua 2005).
So far, the mature thermal control fabric manufacturing craft are coated finish, composite spinning and microcapsule spinning (Ma Shaoping and Zhu Xiaoyan 2004). The material is used in jacket, ski suit, underwear, cap, gloves and sockets, the products sales have increased these years.

4. *Discoloration*: Discoloration material refers to when the light, heat, water or radiation receives outside stimulation, it can change the color of the material automatically and reversibly, including thermo sensitive discoloration material and photosensitive discoloration material. Thermo sensitive discoloration material is the material that changes its color under specific temperature. Photosensitive discoloration material is the material that changes its color under the reflection of specific wavelength. The thermo sensitive discoloration material is to seal thermo sensitive fuel into microcapsule, and then coated on the fabric surface (Ding Yongsheng 2004).
5. *Electronic intelligence material*: Electronic information smart textile is the hot topic of technology fabric field, it blends micro electric, information and computer into fabrics, in order to collect signal according to the set in advance, thus dealt with the signal and received the feedback. In developed products, flexible electronic component embedded inside the textile, and integrated with sensor, flexible fabric switch, flexible power circuit board and conductive yarn.

Results

Medical Monitoring Care Clothing

Sensatex introduced sports T-shirt, which can monitor heart rate, body temperature, breathing and how many calories being consumed. The T-shirt can give an alarm in time when people who wears it has a heart attack, thus reduces the probability of sudden death (Shi Hongbin and Wang Nongyue 2006). It looks like rib cotton knitwear, while in fact the conductive fiber and cotton fiber blend together, in order to receive data from embedded sensor, transferred into a special receptor. To put this receptor at the waist to store information, then showed on mobile phone, PC or wrist monitors, in order to monitor the important vital signs of people who wears it, and to give an alarm in time (Fig. 74.1). Health surveillance used in smart clothing will finally solve the questions between combination of fabric and sensor that collected and solved physiologic signal and relevant equipment (Huang Canyi 2008). The clothing can provide support for these equipments, in order to effectively reduce their shortages of wearing them directly (Fig. 74.2).

Development idea: Smart clothing needs to combine with advanced technology of electronic information technology. sensor technology, textile science and

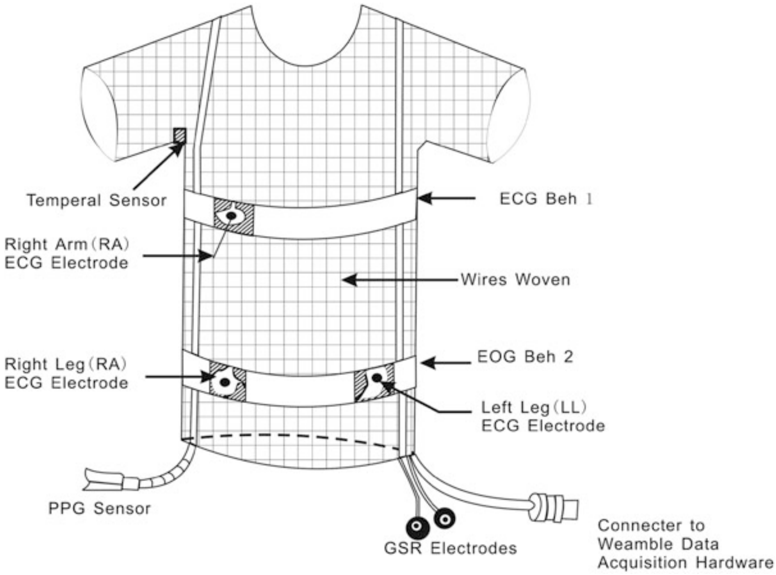


Fig. 74.1 Medical surveillance T-shirt

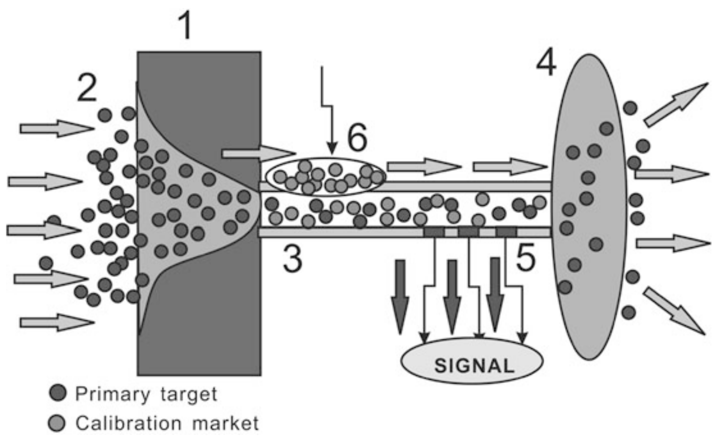


Fig. 74.2 Collection and transmission process of fabric sweat

material science, in order to achieve self intelligence by two ways: one is to use smart clothing material, including shape memory material, phase-change material, discoloration material, stimulated and reacted hydrogel, the other one is to bring information technology and micro electronic technique into people's daily clothing, including application conductive materials, flexible sensor, wireless communication technology and power supply (Liu Feng 2005).

Military Protective Smart Clothing

With the tendency of world multiplarzation, international local conflict, ethnic contradictions of various countries, upgrade and spread of arms weapon, chemical and biological warfare agents lead to loss of life and personal injury frequently. Therefore, functional nuclear biochemical protective clothing emerged. The fabric of surface layer uses functional inflaming retarding tape or aramid fiber fabric, to form functional nuclear biochemical protective layer with PTFE selective osmosis membrane. Meantime, to use glue or linen activated carbon fiber as the adsorption layer, in order to improve adsorption effect, increases life time, prevents carbon fiber infiltrates. To fix up activated carbon fiber non woven to two layers' fabric by laminating and quilting, in order to effectively prevent gas invasion and make it convenient to wash (Jiao Huiqin 2010).

Development idea: To apply reformed and low cost activated carbon fiber to regular clothing in order to resist the severe environment and violation of toxic gases. Meantime it can develop series production.

Fashionable Smart Clothing

In Europe, Levis first introduced music coat, which cannot only play music but also store favorite music in chips, or listen to favorite radio station. It is developed by Massachusetts Institute of Technology media lab. The coat is made of silk organza, music playback function is controlled by full cloth capacitive keyboard. People only need to press the bottom slightly, and then the clothes will start to play music. Music coat is an environmental music player, the energy mainly are sustainable energy of solar energy, wind energy, temperature and physical energy (Hou Haitou 2006).

Development idea: The manufacturers of smart clothing need to search for fashionable channel, high-tech clothing and material are popular for sportswear and outdoor suit. Therefore, outdoor suit should pay more attention on fashion, color and style.

Conclusion

Key words of low carbon, ecology, intellectualization, digitization will be the subject of global textile clothing of twenty-first century. Smart intelligentize textile clothing will become one of the most competitive focus point of clothing area of this century.

Acknowledgments This paper is accomplished with the careful guidance and substantial support of Teachers Xu Dong, Sun Jing, MaDali and Mayu which made me have more inspiration in professional research. Here by to express my heartfelt thanks and sincere respect to the teachers.

References

Ding Yongsheng (2004) Computational intelligence—theory, technology and application (new smart clothing material). Science Press, Marrickville, pp 163–200

Gong Jixin (2004) Situation and expectation of smart clothing. Adv Textile Technol 12(1):47–49

Hao Xinmin, Yang Yuan (2010) Functional textile material and protective clothing (new smart clothing material) (in Chinese). China Textile Press, Beijing, pp 1–20

Hou Haitou (2006) Smart clothing emerge. Tianjin Textile Technol 44(3):48–49

Hu Jinlian (2006) Shape memorize textile material (in Chinese). China Textile Press, Beijing, pp 32–37

Huang Canyi (2008) Electronic smart clothing used in outlook. Shandong Textile Econ 148(6):2

Jiao Huiqin (2010) Research and design of intelligent garment design system models component. Technol Innov Herald 22:2

Lin Min, Ding Jinhua (2005) Computer—controlled technology and engineering applications (new smart clothing material) (in Chinese). National Defence Industry Press, Beijing, pp 179–206

Liu Feng (2005) All kinds of smart clothing. Shanxi Sci Technol 5:99–102

Ma Shaoping, Zhu Xiaoyan (2004) Artificial intelligence (in Chinese). Qinghua University Press, Beijing, pp 1–9

Shan Yufu (2005) Development tendency of future clothing, smart clothing. Textile Inf Wkly 21:15

Shi Hongbin, Wang Nongyue (2006) Introduction to chemical functional materials (in Chinese). Chemical Industry Press, Beijing, pp 339–348

Wang Xuejiao (2002) Green and smart clothing decorated colorful life. Mod Sci 10:105

Ye Xiumin (2004) Fashionable channel of smart clothing. China Text 7:140–141

Yi Jikai, Hou Yuanbin (1999) Intelligent control technology (in Chinese). Beijing Industrial University Press, Beijing, pp 203–275

Chapter 75
Application of Cloud Computing in the Development of Smart Power Grid

Ling Zheng, Bin Zhang, and Li-juan Wang

Abstract With the construction and development of smart power grid, the power system is evolving into the system of accumulating mass of data and information calculation. The advanced analysis, the operation of security and economic and the system control are becoming difficult with the expanding scale and complicating structure of power system. The existing computing platform of centralized power system does not meet the above requirements, which has become one of the main bottlenecks in the achievement of smart power grid. Cloud computing just can integrate the existing calculating resources of power system and provide the powerful capacity of calculation and storage. This paper first simply introduced the characteristic of smart power grid and cloud computing. Then the smart power grid cloud is put forward, and a further analysis and research on its composition, system structure, technology construction and application in smart power grid is done.

Keywords Cloud computing • Smart power grid • Smart power grid cloud • Power system

Introduction

With the interconnection of the power system in the whole country and the development of the remote power transmission system, the super large-scale power systems that cover one or more countries come into being. The modern power system is evolving into the system of accumulating mass data and information calculation. The advanced analysis, the operation of security and economic and the system control are

L. Zheng (✉) • B. Zhang • L.-j. Wang
School of Control and Computer Engineering,
North China Electric Power University, Beijing, China
e-mail: zhengling@ncepu.edu.cn; 592045662@qq.com; wwlljj2007@126.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_75,

becoming difficult with the expanding scale and complicating structure of power system. Recently the intelligent trend of the power system turns into a great upsurge in the world, and this is a challenge to the analysis calculation and control of the existing power system. In accordance with the definition that the energy department of USA determines, the smart power grid has some important characteristics such as strong self-cure capability, resisting extrinsic offensive, sustaining validly large-scale interim renewable energy sources and the join of distributed power source, assuring the reliability of power supply and the quality of electric energy, promoting the justice and effective operation of power market, and boosting users' participation. For meeting the demands above, the future power system should have the strong calculating capacity and the functions of collecting information, integration and analysis. The existing calculating platform of centralized power system is difficult to meeting the demands above, and this has become one of major bottlenecks of achieving smart power grid.

Clouding computing that has developed rapidly in recent years is a new computing mode, the development of distributed processing, parallel processing and grid computing and the business achievement of the computer science concept (Jun-zhou et al. 2011; Vaquero et al. 2009a; Rittinghouse and Ransome 2010). Firstly clouding computing integrates all kinds of wide-area heterogeneous computing resource by using internet into an abstract, fictitious and dynamically expanding computing resource pool, and then it provide services such as computing capacity, storing capacity, software platform and utility software for users by using internet. Through the integration of smart power grid and clouding computing, clouding computing platform of smart power grid is established. This can integrate the existing computing resource in the power system effectively and supply all kinds of computing task, intelligent analysis and decision and intelligence interaction with the strong support such as computing and storing. In a word, the important challenges from computing and disposing information of smart power grid can be effectively solved by applying clouding computing technology to the development of smart power grid. In this paper, the problems that smart power grid, the definition and characteristics of clouding computing, the coming up, components and system structure of smart power grid cloud, and the technology and applicable prospect of the smart power grid cloud in the power system would be discussed in detail.

Smart Power Grid

The smart power grid (Chen Shu-yong et al. 2009; Yu Yixin and Luan Wenpeng 2009) that is based on physics power grid highly integrates advanced the technology of Sensing measurement, communication, information, computer and control with physical power grid into new power grid.

Compared with the traditional power grid, smart power grid should have the major characteristics below:

Self Healing

Self healing is real-time control of the power grid operation condition, discovering in time, diagnosing fast, eliminating hidden dangers, isolating bug quickly, self-recover, and preventing major blackouts happening in the less manual intervention as far as possible. The modernized power grid with self healing would discover and respond to grid stoppage, solving fast and reduce blackout time and economic losses.

Interaction

The interaction of smart power grid is embodied in the interaction of power grid and power generation and the interaction of power grid and users. In the modernized power grid, the energy consumers as the business, the industry and residents would know electricity prices and be capable of selecting the most appropriate power solutions and electrovalence. The character of interaction is one of the important performances in the power grid intellectualization.

Security

The thorough security is considered in the construction of the modernized power grid. The requirements of the smart power grid are that the outage in the large area would not happen and the valuable cost of recovery would not be expended when the smart power grid experiences the physical and network attacks. The smart power grid is less likely to suffer from the influence of natural disasters.

Cloud Computing

Cloud computing is a super calculation model that based on the internet. Thousands of computers and servers are linked into a computer cloud. The users connect to the data center through the computer, laptop and cell phone, and then operate according to their own needs. The shared software and hardware resource and information is offered to computers and other equipments on demand by the compute mode.

Compared with the traditional computing model, cloud computing should have the major characteristics below (Chen Kang and Zheng Wei-Min 2009; Vaquero et al. 2009b; Zhao Junhua et al. 2010):

Integrating Large-Scale Heterogeneous Computing Resources

The traditional distributed computation generally only applies to a small range of computing network such as LAN. There are high requirements to the isomorphism of the computing resource. The computing resources those are different in the computing and storage capacity, the operating system and the development platform are difficult to be disposed. The computing resources those distribute in a vast territory and belong to several organizations could be integrated though cloud computing, and form a computing and storage platform that has very strong functions.

Easy to Dynamic Expansion

The expandability is one of the biggest advantages of cloud computing. The cloud computing could integrate all kinds of computing devices such as the hardware kinds, the network type, the operating system and the software platform, so the computing and storage capacity of the cloud computing platform could be expanded fast when it is needed. The time that the traditional computing platform upgrades is some days or weeks while the time that the cloud computing platform upgrades is generally only a few minutes. It occurs dynamically when the whole running of the system could not be influenced.

Virtualization and Service

The virtualization is also one of the important characteristics of the cloud computing. No matter how many computing devices that the cloud computing platform actually integrates, it is a single entity and the only interface that offers the computing service from users' view. Because of the adoption of virtualization technology, many computing tasks operate in the same powerful equipment of the cloud computing platform, and one computing task could be divided into some parts those operate in multiple devices. In this way, the idle computing resource of the system could be used furthest. Besides, the cloud computing platform distributes computing resource dynamically and structures system platform according to the demands of customers though using the virtualization technology.

The cloud computing abstracts all kinds of different types of computing resources to the service form that is offered to users though using the virtualization technology. The service is generally divided into three different levels those are respectively called infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS), and they are collectively referred to as XaaS (Wang Dewen et al. 2010).

The best advantage that XaaS brings is that most of users' computational tasks are accomplished in the cloud computing platform. So the strong computing and storage capacity in the user terminals is not needed. Users could expediently make use of all kinds of software in the cloud computing platform whenever the network is connected. Specific to the electric power system, basing on the XaaS function of the cloud computing platform, researchers or system operation personnel could accomplish all kinds of analysis tasks of power system and monitor the running state of the whole power system in any place though taking advantage of many different kinds of terminals such as the desk computer, the portable computer and even the mobile phone.

Strong Economies of Scale Benefit

The economic benefit would provide study and application of cloud computing in the power system with a big boost. There are a lot of unused computing and storage resources in the modern power system. Cloud computing could integrate the idle resources and reduce the investment in the information equipment. In the need to upgrade, generally the investment in the cloud computing platform also greatly lower than that in the traditional computing platform.

Smart Power Grid Cloud Computing

Smart Power Grid Cloud Comes Up

The operational characteristic of the existing power system in China is that the provincial power grid as an independent unit on the structure interconnects by the tie-lines, the whole power grid harmoniously operates, and each provincial power dispatch center possesses and maintains the detailed parameters of the power grid (Zhang Wei et al. 2004). At present the provincial power companies have their respective independent computing platforms whose functions are exactly similar. This gives rise to the repeated construction and the resources waste of the power information system. Besides, the computing capability that is required to on-line dynamic analysis and control in the power system will greatly exceed the current actual configuration with the construction of smart power grid, the expansion of power grid and the appearance of collecting device that possesses the faster sampling rate. If the calculation processing resources are just increased, the investment is excessive.

In order to solve the problem above, we may consider integrating each independent computing platform into regional and even national private cloud computing platform of the power system.

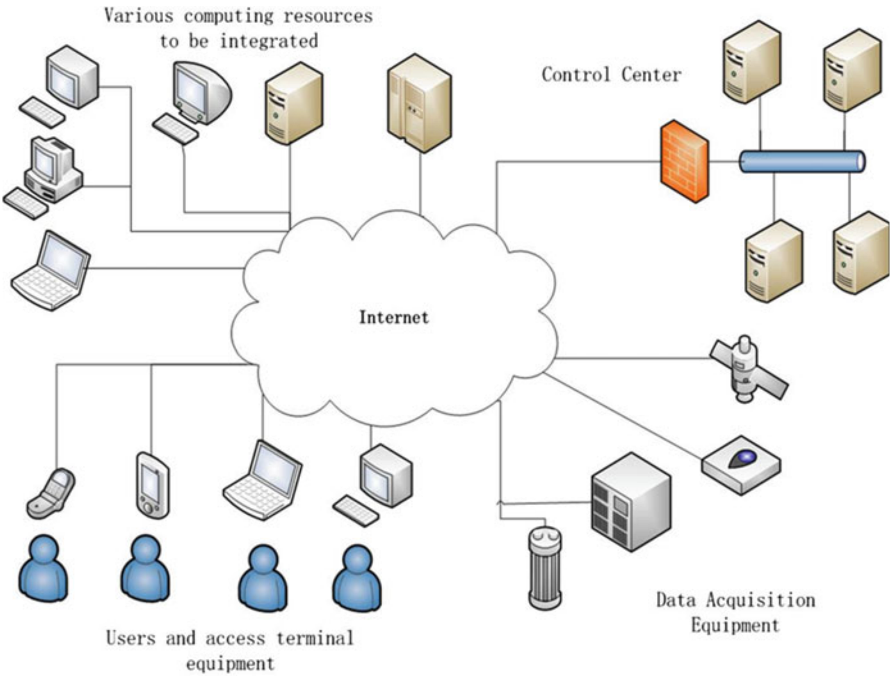


Fig. 75.1 Composition of smart power grid cloud

Composition of Smart Power Grid Cloud

The smart power grid cloud is a complicated entity composed of multiple devices and users interconnected by network as shown in Fig. 75.1. Generally speaking, the smart power grid cloud consists of two major parts: the control centre and computing resources integrated. The main functions of the control centre are providing services for customers, dividing the computing task into several subtasks, and then dynamically assigning each subtask to computing devices integrated by the cloud computing platform though the internet. After the subtasks are finished, the computing results are summarized in the control centre again and sent back to the customers at last. In addition, the control centre is also in charge of distributing the data needed to store into data storage devices, and reading the data from storage devices again when there is a need.

The smart power grid cloud is connected with data acquisition network composed of sensors and data acquisition equipments. To the smart power grid, the future data acquisition network includes both the sensors of traditional SCADA system, and PUM and smart meters set in the homes of terminal users, even the embedded systems of smart consumer electronics. These devices offer the comprehensive information systems in order to support the analysis and decision making of smart power grid. Moreover, the smart power grid cloud connect with other data

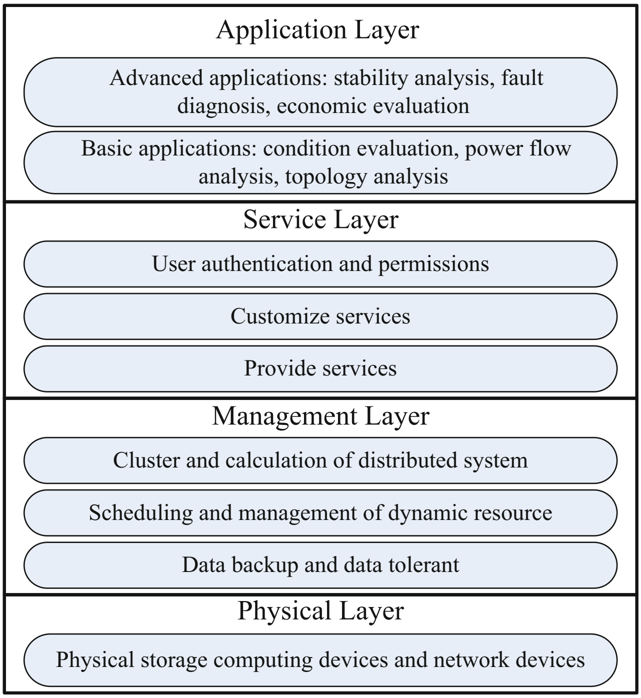


Fig. 75.2 System structure of smart power grid cloud

sources as the regional meteorological database in order to obtain the data of temperature, humidity, wind speed and sunshine. The data volume collected by such a large-scale network will be striking. No other than the powerful computation ability of the smart power grid cloud store and analyze.

System Structure of Smart Power Grid Cloud

The system structure of smart power grid cloud is shown in Fig. 75.2.

- Physical Layer: the physical layer includes the physical storage computing devices and network devices of smart power grid cloud which distribute in different geographical position and connected by WAN or power line in the power system, and it is the physical basis.
- Management Layer: the cluster and distributed system are adopted to realize the cooperative works of all the storage devices in the smart power grid cloud. The cooperative works include the scheduling and management of dynamic resource, the data backup and the data tolerant, and so on.

- Service Layer: the service layer is the most flexible part of the smart power grid. The power operation management institutions at different levels provide different services in accordance with requirements and permissions. The power grid at different levels could log in, customize and obtain the corresponding services by the common interfaces of smart power grid cloud.
- Application Layer: the application Layer provides the powerful software platform which includes advanced applications and basic applications for the operation of the power system. Besides, it could be customizing and developing freely as needed on the basis of the platform.

Technology Construction of Smart Power Grid Cloud Computing

Data Base Model

The current networks of every province generally only consider power grid data models within the scope of home network and not other networks province in the information construction. The own data model library is constructed respectively. The information sharing, data exchange and application integration are difficult to achieve with each other.

IEC61970 provides the technical standard for solving the data exchange and application integration. The two pillars of IEC61970 are the common information model (CIM) and the component interface specification (CIS). CIM defines the semantic of information exchange contents, and CIS stipulates the grammar of information exchange. CIM is the basis of the whole framework of IEC61970 agreement. For the power system, CIM is the model of the power system metadata, and provides the logic description of the unified power system independent of the platform. In the basis of the power system data model taking CIM as a standard, the data exchange among different power databases is realized by CIS. The problem that privatized interfaces inside the systems of various manufacturers hamper the data access of systems is solved by using CIS.

Power Line Communication

One of the construction goals of smart power grid is to structure the hyper-scale power system covering the whole country. The application of cloud computing in the smart power grid needs to integrate all kinds of resources in the power grid. The first problem needing to be solved is that how to structure so large physical transmission network for transferring data.

The power line communication (PLC) is the communication technology of transmitting signals by the power lines. The Chinese transmission and distribution network is the largest cable network in the world. The construction of PLC networks covering the whole country by using the existing power networks and the high speed wireless communication technology as WIFI both saves much manpower and material investment in the network construction and getting rid of the dependent to the telecom operators.

Service Oriented Architecture

The interactivity of smart power grid will be increased in the process of development and construction. Both the interaction between power grid and power generation and the interaction between power grid and users cannot do without the software support. There are higher requirements for the expandability and the upgrade ability of the software. One important characteristic of cloud computing is easy to expand and upgrade. The service oriented architecture (SOA) is an architecture model could distributed deploy, combine and use the application components of loose coupling and coarse granularity as needed by the networks. In the design method of traditional software, the function or class acts the basic function module and the application programming interface (API) acts the communication mean among programs. Unlike the traditional method, the service acts the basic function module in SOA. Each kind of main function is wrapped the service of mutual independence. It is communicating by the extensive makeup language (XML) in SOA, and don't relate to the bottom programming interface and communication model.

Scheduling and Management of Dynamic Resource

The central issue of power cloud platform is the scheduling and management of resources. Firstly it is how to describe resources of users. Each computing device will be integrated before entering the cloud, and the device information is recorded as references for the follow-up process. The data structure describing the status of computer resources is shown as: the million floating point operations per second (MFLOPS) got by the actual measurement is the major index to the property of computer resources, RAM ranks only second to the predecessor in the influence of the computing performance, and the cache direct influence the speed of data communication. Secondly it is how to schedule and manage resources. The load balancing algorithm is the core of cloud computing. The dynamic load balancing has proved a more effective algorithm of distributing computing tasks (Fan Tao et al. 2011; Cui Chunlei and Fang Yanjun 2011; Attiya and Hamam 2004). The fundamental is that the tasks are distributed dynamically in accordance with the computing speed of computing devices in order to ensure computing devices returning results at the same time basically. In the actual visit, the load balancing algorithm is adopted to manage the cloud resources.

Technology Application Prospect of Smart Power Grid Cloud Computing

Intelligent Warning of Smart Power Grid Cloud

The present power system warnings include the local control proceeding in the automatic equipment of substation and the evaluation plan got after offline computing to system typical operation mode in the control center, which is not comprehensive and non-real time. For the real-time simulation of entire network, the real-time computation of large amount of calculation is needed (Yang Weidong et al. 2000). The intelligent warning based on the smart power grid cloud could establish the integration simulation of power system with the characteristics of wide-area distribution of data resources and computing resources, large amount of calculation and high requirements for computing ability. The supercomputing ability of power cloud is sufficient to satisfy requirements of real-time mass data processing. The intelligent warning based on the smart power grid cloud includes (Hu Jun-yi and Fang Xin-yan 2006):

(a) *Voltage warning*: It can monitor in real-time whether the voltage keeps in the prescribed range, whether the node voltage is out of limit and the rationality of distributing reactive power, forecast the margin of the system voltage collapse, confirm weak points of system voltage and prevent the system from the voltage collapse accident.
(b) *Power-angle and tide warning*: It can monitor in real-time the system trend, analyse and judge the normal operation and whether the stability of power-angle will be lost in the condition of prescribed disturbance, forecast the trend data of system when the generator power changes, the structure of power grid changes and the loads are transferred or cut off and prevent the system from the unstability of power-angle and oscillation accident.
(c) *Frequency warning*: It can monitor in real-time system frequency, analysis and compute the influence of system frequency when the generator power changes and the structure of power grid changes, keep the power of tie lines in the desired value and prevent the system frequency from the instability accident.
(d) *Equipment warning*: It can monitor in real-time the condition of system devices, analysis and compute the influence of devices when the generator power, the structure of power grid and the system trend change in normal mode and N-1 mode and prevent the system devices from the dynamic and thermal stability accident.

User Interaction Based on Smart Power Grid Cloud

The electricity is necessity of every household. So the smart ammeters that transformed and set up in users' home by the smart power grid act the interactive terminals between power grid and users and the tentacles of the smart power grid cloud extending to users' home. The strong computing power of cloud computing could achieve the following goals: the remote connections and disconnections, the detection and notice of outage. The smart power grid cloud collect electricity information of users in real-time, analyze the data in a period of time and at last feed back to users in order that users could know electricity prices and according to their actual needs select the power solutions and electricity prices that suit themselves.

Conclusion

In recent years cloud computing has been a new computing model that develops rapidly, integrates the heterogeneous computing resources and possesses the strong ability of computing and storage. The appearance of smart power grid cloud has a major influence on the information exchange, computing ability and storage space in the development of smart power grid.

The cloud computing platform not only provides the ability of computing and storage for the analysis of power system, but also has the advantages of strong expandability, less hardware investment, easy to the development and upgrading of software and so on. So cloud computing will replace the existing centralized computing and become the core computing technology of smart power grid.

References

Attiya H, Hamam Y (2004) Two phase algorithm for load balancing in heterogeneous distributed systems. In: Proceedings of the 12th Euromicro conference on parallel, distributed and network-based processing: PDP'04, Noisy-Le-Grand, 11–13 Feb 2004, pp 434–439

Chen Kang, Zheng Wei-Min (2009) Cloud computing: system instances and current research [J]. J Softw 20(5):1337–1348 (in Chinese)

Chen Shu-yong, Song Shu-fang, Li Lan-xin, Shen Jie (2009) Survey on smart grid technology [J]. Power Syst Technol 33(8):1–7 (in Chinese)

Cui Chunlei, Fang Yanjun (2011) Application of AGA in dynamic load dispatch [J]. Electr Power Autom Equip 31(1):67–70 (in Chinese)

Fan Tao, Tan Wen, Ma Chenhui (2011) Research of dynamic load distribution based on starting time [J]. Electr Power Sci Eng 27(10):17–20 (in Chinese)

Hu Jun-yi, Fang Xin-yan (2006) Application of grid technology to accident forecast for power systems [J]. East China Electr Power 34(11):8–11 (in Chinese)

Luo Jun-zhou, Jin Jia-hui, Song Ai-bo, Dong Fang (2011) Cloud computing: architecture and key technologies [J]. J Commun 32(7):3–21 (in Chinese)

Rittinghouse JW, Ransome JF (2010) Cloud computing: implementation, management, and security. CRC Press, Boca Raton

Vaquero LM, Rodero-Merino L, Caceres J et al (2009a) A break in the clouds: towards a cloud definition. ACM SIGCOMM Comput Commun Rev 39(1):50–55

Vaquero LM, Rodero-Merino L, Caceres J (2009b) A break in the clouds: towards a cloud definition. ACM SIGCOMM Comp Commun Rev 39(1):50–55

Wang Dewen, Song Yaqi, Zhu Yongli (2010) Information platform of smart grid based on cloud computing [J]. Autom Electr Power Syst 34(15):1–8 (in Chinese)

Yang Weidong, Xu Zheng, Han Zhenxiang (2000) Review and objective of research on power system collapse prevention [J]. Autom Electr Power Syst 24(1):7–12 (in Chinese)

Yu Yixin, Luan Wenpeng (2009) Smart grid [J]. Power Syst Clean Energy 25(1):7–11 (in Chinese)

Zhang Wei, Shen Chen, Lu Qiang (2004) Framework of the power grid system part one development of power network monitoring from centralized to distributed processing [J]. Autom Electr Power Syst 28(22):1–4 (in Chinese)

Zhao Junhua, Wen Fushuan, Xue Yusheng, Zhenzhi (2010) Cloud computing: implementing an essential computing platform for future power systems [J]. Autom Electr Power Syst 34 (15):1–8 (in Chinese)

Chapter 76
Research on Eco-Industry Symbiosis System Based on Complex Network

Jian Li and Yang Gao

Abstract The construction of Eco-Industrial Park (EIP) is the basis of Eco-Industry System (EIS) and an important guarantee for implementing the scientific outlook on development, which has a great significance for promoting regional sustainable development. Industrial Symbiosis Network (ISN) is the main organization form for cooperating enterprises in Eco-Industrial Park (EIP) and the key content of the construction of EIP. This paper analyzes the drawbacks of traditional linear model of industrial development and explains the importance of the development of Eco-Industry, also system analyzes the circulation development pattern of eco-industrial symbiosis system. Based on Complex Network, this paper puts forward to build the model of eco-industrial symbiosis system from three aspects that include node, degree and weight, and finally verify the feasibility of the model through the analysis of case. The conclusion can offer a certain guidance and practical significance for development of circular economy and construction of Eco-Industrial Park.

Keywords Complex Network • Development model in Circular • Eco-Industrial Symbiosis Network • Eco-Industrial Symbiosis System

Introduction

The traditional industrial development is a linear industrial economic pattern, namely, "to extract resources from earth and to transfer the resources into products and services; and then put the rest of the stuff (garbage) return to the eco-system

J. Li (✉)
Department of Management, Tianjin University of Technology, Tianjin, China
e-mail: hermanngy87@126.com

Y. Gao
Department of Management and Economy, Tianjin University, Tianjin, China
e-mail: lijian631219@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_76,

(Li Huibo 2006). Because of the traditional linear mode of production brought about increasing pollution which has aroused the concern of the relevant government departments, a series of laws, regulations and policies having been introduced that require companies have to deal with the production of garbage, and the one that meet the requirements can be authorized to emission, but it's only the end of the treatment approach that can not address the root questions. At this time the development of circular economy and clean production came to be introduced. To establish Eco-Industrial Symbiosis System is an important way to achieve clean production and the development of circular economy. Denmark Kalundborg eco-industrial park is a typical eco-industrial symbiosis. Kalundborg eco-industrial park recycles and reduces the emissions of industrial waste, it's not only can reduce the pollution of the environment, but also make the industrial waste recycled and the efficiency of resource utilization promoted.

Eco-Industrial Symbiosis System and Complex Network

Eco-Industrial Symbiosis System

Eco-industrial symbiotic system is a complex organic system, there are a variety of direct or indirect symbiotic relationship among its internal industry, Eco-industrial symbiotic system is a complex system of enterprises and inter-enterprises relations that formed by the close cooperation of all types of enterprises through the economic, social and environmental aspects, the basic starting point is that there must exist the environmental cooperation between enterprises, the fundamental purpose is to improve resource utilization and ecological efficiency. Eco-industrial symbiosis system emphasizes the coordination and sustainable development among economic, environment and society.

The eco-industrial symbiosis system is to emulate natural ecosystem and to apply ecosystem integrity principle, using the interaction between its physical and chemical composition and putting a variety of raw materials, products, by-products and even waste emissions make up a reciprocal causation symbiotic network with coordinated structure and function. In eco-industrial symbiosis system, the industrial waste generated by a business or department of industrial production is regarded as the by-product, which can be used as the raw material of another enterprise or department, and form a pattern that is "resource-industrial waste-resource", thereby can reduce the emissions of industrial waste and form a symbiosis system that include multilayer utilization of substance and energy and a win-win situation between economic benefits and ecological benefits, and can make the effective circle of economic development (Yin Yanbin and Zhao Tao 2008).

The development of eco-industrial symbiosis system is from the pattern of linear development change to the circular pattern of resources-products-renewable resources (Liu Yifang and Tong Rencheng 2011), in order to change from the

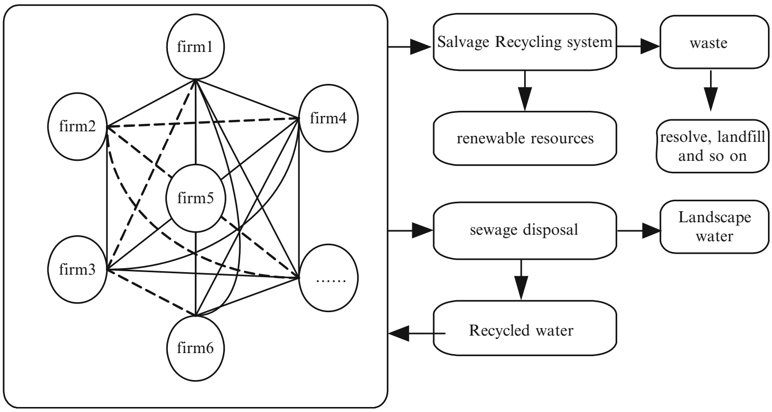


Fig. 76.1 Type of eco-industrial symbiosis network

traditional growth pattern that depend on utilization and exploitation of resources to the pattern that establish the symbiotic relationship between enterprises, make the substances in the enterprises circulate within the system, and put regard production waste as raw materials of another enterprise, which can improve resource utilization, at the same time, to establish an effective system that can achieve clean production is a important method for developing of circular economy (Fig. 76.1).

Complex Network

Complex Network mainly refers to a complex topology and dynamic behavior of large-scale networks, it is diagrams that constituted by the large number of nodes interconnected by edge (Bai Tingting and Zheng Xinqi 2011). Large number of complex systems which exist in the real world can be described through network. Such as the Internet network, transport network, human social relations network, neural networks and so on. Network research mainly includes three aspects. The first one is to define a variety of quantities of network characteristic and to characterize the macroscopic properties of real complex systems. The second one is to establish a network model to help people understand the macroscopic properties of real systems in a variety of micro-generation mechanism. The third one is do research on the characteristics of the dynamic process in the network with a different structure.

In recent years, the research on Complex Network is becoming a hot issue focus of various fields (Albert and Barabás 2002; Dorogovtsey and FMendes 2002; Strogatz 2001). Complex Network is a research methods of complex systems with multi-disciplinary, especially in mathematics, statistical physics, computer and information sciences (Xiao Zhongdong et al. 2010). The following figure shows the main contents and methods of complex network theory (Fig. 76.2).

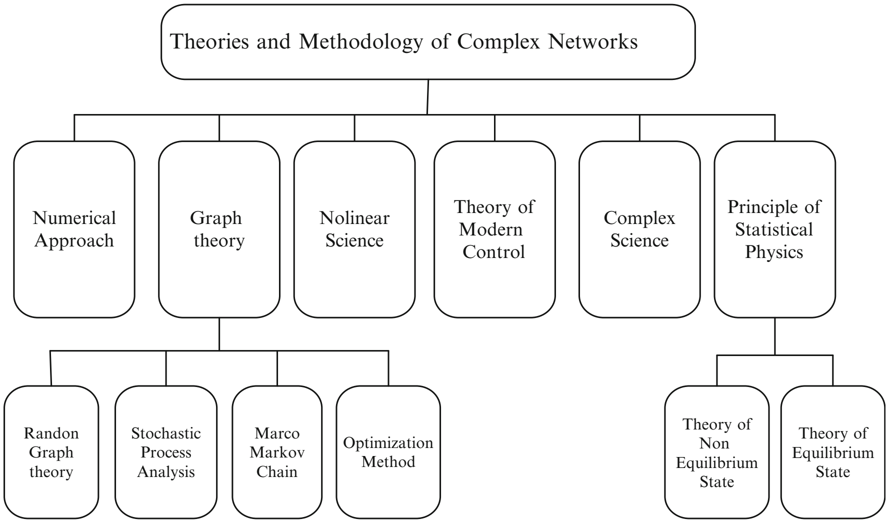


Fig. 76.2 Theories and methodology of complex network

The Model of Eco-Industrial Symbiosis System

Traditional economic mode of production is a predatory type of resource consumption patterns, the industry is too simplex and large-scale, the situation of duplication investment is rather serious, we adopt the end of treatment to protect environment, which have to take high cost, but get low return, the overall efficiency is rather low, so it's form the vicious cycle pattern of "production – consumption – pollution". The traditional pattern has not a mechanism of recycling of resources, the eco-industrial symbiosis system is a new production pattern that for the recycling of resources. Eco-industrial symbiosis system is not simply start under control of pollution, but starting from the change of production mode, by changing the mode of economic and social development to achieve the purpose of environmental protection and economic development. Eco-industrial symbiosis system requirements economic construction to improve efficiency of resource productivity, reduce energy consumption of resources, improve the economic quality and reduce the economic substance and energy density, promote the greening industry, get regard the implementation of the "3R" principle (Reduce, Reuse, Recycle) (Wang Zhaohua 2002) as the main principles for clean production, we must develop eco-industry and circular economy and promote technological innovation, and promote mutually benefit of economic and environmental.

Based on complex network to analyze the eco-industrial symbiosis network mainly consider the following three aspects:

Node

In the model of eco-industrial symbiosis system, the node refers to the enterprises in the symbiotic system. This node as well as can supply production of raw materials to meet other nodes, the raw materials which may be the production enterprises produced or the waste enterprises discharged, at the same time, this node could be accept raw materials or waste that come from other node as its raw materials for production. It may also be the garbage generated in their production, while the node to receive the product or waste from other nodes as the raw materials needed.

Eco-industrial symbiosis system is consisted of nodes. Node is at the core of the eco-industrial symbiosis system. Numerous nodes (Enterprise) that have mutually beneficial symbiotic relationship form an industrial symbiosis system.

Some enterprises have a symbiotic relationship with numerous other enterprises in the eco-industrial symbiosis system, some enterprises have symbiotic relationship with just a few enterprises. The enterprises have most symbiotic relationship with other enterprises and these enterprises are the core enterprises in the eco-industrial symbiosis system.

Wang Xiaofan, Li Xiang and Chen Guangrong pointed out in "theory of complex network and application" that 20% of the nodes determine the nature of 80% of the eco-industrial symbiosis system. There are studies have shown that if remove and load of the largest single node on the network can cause the loss of 25% or more efficiency.

It must be noted that the production advance of eco-industrial symbiosis system is manifested by the symbiotic relationship between the node and the node's own mode of production.

Degree

Degree refers to the number of connections between nodes with other nodes in the eco-industrial symbiosis system (He Yu and Zhao Hongli 2011), the degree i is indicated by k_i. What the degree shows is the materials exchange between the nodes (enterprises), which show symbiotic relationship between enterprises (node) in the eco-industrial symbiosis system. What degree reflects is the existence of material exchange between the two nodes. Degree includes out-degree and in-degree. The out-degree is the number of edges from the node to point to other nodes, the out-degree of node i is indicated by k_{i-out}, which is equal to $k_{i-out} = \sum_{j=1}^{n} k_{ij}$, k_{ij} is the connected edges that from node i direct to node j. The in-degree of node i is indicated by k_{i-in}, which is equal to $k_{i-out} = \sum_{j=1}^{n} k_{ji}$, k_{ji} is the connected edges that from other node direct to node i (Wang Xiaofan et al. 2006). The economic significance of in-degree represents is that the raw materials needed by node (enterprise) are supplied by other nodes, namely, the node (enterprise) accepts the other products or waste from node (enterprise) in the industrial symbiosis system as its own raw materials needed.

As for the degree of the node i:

$$k_i = k_{i-out} + k_{i-in} = \sum_{j=1}^{n} k_{ij} + \sum_{j=1}^{n} k_{ji} = \sum_{j=1}^{n} \left(k_{ij} + k_{ji}\right) \quad (76.1)$$

Degree is the main manifestations of the nature of nodes in eco-industrial symbiosis system. The greater the degree of a node, the more important the node relative to the whole, if the degree of a node larger than that of other nodes, we define the node as the core node in eco-industrial symbiosis system, which indicated by the following formula:

$$\max(i) = Max(k_1, k_2, \ldots, k_n) \quad (76.2)$$

The core node can be defined by the following way to confirm in eco-industrial symbiosis system:

$$\max(i) = Max(k_i), i = 1, 2, \ldots, n \quad (76.3)$$

$$\max(i) > Max\left(k_j\right), j = 1, 2, \ldots, n \text{ and } j \neq i \quad (76.4)$$

If the node i can meet the formula (76.3) and (76.4), so the node i is the core node in eco-industrial symbiosis system. The core node determined the structure of eco-industrial symbiosis system to a great extent, namely, which determined the nature of eco-industrial symbiosis system to a great extent.

Weight

What the degree shows is a relationship that materials exchange between the nodes (enterprises) in the eco-industrial symbiosis system. What the weight shows is the specific amount of this relationship of material supply. The weight is indicated by w_i. The weight is the edge weight (Xing Lizhi 2012). A supply relationship that one enterprise correspond to other enterprises may consist of two parts in eco-industrial symbiosis system, namely, there may be a supply relationship between the two enterprises or not in the eco-industrial symbiosis system, By setting a variable node x_{ij} to show the relationship that node i input its products to node j, in which the x_{ij} is defined as 0 or 1. When the variable x is 0, indicating that the node i will not input the products to node j. When the variable x is 1, indicating that the node i will input the products to node j. Similarly, by setting a variable node y_{ij} to show the relationship that node i input its waste to node j, in which y_{ij} is defined as 0 or 1.

The weights includes out-weight and in-weight. Out-weight refers to the sum of products and by-products (waste and garbage generated in the production of products) of the node want to output to all other nodes, the out-weight indicated by w_{i-out}, In-weight refers to the sum of the node receives products and by-products from all other nodes, which indicated by w_{i-in}. Obviously, the out-weight and the in-weight both include products and by-products.

As for the node i, the products of node i are defined as p_i and the by-products are defined as sp_i. Then the output that the from node i to node j could be defined as $x_{ij}p_{ij} + y_{ij}sp_{ij}$. So sum of output is the following formula:

$$OUT_i = y_{ij}sp_i + x_{ij}p_i = \sum_{j=1}^{n} \left(y_{ij}sp_{ij} + x_{ij}p_{ij}\right) \tag{76.5}$$

Similarly, the sum of input that from node i to node j could be defined as:

$$IN_i = \sum_{j=1}^{n} \left(y_{ji}sp_{ji} + x_{ji}p_{ji}\right) \tag{76.6}$$

There will get the following balance relationship under the condition that takes no account of product time of node produces products:

$$OUT_I = IN_I \tag{76.7}$$

Namely, it's equal that:

$$\begin{aligned} y_{ij}sp_i + x_{ij}p_i &= \sum_{j=1}^{n} \left(y_{ij}sp_{ij} + x_{ij}p_{ij}\right) \\ &= \sum_{j=1}^{n} y_{ji}sp_{ji} + \sum_{j=1}^{n} x_{ji}p_{ji} = \sum_{j=1}^{n} \left(y_{ji}sp_{ji} + x_{ji}p_{ji}\right) \end{aligned} \tag{76.8}$$

It can assume that all nodes (enterprises) will not produce by-products in the production course (Zhang Jianyi 2011), and then the balance relationship of the node i could be change to:

$$OUT_i = \sum_{j=1}^{n} x_{ij}p_{ij} = \sum_{j=1}^{n} x_{ji}p_{ji} = IN_i \tag{76.9}$$

Based on the mentioned three aspects and we can get the model of eco-industrial symbiosis system, as the following Fig. 76.3:

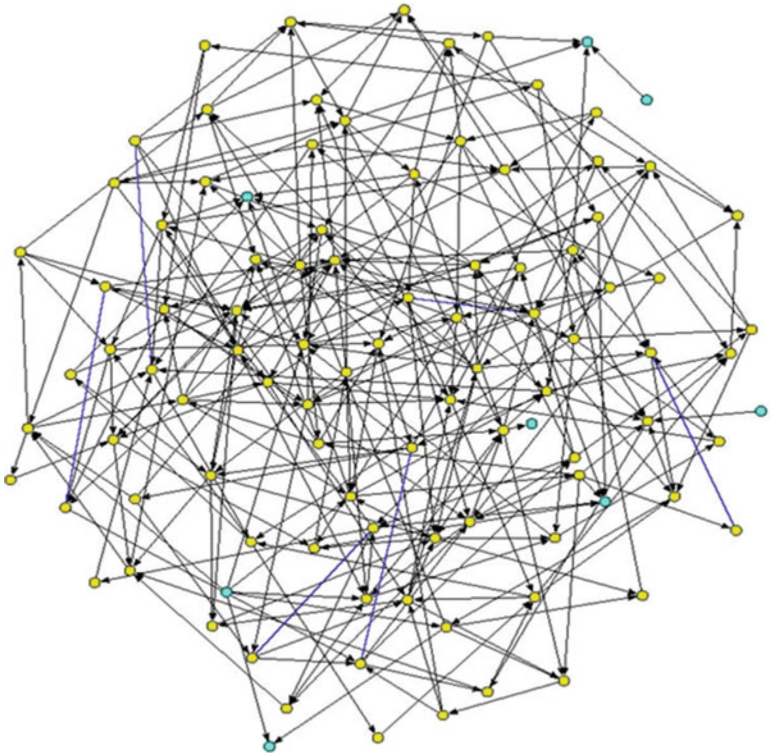


Fig. 76.3 Model of eco-industrial symbiosis network

Example Analysis

Modeling

Because the model is a theoretical model (Liu Guangwei and Zhao Tao 2011; Wu Di and Wu Chunyou 2011), at present, it is hard to find a good case in the existing eco-industrial symbiosis system. In order to illustrate the application of eco-industrial symbiosis network model, where assume there are five nodes in the eco-industrial symbiosis system and give the following assumptions:

1. There are not external factors to affect eco-industrial symbiosis system.
2. Self-sufficient mode of production. The system does not accept the production of raw materials from outside the system, while the products are not input to the external system.
3. The structure of the system is stable and the changes of the structure system under no consideration, namely, the product type and quantity of production is not changed.
4. Take into no account of changing in technology.
5. The products of the production is united, there is no need to convert the unit.

Table 76.1 Relevance of amount of substance among the enterprise in eco-industrial symbiosis network S

	Raw material		Production			
Enterprise	Type	Supply	Type	Output	"By-Production"	
A	B1	20	A1	25	a1	10
	b1	10				
	C1	10	A2	15		
	E1	10				
B	D1	20	B1	30	b1	10
	c1	20				
C	A1	25	C1	10	c1	20
	E3	5				
D	a1	10	D1	20	d1	15
	E2	25				
E	A2	15	E1	10	0	
	B1	10	E2	25		
	d1	15	E3	5		

Five nodes, it assumes that there are five nodes represent respectively enterprise A, B, C, D, E. A produces two kinds of products A_1 and A_2, the by-products is a_1; B produces two kinds of products B_1 and B_2, the by-products is b_1; C produces two kinds of products C_1 and C_2, the by-products is c_1; D produces two kinds of products D_1 and D_2, the by-products is d_1; E produces two kinds of products E_1 and E_2, the by-products is e_1. The number of products and material supply relationships are showed in the Table 76.1.

According to the number of products and material supply relationships in the production of all enterprises in the eco-industrial symbiosis system S is given in Table 76.1, the eco-industrial symbiosis model can be got as shown in Fig. 76.4.

Model Analysis

Based on the formula (76.1) we can get the degree of the nodes in eco-industrial symbiosis system S, namely, each node A, B, and C and D and E can degrees respectively, which are 6, 4, 5, 5, 6. According to the formula (76.2), (76.3), and (76.4) we can get the core nodes are node A and node E in the eco-industrial symbiosis system S. If we remove the node A or node E, the eco-industrial symbiosis system will undergo large changes. However, the eco-industrial symbiosis system itself has little nodes and every degree of node has little difference, therefore, the role of the core nodes in the system are not obvious enough, and the core node is the same with the other nodes that remove any node will have big impact the whole system.

Based on the formula (76.5) to solve the total output of the node A is 50; based on the formula (76.6) to obtain the total input of the A is 50. Taking the total input and total output of node A into the formula (76.7) and (76.8), the equation is set up.

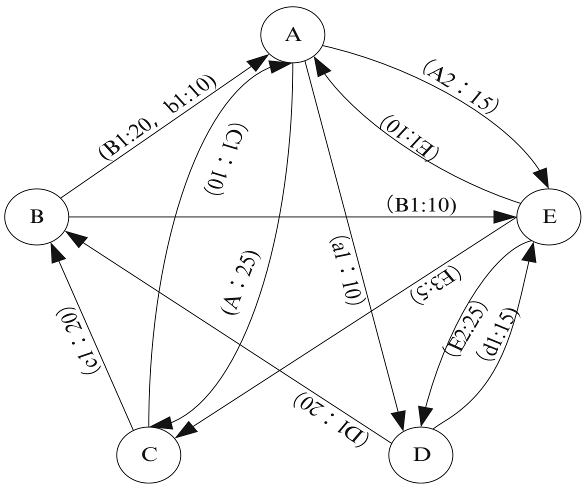


Fig. 76.4 Model of eco-industrial symbiosis network S

Similarly, taking the total input and total output of node B, C and D into the Eqs. (76.7) and (76.8), equations are set up. The node E also satisfy the formula (76.7) and (76.8), but what the E outputs are all the manufactured products without by-product, which is equivalent to the role of waste recycling and processing enterprises in the real eco-industrial symbiosis the system. But the waste recycling enterprises could generate the ultimate waste, in this paper it will not be considered in this system.

Conclusion

This paper gives an introduction to the problems brought up by in the tradition of industrial production and leads to the great significance to build eco-industrial symbiosis system and does an analysis of development pattern of eco-industrial symbiosis system (Fig. 76.1); and gives an introduction of complex network and analyzes its theoretical content and methods (Fig. 76.2); and node do an analysis and construction of eco-industrial symbiosis system from three aspects that are node, degree and weight (Fig. 76.3) and focus on the degree and weight. This paper focus on the balance relationship between input and output among enterprises, and constructs a virtual eco-industrial symbiosis system in order to does an empirical analysis of the contents of this study and to prove the feasibility of this study, the conclusion has a guiding significance for eco-industrial symbiosis system.

References

Albert R, Barabás A-L (2002) Statistical mechanics of complex networks [J]. Rev Mod Phys 74:47–97

Bai Tingting, Zheng Xinqi (2011) Analysis of complex network status based on co-word analysis [J]. Resour Dev Mark 27(2):122–126

Dorogovtsey SN, FMendes JF (2002) Evolution of networks [J]. Adv Phys 51:1079–1187

He Yu, Zhao Hongli (2011) A survey on evolution of complex networks [J]. J Acad Equip Command Technol 22(1):121–125

Li Huibo (2006) Thermodynamic frameworks of cleaner production and optimized energy distributions of ecology industry system [D]. Tianjin University Press, Tianjin

Liu Guangwei, Zhao Tao (2011) Construction and implementation of industrial symbiosis network in eco-industrial park—based on “brownfield” theoretical research on eco-industrial park construction [J]. J Xidian Univ (Social Sciences Edition) 21(6):40–48

Liu Yifang, Tong Rencheng (2011) An energy-theory-based analysis of the input-output model of the circular economy [J]. Manage Rev 23(5):9–17

Strogatz SH (2001) Exploring complex networks [J]. Nature 410:268–276

Wang Xiaofan, Li Xiang, Chen Guanrong (2006) Complex network theory and application [M]. Tsinghua University Press, Beijing, pp 9–14

Wang Zhaohua (2002) Research on industrial symbiosis network in eco-industrial Park [D]. Dalian University of Technology, Dalian

Wu Di, Wu Chunyou (2011) Research on the construction of eco-industrial clusters and its model [J]. Contemp Econ Manag 33(7):64–68

Xiao Zhongdong, Zha Zhongpeng, Xu Chen (2010) Application research on complex network of industrial ecological system [J]. Syst Eng 28(5):59–63

Xing Lizhi (2012) Analysis of regional industrial structure model based on complex networks theory [J]. J Ind Technol Econ 2(2):19–29

Yin Yanbin, Zhao Tao (2008) Industrial symbiosis system in eco-Industrial park based on recycled economy [J]. J Xidian Univ (Social Sciences Edition) 18(1):40–44

Zhang Jianyi (2011) Analysis of circular economy in ecological industrial zone—a case study of xunyang ecological industrial zone [J]. Environ Sci Manag 36(6):143–146

Chapter 77
Research on the Ability Training System of Engineering Management Based on the Ascension of Personnel Value Oriented

Hua Wang and Li-ming Zhao

Abstract Promotion of talents' value in Engineering Management refers to several main processes, for example, basic professional capability training, core capability training and development capability training. Professional capability training system requires that the set of basic course system is fit for the capital standard of specific human resource in each stage and driving factors formed by specific human resource value must suit the practice ability course system. This paper propose a practice teaching system based on ascension of personnel value oriented, which includes basic ability course system and corn ability course system and development ability system, then present countermeasures for the promotion of Human Capital value in Engineering Management in our country.

Keywords Engineering Management • Personnel value • Practice teaching • Core capability • Development capability

Introduction

Professional Human Capital value promotion means the total process from advanced basic ability training which teaches professional knowledge and technology to formation of professional corn ability and development ability. In the whole life cycle of professional human resource, the formation method and content are different in each stage, and it can be basically divided into several main processes, for example, professional basic ability training stage, corn ability training stage and development ability training stage. In professional ability training stage, the goal

H. Wang (✉)
School of Management, Shenyang University of Technology, Shenyang, China
e-mail: llyywwhh@163.com

L.-m. Zhao
School of Management, Tianjin University, Tianjin, China

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_77,

can be achieved through professional course system and practice. In corn ability training stage, the formation of professional human resource is mainly by related practice and internship in professional practice activities (Ying-luo Wang and Neng-min Wang 2006). The formation of professional Human Capital in development ability stage needs to turn practice experience into professional skills through specific project practice, then to promote professional ability in Engineering Management.

The Main Process to Promote Engineering Management Professional Human Resource Aimed at Promotion of Human Value

In the whole life cycle of professional Engineering Management human resource, the process of professional resource promotion is the formation of professional ability system. In the total process of Engineering Management human resource formation, the professional human resource ability standard system can be achieved through various methods in different stage (Ying Ou 2006). The professional ability system of professional human resource has close relationship with the formation methods of professional human resource. Only the driving factors in every stage arrange and organize the professional knowledge and practice activity, the ability requirement of professional human training in each stage can be achieved effectively. The relationship between human resource ability training and value promotion in each stage is shown in Fig. 77.1.

Basic Ability Training System of Human Capital in Engineering Management Based on Ascension of Personnel Value Orientated

The basic ability of the ascension of Human Capital value mainly refers to the most basic ability completing project management work, the systematicness is mainly established by degree education and simple practice (Bing Yu 2009). Usually the framework training system for the formation of basic ability in Engineering Management include four aspects: economic courses, civil engineering technology courses, management courses, law courses, the basic system of courses are shown in Fig. 77.2.

The Ascension of the Value of Talent Orientated Core Ability Training System of Human Capital in Engineering Management

Core ability is established on the basis of basic ability, it is a kind of ability be equipped with to be a project management professional who reflects the competitive

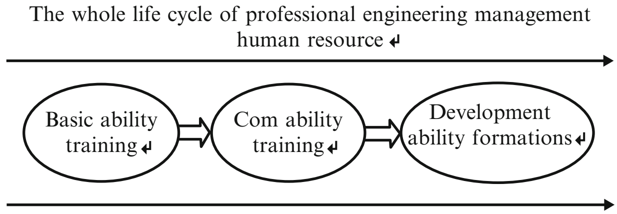


Fig. 77.1 The promotion of professional Human Capital value in Engineering Management

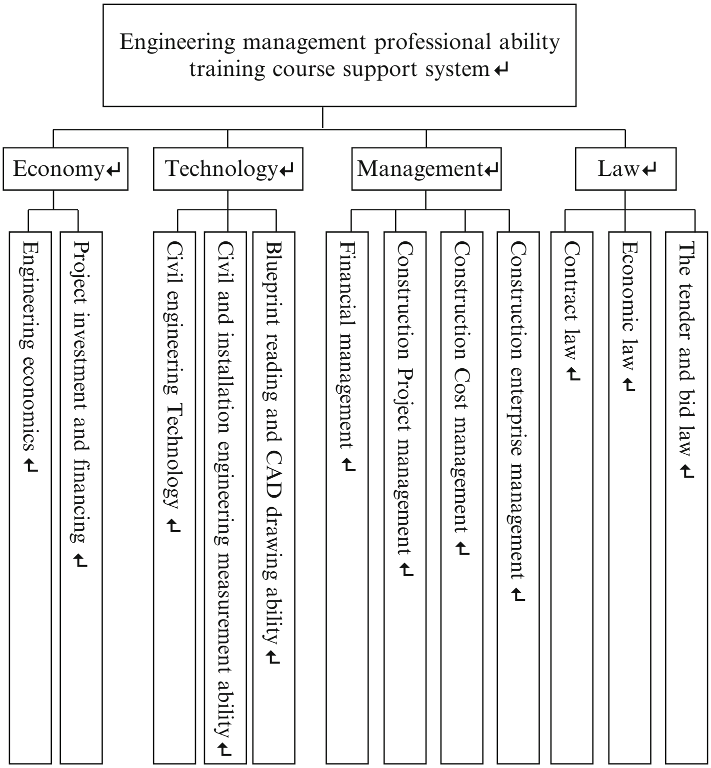


Fig. 77.2 Basic ability training system in Engineering Management

ability of practical ability of professionals on the aspects of engineering project management and engineering cost management. Project management is a applied professional, students must be equiped with superior practical ability. Enrich practice session can make students learn to train their basic ability which will be quickly

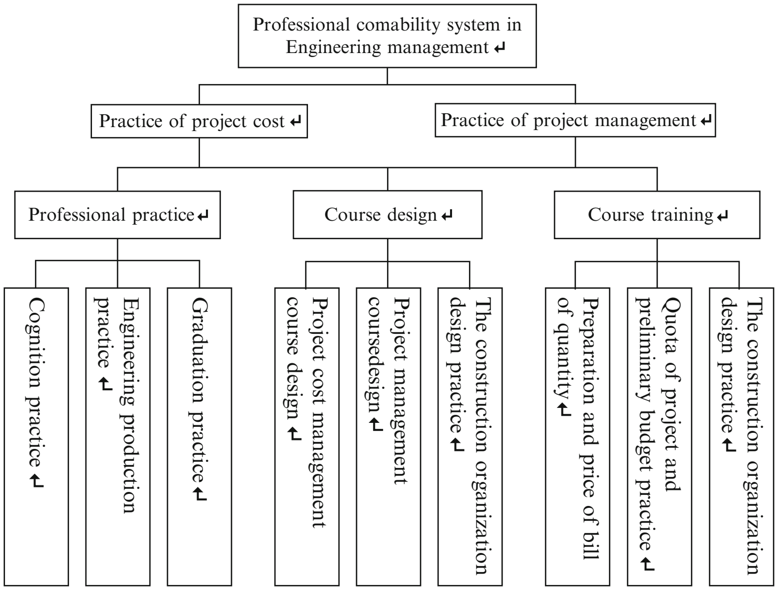


Fig. 77.3 The schematic diagram of basic ability training system in Engineering Management

applied in practice and form the core capability that professional personnel need to be possess. At present higher institutions' teaching steps of the formation of core ability in Engineering Management in our country is basically includes several main links, as follows: cognition practice, course design, engineering practice, extracurricular practice, final projects and so on, the main content and function is shown in Fig. 77.3.

According to the difference of the subject and object of practice teaching, the present practice teaching in project management in our country can be divided into campus practice teaching and practice teaching outside school. The main forms of practice teaching outside school mainly include cognition practice, measurement practice and graduation practice. The main form of practice teaching outside school is holistically follow the law of human's understanding new things, that is from perceptual knowledge to rational knowledge, from point to surface, from plane to solid (Fig. 77.4) (Hua and Yun-gang 2011).

Talent Value Promotion Oriented Training System of Development Ability of Human Capital in Engineering Management

Development ability is mainly expanded on the basis of basic ability and core ability; the specific ability standard can be adjusted based on the new development of cost management and project management. It is a indispensable ability to be Industry expert, its main contents include: Ability of learning new knowledge,

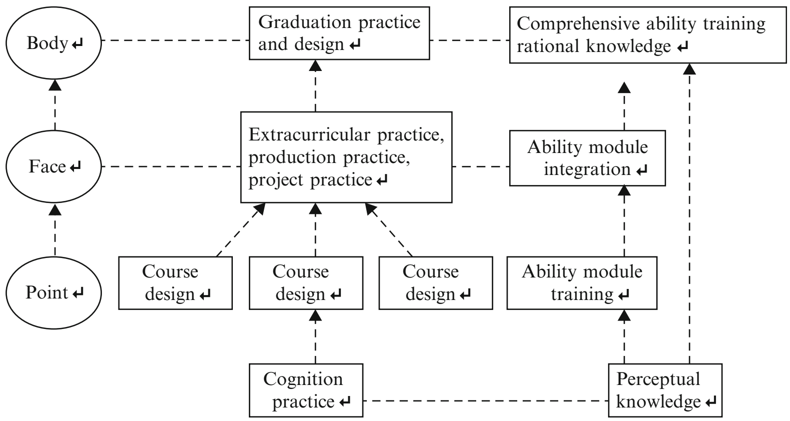


Fig. 77.4 Schematic diagram of the main form and function of practice Teaching outside school

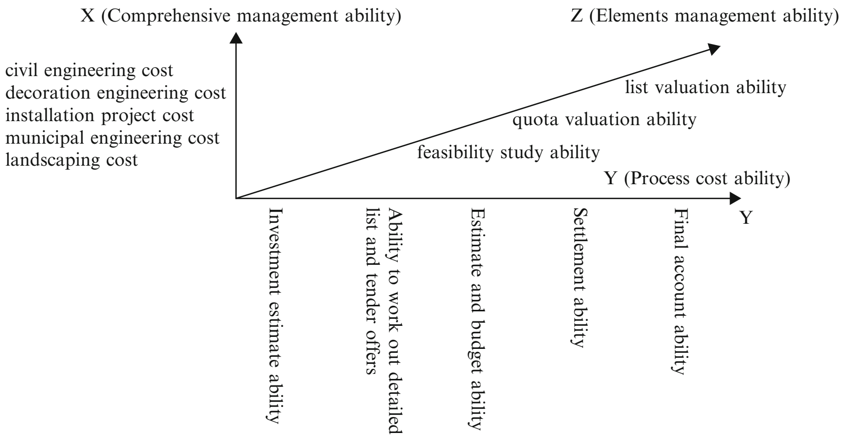


Fig. 77.5 Formation picture for development capability system of engineering cost direction

review engineering project and evaluate the performance of project management; Ability of flexibly master and use the following knowledge: risk management, quality management, information management, accounting, auditing, dispute settlement; Ability of conducting analysis and decision making in the process of construction and management. The talent value up oriented training system of development ability of human capital in Engineering Management mainly include the development ability training system of engineering cost direction and project management direction. The main development ability system is shown in Figs. 77.5 and 77.6.

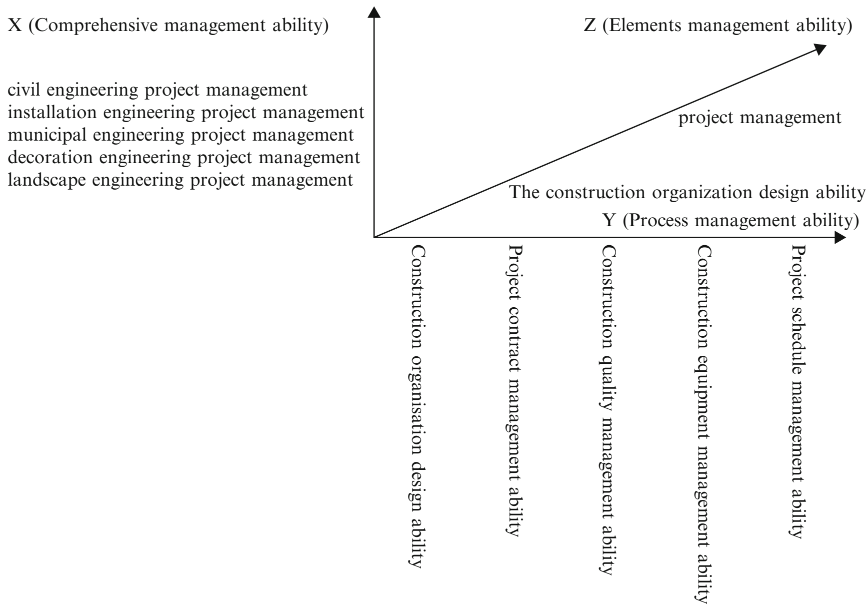


Fig. 77.6 Formation of development capability system of project management direction

Guidance of Half Structural Model of Human Capital Ascension in Foreign Engineering Management

Engineering Management of higher learning in foreign countries, including Britain, the United States, Canada and other countries, offer the students abundant time and opportunities to practice in their professional teaching plan, they attach importance to the training of practical ability of students in Engineering Management, and also are in continuous exploration for the best teaching mode in the practice session of Engineering Management in higher education, they have created a more classical half structural ability training teaching paradigm. For instance, there are several kinds of typical half structured teaching mode in the practice ability training session in foreign Engineering Management.

Workshop Team Mode

The typical workshop team practice teaching model is used in the Hong Kong polytechnic university, cost practice is the main of their surveying studio. Usually students were divided into several groups that relatively fixed according to the school year standard, team members were randomly constituted, self-selected, the group run by students and each group member has the chance to be the managing director in a period of time, members in the same team can participate in grading other members. According to different grade, design and develop different themes and cases of the surveying studio for study. Learning model of this workshop team has some change, from in basis of guidance to make the students as the center of learning (Yu-huan Li 2010). In the link of surveying studio, students need to use the knowledge they have learned in class to solve practical problems, and some questions are beyond the scope of the courses, they tested the conversion degree of students' practical ability and professional skills. The workshop team often has some pass questions which are designed by team members of workshop according to the problems they met with in engineering practice. In a credible background, the pass question includes some questions without optimal answer, for example, open-ended and unstructured. It allows students from different ways, different points of view, and different way to get different solution. Students would write down their own learning experiences and their contribution for each pass question. The instructor writes comments according to the contents, the process and the results of each student's daily record.

Cooperative Education Mode Between Enterprise, College and Scientific Research

The typical cooperative education mode between enterprise, college and scientific research is applicated to Engineering Management of some higher learning institutions in Britain and Canada. Engineering Management in British University has realized finishing the transition from school to the actual work before their students getting into the actual work. Similar with practice session of Engineering Management in British University, in Canada, in order to improve the students' innovation ability, guarantee the education quality and train students' practical ability, many schools have set up the joint projects between university and enterprises (Yu-huan Li 2010). School affiliate internship units for part of the excellent grade three students, let them work 3–4 months until go back to school to continue taking courses. During the period of school, students can get the opportunity to be internship and go to enterprise or other departments offered by school. While the students in Engineering Management in some other foreign college need to attend continuous paid internships in relevant departments or enterprise for a year or more when they complete junior courses, and then go back to school to finish school.

Flexile Case Teaching

In order to improve the teaching efficiency, although Engineering Management in the institutions of higher learning in Britain, the United States and other countries attached great importance to the flexile case teaching mode in Engineering Management, based on the construction of computer room, many of them also pay attention to bring the modern information means into teaching process, to promote the multimedia, video conference, the Internet and other modern teaching means. Through electronic means to provide students with practical place (Zen-xing Long and De-yuan Huang 2008). Trying to realize the informatization, digitization, visualization of the case teaching of project management, such as some colleges and universities are systematically collecting the full sets of project's implementation process video and engineering documents material, some universities are trying to construct project management simulation experiment based on virtual reality technology. Also they stress students' participation, alternate it through the way of case discussion, encourage students to think for themselves, and use the explicit knowledge of tacit knowledge in project management to solve the raised problems.

Countermeasures for Improving the Value of Human Capital in Engineering Management in Our Country

According to the typical model of the link of Engineering Management ability training in China in recent years, it is easy to see that the practice teaching process of the most Engineering Management in domestic colleges focused on the acquisition of dominant knowledge, especially on the intuitive feel and knowledge to technical knowledge of engineering and project management technology, while the learn and master of tacit knowledge (such as management decision and organizations, cost auditing and estimating and so on.) in the project management is generally ignored. In the process of practice, pay much attention to engineering technology, while neglect the practice and use of the process of managerial decision.

Thus, to the Engineering Management ability training based on the ascension of the Human Capital value orientated, this paper put forward the following suggestions:

A. *Practice for enhancing the ability of engineering project management organization and decision-making*
   The purpose of management is how to improve the level of productive forces by reasonable organization and configuration of human, financial, material and other factors under the current conditions. While the purpose of project management is to effectively plan, coordinate, control, arrange and normalize the whole process of engineering, from the concept design to the formal operation, including activities such as study of investment opportunity, preliminary feasibility study, final feasibility study, survey and design, invite bids, procurement, construction, commissioning, to ensure the engineering quality and quantity meet the predetermined requirements. It requires the engineering managers possess the systematic Engineering Management qualities, take control of the whole progress of trends in engineering. At the same time to accumulate management experience, so as to put forward emergency countermeasures to unexpected problems in project progress.

B. *Enhance practice ability of economic accounting and financial analysis*
Construction activities usually involve plentiful investment, at least hundreds of thousands, more than tens of millions or even billions, as the decision maker, must have the scientific quantitative analysis of the data and results as the basis of judgment and decision making. Project management activities involving all aspects such as the study of construction projects' investment opportunity, preliminary feasibility study, final feasibility study, survey and design, invite bids, bidding, bids designing, procurement, construction, settlement and final accounts, commissioning. They all demand that the managers can skillfully use economic method, scientific and critically control the economic indicators and activities to run toward expected target.

C. *Improve the psychological quality and strain quality of project management*
Project management is a kind of total process management, it is not only a kind of technical management, but also a kind of risk control management, in many cases is a kind of crisis management. Due to the existence of many unexpectation variables and unknown in internal and external environment of the project progress, makes the new problems, new contradictions and new condition are endless. Managers will encounter all sorts of unexpected emergencies, in these cases, the manager need to be placid and calm to analyze the environmental change, took out the solving methods timely and effectively. Excellent strain capacity and favorable psychological quality is the indispensable quality for managers in contemporary architectural activities.

D. *Promote cooperative education mode in Engineering Management*
To establish a stable practical teaching base outside school, in the course arrangement, we should focus on the strengthening of cooperation with related construction enterprise, architectural design institute and the investigation court, the construction unit and the construction cost consultation firm, to establish training base, strengthen the practice teaching, using the integrated model of infiltration, to make the students to enter the actual production areas during the period of school, to get the exercise of production practice. Secondly, can try to implement the double tutors which is the combination of school supervisor and outside supervisor, made full use of social resources to serve the teaching service of Engineering Management, at the same time strengthen the two-way contact between classroom teaching and engineering practice, promote raising school standards of our field, encourages the students to use tacit knowledge to solve problems beyond their course scope. Furthermore, puts forward the pattern of unstructured practice teaching to apply theory into practice.

Conclusion

At present, the scale and level of construction in our country are all lie in forefront in the world, but high quality engineering management personnel, especially talents who can manage the large or overseas engineering is in short supply. At present most of the supervisor of construction in our country are come of technical staff, professional training focused on technical ability, while the comprehensive quality is not high, communication ability is not enough, and lack of the concept of systematic, comprehensive and global, and that the ability of investment operation and cost auditing is weak, the compound talents are badly needed. Thus cultivating Engineering Management with competitive power and high comprehensive quality and realizing the ascension of the value of human capital in Engineering Management through ability training are of important practical significance.

Acknowledgment Thanks for my supervisor's help, so I can complete this paper in time.

References

Bing Yu (2009) On cultivating managers in engineering and the training programs of engineering management authentication. Res Higher Educ Eng 10(3):34–36 (Chinese)

Hua Wang, Yun-gang Wang (2011) Risk decision-making of engineering project based on information entropy, social edn, vol 8, no 2. Shenyang University of Technology Press, Shenyang (Chinese)

Ying Ou (2006) Opinions on training creative personnel of engineering management. Technol Innovation Manage 17(4):23–26 (Chinese)

Ying-luo Wang, Neng-min Wang (2006) The actuality and development of the engineering management subject in China. Eng Sci Press 23(8):34–39 (Chinese)

Yu-huan Li (2010) Discussion on talent culturing concerned engineering management. Shanxi Archit 34(4):56–62 (Chinese)

Zen-xing Long, De-yuan Huang (2008) Some thoughts on undergraduate course profession praxis education in engineering management. Shanxi Archit 33(8):23–26 (Chinese)

Chapter 78
Appliance of DEA-CCR in Research on Sustainable Development of Real Estate Industry in China

Da-lei Wang, Ben-zheng Xie, Yan-yan Wang, and Li Yang

Abstract China has issued several strict policies since 2008 to regulate and adjust the real estate industry, which would have substantial effect on the sustainable development of the industry. The effects seem have already showed by the great reduction of profit of leading companies and bankruptcy of small ones. So, study on the effect the strict regulating policies, from the prospect of sustainable development, has great meaning for government and its decision making. The previous theories mostly emphasized on the levels of several financial indexes in order to conclude the prospect of the industry, for example the profitability, liquidity and asset-liability ratio. But actuality shows even the company, with high profitability and low asset-liability ratio, would occur to bankrupt in the near future. Therefore, we must emphasize the operation efficiency of the industry or leading companies, which can conduct us to research the development of industry in near future. DEA has been successfully used for predicting one company's bankruptcy. In this paper we would use the model for 20 leading real east companies whose operation would stand for the whole industry's status mostly. The result shows there is great difference in the conclusion between DEA and the traditional manners.

Keywords Real estate industry • Sustainable development • Efficiency analysis • DEA-CCR

Introduction

The extensive development of real estate industry has great impact on the national economy structure in China. Under more and more strict policies of controlling this industry, it is no doubt that the scale of the industry and the manner of the industry

D.-l. Wang (✉) • B.-z. Xie • Y.-y. Wang • L. Yang
College of Management Science and Engineering, Shandong Jianzhu University, Jinan, China
e-mail: asoka518@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_78,

will be changed inevitably. The first series of such policies have been executed for nearly 5 years. Before we issuing the other series of controlling policies, it is very important to review that on what extent the status of the industry has changed, especially as related to its sustainable development.

The previous research about sustainable development mostly focused on the expenditure of natural resources, the affection to environment and some single financial indexes (for example the level of profitability, ratio of asset liability). Indeed, these theories play an important role in their appliance to the other industries. But, it is inconsiderately to use them to the real estate industry regardless its own characteristics. First, development of real estate is a process with huge consuming of natural resources, whether it is healthy sustainable developing or not. Second, its affection to environment is not worse than the traditional manufacture industries. Last but not least, nowadays the real estate industry is in extensive stage with high profitability, from 30 to 50%. So, according to the traditional financial theory, this industry is healthy and not deserved any further study on its sustainable development. Therefore, we must apply a new method or theory to diagnose the problem with the special industry.

To study the development of real estate industry well, we must pay attention to its production efficiency and technology development. Efficiency measurement was firstly used by Farrell (1957). On the basis of study the previous literatures, Charnes et al. (1978) bring forwards the conception of Data Analysis Envelopment (DEA) in the technical evaluation of decision making units (Charnes et al. 1978). After that, DEA, as one of the most popular efficiency evaluation manner, has been widely applied. Maria Psillaki (2010) firstly used DEA to analyze company's operation efficiency when he evaluated the relationship of credit risk and production efficiency. He put the final DEA value into a logistic regression model together with the indexes of scale, liquidity, profitability and so on. The result of model showed that the operation efficiency index was more sensitive and accurate than the other traditional financial indexes for the purpose of bankruptcy prediction (Psillaki et al. 2010).

Methodology

DEA model has been developed for several decades, and changed into some special patterns which are for different circumstances, including CCR, BCC model (Banker et al. 1984), FG model (Fare and Grosskopf 1985), ST model (Seiford and Thrall Recent 1990) and the CCW model (Charnes et al. 1986). In this paper we use the DEA-CCR model. And the result of model shows significant difference from the traditional manners.

In order to study the sustainable development of the real estate industry, we must choose the companies restrainedly, which should be specialized in real estate business and more important should take the leading positions in this industry. Such specialization is very important because the abnormal high profitability of real estate business attract many other industry's companies to take part in this industry. It is quite inappropriate to use their analyzing results to deduce how the real estate industry's status is. This paper chooses 20 companies from 144 ones of stock market's real estate groups. The study period is from October of 2009 to September of 2011, quite accordant with the first series of government's controlling policies' execution. The 20 companies' real estate business takes proportion over 90% in their total business. Also, the 20 companies must be the leading ones in scales. Therefore, the finally selected companies can appropriately stand for the whole industry. The 20 companies are placed in Table 78.1 by the descending order of total assets scale. WK has the total assets scale over 44.251 billion dollars. QXJS's scale is 1.531 billion dollars.

Firstly, we follow the traditional theory, and study the companies' profitability, in Table 78.1.

Table 78.1 indicates that the industry's profitability is apparently higher than the others and keeps stable through the study period. The variances, used to evaluate the fluctuation of profitability, are mostly under 50, showed in Table 78.2.

According to the traditional theories, the real estate industry, keeping stable and high profitability, have no doubt to be healthy and will go through sustainable development. But, each industry, after its period of extensive development, will inevitably be confronted with the change of developing mode. To study the real estate industry which is in the extensive period, the most important work is to evaluate the extent of its "extensive", i.e. the status of production efficiency.

Appliance of DEA-CCR Model

Before using the model, we should set the returns to scale.

The earlier DEA model, for example the Input-Orientated DEA model by Charnes et al. (1978), assumes the returns to scale is constant. But the assumption is suitable to the real production. Some factors, like the non-free competition and financial restriction, could drive the production away from the optimum production scale (Coelli 1996). Banker et al. (1984) used a new DEA model with variable returns to scale. In 1990s of twentieth century, most literatures set variable returns to scale in DEA. We cannot make conclusion that variable returns to scale is more appropriate in any circumstances than the constant returns to scale. But there is one thing for sure that the change of DEA model from constant to variable returns to scale will substantially improve the numbers of efficient decision making units. So this paper set the constant returns to scale in DEA.

The DEA model need variables classified into input variables and output variables. We must select the variables carefully. Altman (1968) utilized financial ratios calculated from assets, liabilities, net profit and earnings per share (Altman 1968). Lin et al. (2007) taked accounts receivable turnover ratio, current ratio, earnings per share and gearing ratio into their study of company financial crisis (Lin et al. 2007).We set the revenue as the output variable, and set the total liability

Table 78.1 Quarterly profitability

UNIT: %

Name	2009 4th Season	2010 1st Season	2010 2nd Season	2010 3rd Season	2010 4th Season	2011 1st Season	2011 2nd Season	2011 3rd Season
WK	10.9	15.01	16.77	14.62	14.36	15.12	14.9	12.23
BLDC	15.31	13.52	14.47	13.25	13.71	19.45	18.4	15.89
JDJT	14.68	16.14	14.04	12.85	13.75	7.57	9.27	7.39
ZSDC	16.22	15.88	15.04	14.89	14.59	19.82	18.15	16.71
SMGF	19.41	8.92	14.99	13.85	19.13	17.92	14.49	15.34
RSFZ	18.53	13.03	14.02	13.27	15.65	10.97	15.38	15.67
ZHQY	15.44	21.92	8.56	7.76	23.25	20.5	3.2	8.81
ZLDC	16.65	11.09	11.32	17.57	21.95	14	6.8	5.59
SSFZ	10.86	6.16	8.62	9.52	9.78	11.34	13.12	13.56
BJCJ	24.72	105.66	81.47	44.98	25.85	17.01	19.52	14.79
SNHQ	25.56	21.61	16.84	22.56	22.21	24.67	23.17	26.5
LSZY	17.57	8.21	8.88	12.31	14.61	10.82	7.74	8.39
STLG	84.03	1.07	15.57	8.22	41.1	16.68	16.42	15.04
ZTCT	28.16	20.57	19.67	16.51	16.67	15.01	25.37	16.19
TFFZ	13.88	21.68	15.8	13.26	11.39	9.25	8.69	11.5
WTDC	11.14	4.29	0.51	14.84	11.59	0.22	0.98	3.27
GLDC	45.85	20.78	18.98	17.29	12.45	22.56	23.38	18.7
TJSJ	8.48	2.44	0.77	−4.53	10.45	−34.68	−52.62	−49.19
MLZY	31.54	7.76	4.86	6.57	10.26	9.44	8.49	7.94
QXJS	10.13	10.05	9.34	8.66	9.05	10.56	12.34	12.14

Table 78.2 Mean and variance of profitability

Name	Mean (%)	Variance
WK	14.24	3.37
BLDC	15.50	5.35
JDJT	11.96	11.51
ZSDC	16.41	3.22
SMGF	15.51	11.66
RSFZ	14.57	5.15
ZHQY	13.68	57.70
ZLDC	13.12	30.72
SSFZ	10.37	5.83
BJCJ	41.75	1,149.79
SNHQ	22.89	8.89
LSZY	11.07	12.52
STLG	24.77	704.07
ZTCT	19.77	22.59
TFFZ	13.18	17.32
WTDC	5.86	33.54
GLDC	22.50	100.56
TJSJ	−14.86	690.41
MLJS	10.86	72.60
QXJS	10.28	1.84

(TL), operational cash flow out (OCFO), operation cost (OC), operating expenses (OPE) and overhead expenses (OVE) as the input variables. Then calculate the 20 companies' efficiency values in each period, the result showed in Table 78.3.

In the third quarter of 2009, there are nine companies whose efficiency values are 1, which mean their technique being efficient. The number of companies with technique efficient drops to four in the fourth quarter of 2009. According to the orderliness of China real estate market, the fourth quarter should be the golden time, more revenue and less overstocks. The only reason which explains the huge contrast is the execution of related national controlling policies for real estate industry begins to have effects. The national controlling policies are issued for avert the real estate industry being over-invested. These policies' effect is continuous and makes the number of technical efficient companies no more than six. In other words, the whole industry's total efficiency deteriorates gradually since the fourth quarter of 2009. It indicates that the series of national controlling policies reduce the technical efficiency of the real estate companies. So, the efficiency value in Table 78.3 is useful and critical for China government considering the issuing of further controlling policies.

According to the comparison of the 20 companies, we find that the three biggest companies in total assets scale (i.e. WK, BLDC and JDJT), respectively achieve the technical efficiency once time. In contrast with the biggest companies, the small ones appear well in technical efficiency. SNHQ, with the total assets scale 2.533 billion dollars, matins technique efficient through the whole study period, and the smallest one (QXJS) also appears well in nearly whole period.

Table 78.3 Value of technical efficiency

Name	2009 4th Season	2010 1st Season	2010 2nd Season	2010 3rd Season	2010 4th Season	2011 1st Season	2011 2nd Season	2011 3rd Season
WK	1	0.857	0.941	0.835	0.921	0.816	0.828	0.777
BLDC	0.909	0.872	0.944	0.879	1	0.877	0.948	0.858
JDJT	0.796	1	0.943	0.883	0.935	0.726	0.738	0.715
ZSDC	0.979	0.948	1	1	1	1	1	1
SMGF	0.699	0.919	0.937	0.835	0.951	0.882	0.991	0.852
RSFZ	1	0.918	1	0.967	0.971	0.939	1	1
ZHQY	1	0.834	0.766	0.723	0.838	0.731	0.599	0.793
ZLDC	0.88	0.783	0.745	0.626	0.73	0.594	0.683	0.676
SSFZ	0.87	0.963	0.94	0.953	0.931	1	0.901	0.819
BJCJ	1	1	1	0.954	0.979	1	1	1
SNHQ	1	1	1	1	1	1	1	1
LSZY	1	0.769	0.842	0.807	1	0.741	0.691	0.707
STLG	1	0.698	1	1	0.593	1	0.911	1
ZTCT	0.832	0.963	1	0.863	0.889	0.806	0.803	0.722
TFFZ	0.678	0.658	0.806	0.757	0.811	0.96	1	0.974
WTDC	0.827	0.762	0.777	0.895	0.916	0.716	0.696	0.844
GLDC	0.628	0.939	0.934	0.855	0.787	0.991	0.913	0.836
TJSJ	1	0.733	0.757	0.673	0.815	0.442	0.376	0.319
MLJS	0.922	0.787	0.786	0.683	0.873	1	0.76	0.805
QXJS	1	1	1	1	1	0.93	1	1

Table 78.4 Ratio of slack value to original variable value

UNIT: %

Name	TL	OCFO	OC	OPE	OVE
WK	21.92	41.17	0.00	28.63	26.68
BLDC	29.44	35.83	0.00	8.47	0.00
JDJT	31.19	41.56	0.00	38.21	42.39
ZSDC	0.00	0.00	0.00	0.00	0.00
SMGF	0.00	14.56	0.00	24.31	30.86
RSFZ	0.00	0.00	0.00	0.00	0.00
ZHQY	24.09	0.00	0.00	0.00	27.36
ZLDC	10.21	36.11	0.00	13.25	38.02
SSFZ	5.80	0.00	0.00	0.00	21.70
BJCJ	0.00	0.00	0.00	0.00	0.00
SNHQ	0.00	0.00	0.00	0.00	0.00
LSZY	49.45	56.89	0.00	41.57	16.80
STLG	0.00	0.00	0.00	0.00	0.00
ZTCT	6.65	39.22	0.00	17.45	28.41
TFFZ	0.00	0.00	16.74	12.60	38.86
WTDC	0.00	0.13	0.00	18.85	1.53
GLDC	43.19	49.53	0.00	16.00	31.89
TJSJ	25.40	26.80	0.00	23.02	27.17
MLZY	0.00	12.18	0.00	7.55	20.36
QXJS	0.00	0.00	0.00	0.00	0.00

This obvious contrast indicates the big companies do not fully use their advantages in total assets scale. The other very important meaning for the government is the industry is still in the extensive development period indeed. The first characteristic for mature or fully developed industry is the positive correlation between asset scale and operation efficiency, i.e. the biggest company has the highest technical efficiency. In China the high abnormal profitability drives all the real estate companies to develop new project other than improve the operation efficiency.

DEA-CCR model's biggest advantage over the traditional theory is to evaluate the adjusting amount and direction for the technique inefficient companies changing to the efficient ones. Such slacks, very important to the operational management, show us the way of achieving technique efficient by optimizing input amount. We study the input slacks in the last period. Calculating the ratio of each variable's slack we obtain from the model, we can easily find the comparison of each variable's adjustment, in Table 78.4.

In this period there are six companies with technical efficiency and so their input slacks are zero. Among all the five variables, operation cost is best, nearly all the companies do not need any adjustment except TFFZ. In the following part we will discuss the slacks of the other four input variables.

The Slack of Total Liability

Liability is favorable to real estate industry which is in extensive development period with high profitability. The bigger scale of liability the companies obtain, the more power it has to develop new projects. But when this scale breaks through certain normal level, the relationship, between the enhanced power to share the market and the increasing of financial risk, will lose its balance. Therefore, the best scale of liability is to keep the liability lowest while maintaining the same level of productivity. According to the Table 78.4, only ZSDC, in the top four companies, achieves the optimum scale of liability. The other three leading companies (which are WK, BLDC, and JDJT) need to reduce the liability by a huge off, separately by 21.91, 29.44 and 31.19%. Compared with the huge amount of slack liability, among the other 16 small companies, only 7 of them need to reduce the amount of liability. Actually, SSFZ and ZTCT need a lightly adjustment of scale of liability. So, we can easily conclude that the small companies use the liability more efficiently than the big leading companies. The big companies, having the advantage of large scale of asset, obtained much more liability than they really need. The small companies keep the scale of liability matching its productivity well, meaning high efficient usage of assets.

The Slack of Operational Cash Flow Out (OCFO)

In China the OCFO of real estate companies mainly consist of the land royalties and construction cost. In order to raise the proportion of the market share, a lot of companies buy amounts of lands and store them for over 5–8 years without any substantial usage and development. China government obviously pay attention to such problem's Seriousness, and put a new policy in practice to prohibit the idleness and waste of land. Unlike the construction cost which can be compensated when houses or buildings are sold out, the land royalties cannot be compensated totally if there still is land storage. In Table 78.4 there are 11 companies which have the slack of OCFO, and four of them must reduce the OCFO off by over 40%. So, the real estate companies use operational cash inefficiently.

The Slacks of Operating Expenses (OPE) and Overhead Expenses (OVE)

There are 15 companies with slack of OPE or OVE. The nine smallest companies whose total assets are below 2.5 billion dollars need reduce the OPE or OVE expect STLG and QXJS. This shows that the operating and management efficiency of small companies is obviously lower than big companies.

Conclusion

This paper gives us several valuable messages and creative several useful and precise valued management indexes, for example the efficiency value and slack of input variables. All of messages and indexes offer great support for China government's further controlling policies to the real estate industry, as the followings:

A. Chinese real estate has already been overinvested. The high profitability should not and cannot mean the high efficiency of production. During the study period, nearly all the companies maintain the profitability over 10%, while only nine of them can achieve the technical efficiency. In a normal economic system, the existence of industry, with high profitability and low efficiency in long time, would inevitably and negatively influence the proper allocation of natural and social resources.
B. It is necessary to carry out different loan policy in real estate industry. The big companies have more slacks of liability than the small ones. Government should decrease the loan rate of small companies in order to reduce their financing cost.
C. Improve the usage of land in real estate industry. In the study of model output, we conclude that some companies do not make full use of land they have already bought, and result in the low efficiency of operational cash. So, the government should prohibit land storage in this industry, or increase the cost of real estate companies holding idle land.

Acknowledgment Within the early period of this paper, Professor Wei-dian HUANG gives us many constructive and valuable instructions and a lot of advice which are helpful to us to outline the structure of this paper. And Shandong Jianzhu University has been fully sponsoring our research on real estate industry's sustainable development since 2009. The authors, Da-lei, WANG, Yan-yan, WANG and Qi-jun, CHEN, highly appreciate and thank the valuable help from Professor Wei-dian HUANG and Shandong Jianzhu University.

References

Altman EI (1968) Financial ratios: discriminant analysis and the prediction of corporate bankruptcy. J Finance 23(4):589–609

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci 30(9):1078–1092

Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2(6):429–444

Charnes A, Cooper WW, Wei QL (1986) A semi-infinite multicriteria programming approach to data envelopment analysis with many decision-making units. Center for Cybernetic Studies Report, CCS551, The University of Texas, Austin

Coelli J (1996) A guide to DEAP version 2.1: a data envelopment analysis program. CEPA working paper: ISBN 863894969

Fare R, Grosskopf S (1985) A nonparametric cost approach to scale efficiency. J Econ 87 (4):594–604

Farrell MJ (1957) The measurement of productive efficiency. J R Stat Soc 120(3):253–290
Lin SP, Huang SY, Cai KL (2007) A study on prediction models of financial distress-a comparison of DEA-DA, neural network and logistic regression. J Account Corporate Govern 4(1):33–56
Psillaki M, Tsolas E, Margaritis D (2010) Evaluation of credit risk based on firm performance. Eur J Oper Res 201(2):873–881
Seiford LM, Thrall Recent RM (1990) Development in DEA: the mathematical programming approach to frontier analysis. J Econ 46(1):7–38

Chapter 79
Balancing Serial U-Lines in Lean Production

Jing Zha, Hao-ping Li, and Xiang-feng Zeng

Abstract In lean production, multiple U-lines are always combined to eliminate waste, which is called large room effect. The paper discusses three types of serial U-lines balancing including tail-to-head type, head-to-head type and hybrid type. A goal programming model which considered the minimization of workstations and the first or last workstation's operation time is established in each situation. Example applications indicate that serial U-lines with tail-to-head type are more efficient to reduce manpower and serial U-lines with head-to-head type are more convenient of material flow. The hybrid way owns the above two type's advantages and demonstrates its effectiveness.

Keywords Serial U-lines • U-line balancing • Lean production

Introduction

In order to meet the varying demand flexibly and eliminate waste, lean production requires proper design of machinery and workstation layout, such as serial U-lines.

In a U-line, the input of material and the output of products are close to each other, forming a "U", and operators walk to perform combinations of tasks in two sides. U-line balancing problem (ULBP), which belongs to physical design of the U-line, is the problem of assigning tasks to a minimum number of workstations under the restriction of precedence relationship and cycle time (Boysen et al. 2007). Because there are more possibilities for grouping tasks into stations in a U-line, the number of stations required in a U-line is never more than that required in a straight line. More important, when the demand is changing, it is easy to wide or narrow the

J. Zha (✉) • H.-p. Li • X.-f. Zeng
College of Mechanical and Material Engineering, China Three Gorges University, Hubei Yichang, China
e-mail: maria_zhajing@hotmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_79,

group of tasks assigned to each operator in a U-line to increase or decrease the number of operators. This principle is called Shojinka in Japanese (Monden 1983).

Furthermore, the design of the single line like an islet is avoided in lean production. In contrast, it prefers to concentrate idle time in a single workstation when balancing a single U-line and build multiline workstation among the neighboring serial lines. The number of operators or workstations can be decreased in this way. According to the location of multiline workstation, serial U-lines can be divided three types: tail-to-head type, head-to-head type and hybrid type.

The paper discusses three types of serial ULBP and the rest of the paper is organized as follows. The next sections are about three versions of serial ULBP respectively. A goal programming model is established and example calculation is utilized in each section. Discussion and conclusions are given in the last section.

Literature Review

Miltenburg and Wijngaard (1994), that is the first study on U-line balancing in the literature, formulated dynamic programming model to solve ULBP. Urban (1998) proposed the first integer programming formulation for ULBP by establishing a "phantom" network attached to the original precedence graph. Scholl and Klein (1999) defined three version problems with respect to the precedence constraints: (79.1) ULBP-1. Given the cycle time, minimize the number of workstation; (79.2) ULBP-2. Given the number of workstation, minimize the cycle time; (79.3) ULBP-E. Maximize the line efficiency for cycle time and workstation being variable. U-LINO, a kind of depth-first branch and brand procedure are developed to solve the three problems. Deshpande et al. (2002) developed an integer programming formulation and developed a solution procedure based on Lagrangian relaxation to address ULBP. Gokcen et al. (2005) put forward a shortest route formulation of ULBP. Based on the integer programming formulation developed by Urban (1998), Gokcen and Agpak (2006) presented a goal programming model which considers several conflicting goals simultaneously and provides a considerable amount of flexibility to the decision maker. In real world, it is not easy to determine goal values precisely but generally defined these values such as "somewhat larger than", "substantially lesser than" or "around" the vague goal. Kara et al. (2009) proposed a binary fuzzy goal programming model to solve these problem. In order to solve large-scale ULBP, Baykasoglu (2007), (Sabuncuoglu and Ozbakir 2007) and Hwang et al. (2008) applied genetic algorithm. Sabuncuoglu et al. (2009) and Baykasoglu and Dereli (2009) modified ant colony optimization. All above literatures solve single U-line balancing problem.

Miltenburg (1998) presented a reaching dynamic programming algorithm to balance U-lines in a multiple U-line facility and only considered serial ULBP with tail-to-head type. Chiang et al. (2007) formulized three version multiple ULBP which were similar to Scholl (1999). Multiple U-lines in that paper were parallel lines and executed the same tasks to produce the same products. Therefore, it still needs to exploit serial ULBP systematically.

Serial U-Lines with Tail-to-Head Type

In this type, the last workstation of the former U-line and the first workstation of the next U-line are close to each other and combined as multiline workstation which is operated by one operator. Suppose that serial U-lines have the same cycle time. At first, balancing the first U-line to minimize the number of workstation and concentrate the idle time in the last workstation. Next, balancing the second U-line with the same objectives under the condition the first workstation has been assigned tasks of the last workstation in the first U-line. And then balancing the next U-line with the same method until all U-lines are balanced. In the end, the number of workstations in all serial U-lines is minimized.

Based on above analysis, goal programming model I of U-line l balancing is developed as follows.

$$Min \quad P_1({d_{ls}}^+), P_2({d_{lt}}^+) \tag{79.1}$$

$$s.t. \quad \sum_{k=1}^{m_{\max}} S_k - {d_{ls}}^+ = m_{\min}, {d_{ls}}^+ \geq 0 \text{ and integer} \tag{79.2}$$

$$\sum_{i=1}^{n} t_i (x_{i(m_{\min}+{d_{ls}}^+)} + y_{i(m_{\min}+{d_{ls}}^+)}) - {d_{lt}}^+ = 0,\ {d_{lt}}^+ > 0 \tag{79.3}$$

$$\sum_{i=1}^{n} t_i (x_{i1} + y_{i1}) \leq C - {d_{(l-1)t}}^+ \tag{79.4}$$

$$\sum_{i=1}^{n} t_i (x_{ik} + y_{ik}) \leq C \cdot S_k,\ k = 2, \ldots, m_{\max} \tag{79.5}$$

$$\sum_{k=FE_i}^{m_{\max}} x_{ik} + \sum_{k=BE_i}^{m_{\max}} y_{ik} = 1, \quad i = 1, 2, \ldots, n \tag{79.6}$$

$$S_{k+1} \leq S_k,\ k = m_{\min}, \ldots, m_{\max} - 1 \tag{79.7}$$

$$\sum_{k=FE_i}^{m_{\max}} (m_{\max} - k + 1) x_{ik} \leq \sum_{k=FE_j}^{m_{\max}} (m_{\max} - k + 1) x_{jk},\ \forall (i,j) \in G \tag{79.8}$$

$$\sum_{k=BE_i}^{m_{\max}} (m_{\max} - k + 1) y_{ik} \geq \sum_{k=BE_j}^{m_{\max}} (m_{\max} - k + 1) y_{jk},\ \forall (i,j) \in G \tag{79.9}$$

$$x_{ik}, y_{ik}, S_k \in \{0, 1\},\ \forall i, j, k \tag{79.10}$$

Notation: C – cycle time; t_i – operating time of task i; FE_i – the earliest workstation which task i can be assigned in the front side; BE_i – the earliest workstation which task i can be assigned in the back side; $\forall(i,j) \in G$ – in precedence graph, task j can be started only after task i is finished; ${d_{ls}}^+$–position deviation of the actual U-line l workstation number from lower bound of workstation number; ${d_{lt}}^+$ – operating time of the last workstation in U-line l; m – workstation number. $m_{\min}$ – Lower bound of workstation number. $m_{\max}$ – Upper bound of workstation number. $m \in [m_{\min}, m_{\max}]$;

$$x_{ik} = \begin{cases} 1 & \text{if task } i \text{ is assigned to the front side of workstation } k \\ 0 & \text{otherwise} \end{cases};$$

$$y_{ik} = \begin{cases} 1 & \text{if task } i \text{ is assigned to the back side of workstation } k \\ 0 & \text{otherwise} \end{cases};$$

$$S_k = \begin{cases} 1 & \text{if workstation } k \text{ is utilized} \\ 0 & \text{otherwise} \end{cases};$$

Objective P1 is to minimize the workstation number of U-line l. Objective P2 is to minimize the last workstation's operating time. P1 is superior to P2. Constraint (79.2) and (79.3) are soft constraints in goal programming. Constraint (79.4) restricts the first workstation's operating time no more than cycle time subtracting the last workstation's operating time of U-line (l-1). Constraint (79.5) restricts other workstations' operation time no more than cycle time. Constraint (79.6) means that every task should been assigned to one and only one workstation. Constraint (79.7) requires to assign the workstation with little index k first. Constraint (79.8) and (79.9) enforce the precedence relationships of tasks. If the task is assigned to the front side, constraint (79.8) should be ensured. If the task is assigned to the back side, constraint (79.9) should be ensured.

Next an example is solved to illustrate the serial U-lines with tail-to-head type discussed here. The precedence graph of U-line A and B are given in Figs. 79.1 and 79.2. The goal programming model is solved using MATLAB 7.3. Cycle time = 20. If separately balanced, U-line A needs 3 workstations and U-line B needs 3 workstations. If U-line A and B are located tail-to-head, task assignments are shown in Table 79.1 and line layout is shown as Fig. 79.3. After combined, U-line A and B needs 5 workstations or operators and one operator are reduced.

Serial U-Lines with Head-to-Head Type

However, from Fig. 79.3, we can see that there is complicated path of material flow because U-line A's output is far way from U-line B's input and it leads to wastes of material handling. Head-to-head type is an alternative layout. Multiple U-lines are located head-to-head and all input and output are close to each other. The output

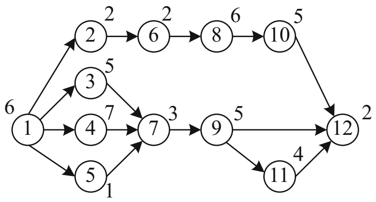


Fig. 79.1 Precedence graph of U-line A

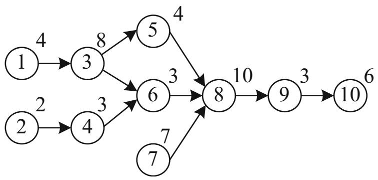


Fig. 79.2 Precedence graph of U-line B

Table 79.1 Task assignments

No of workstation	U-line	Front side	Back side	Time	Workstation time
1	A	1,2,5	12,11,10	20	20
2		3,4	9,7	20	20
3		6	8	8	20
	B	1,2	10	12	
4		–	9,8,7	20	20
5		2,3,4,5	6	20	20

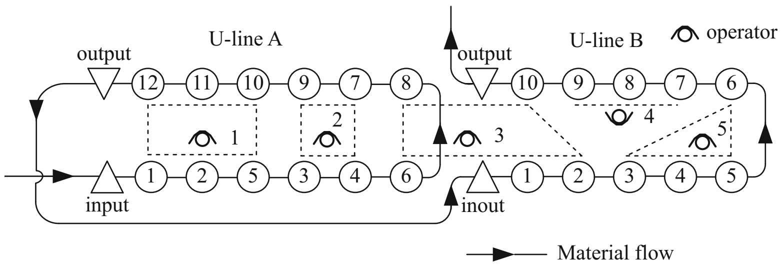


Fig. 79.3 Serial U-Lines layout with tail-to-head type

semi-finished product of the U-line can be transferred to the next U-line directly. Useless material handling is reduced and production rate is enhanced. Moreover, one operator can handle tasks in the input and output of multiple U-lines. It helps to achieve pull production. The operator is easy to perceive the unbalance between multiple U-lines and then trigger the improving actions.

The characteristic of this type is that the first workstations of multiple U-lines are combined as a multiline workstation. At first, balancing single U-line to minimize the number of workstation and concentrate the idle time in the first workstation. Next, assigning tasks in the first workstations of multiple U-lines with the

Table 79.2 Task assignments

No of workstation	U-line A			U-line B		
	Front	Back	Time	Front	Back	Time
1	1	12	8	1	10	10
2	2,3,5	11,9,7	20	–	9,8,7	20
3	4,6	10,8	20	2,3,4,5	6	20

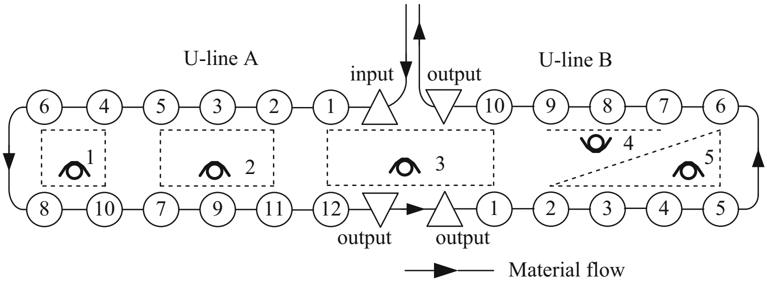


Fig. 79.4 Serial U-lines layout with head-to-head type

restriction of cycle time and determining multiline workstation's number. And then the number of workstations in all serial U-lines is minimized.

Goal programming model II of U-line l balancing is developed as follows.

$$Min \quad P_1({d_{ls}}^+),\ P_2({d_{lf}}^+) \tag{79.11}$$

$$s.t. \quad \sum_{i=1}^{n} t_i(x_{i1} + y_{i1}) - {d_{lf}}^+ = 0,\ {d_{lf}}^+ > 0 \tag{79.12}$$

$$\sum_{i=1}^{n} t_i(x_{ik} + y_{ik}) \le C \cdot S_k \quad k = 1, \ldots, m_{\max} \tag{79.13}$$

The rest restrictions are the same as (79.2), (79.6), (79.7), (79.8), (79.9), and (79.10).

Notation: ${d_{lf}}^+$ – operating time of the first workstation in U-line l;

If U-line A (see Fig. 79.1) and U-line B (see Fig. 79.2) are located head-to-head, task assignments are shown in Table 79.2 and line layout is shown in Fig. 79.4. Cycle time = 20. After combined, line A and B also needs 5 workstations or operators and the material flow is more simple and fluent.

Serial U-Lines with Hybrid Type

With the restriction of production environment such as factory building, it is not possible to use tail-to-head type or head-to-head type simply, but use the hybrid of two types flexibly. That is called large room effect (Boysen et al. 2007). The

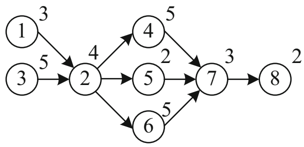


Fig. 79.5 Precedence graph of U-line C

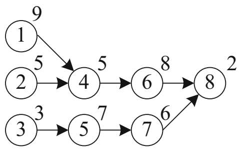


Fig. 79.6 Precedence graph of U-line D

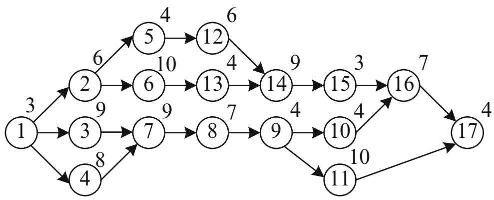


Fig. 79.7 Precedence graph of U-line E

characteristic of this type is that the large building is divided as multiple sectors by aisles. Each U-line is located at both sides of aisles. Some U-lines are tail-to-head and some U-lines are head-to-head in order to ensure fluent material flow and high production efficiency.

In a factory, there are U-line C, D and E besides A and B. Figs. 79.5, 79.6 and 79.7 are the precedence graphs. Cycle time = 20.

If separately balanced, U-line A needs 3 workstations; U-line B needs 3 workstations; U-line C needs 2 workstations; U-line D needs 3 workstations and U-line E needs 6 workstations. Totally needs 17 workstations. If U-lines are combined in head-to-head type, the first workstation's operating time of U-line A is 8; the first workstation's operating time of U-line B is 10; the first workstation's operating time of U-line C is 9; the first workstation's operating time of U-line D is 5 and the first workstation's operating time of U-line E is 7. With the restriction of cycle time, 3 multiline workstations are required. Totally needs 15 workstations or operators and 2 operators are reduced.

Supposed the locations of U-lines in the building are given. U-line A and B are at the left side of aisle 1; U-line C and D are between aisle 1 and 2 and U-line E is at the right side of aisle 2. Firstly, U-line A and B are balanced using goal programming model II and the first workstations' operating time is 8 (t_A) and 10 (t_B). ${d_{(l-1)t}}^+ = 8 + 10 = 18$. U-line C are balanced using goal programming I and the last workstation's operating time is 7 (t_C). And then U-line D and E are balanced using goal programming II and the first workstations' operating time is 5 (t_D) and 7 (t_E). A multiline workstation can cover t_C, t_D and t_E. Hybrid U-lines layout is shown in Fig. 79.8. Only 2 multiline workstations are required. Totally needs 14 workstations and 3 operators are reduced.

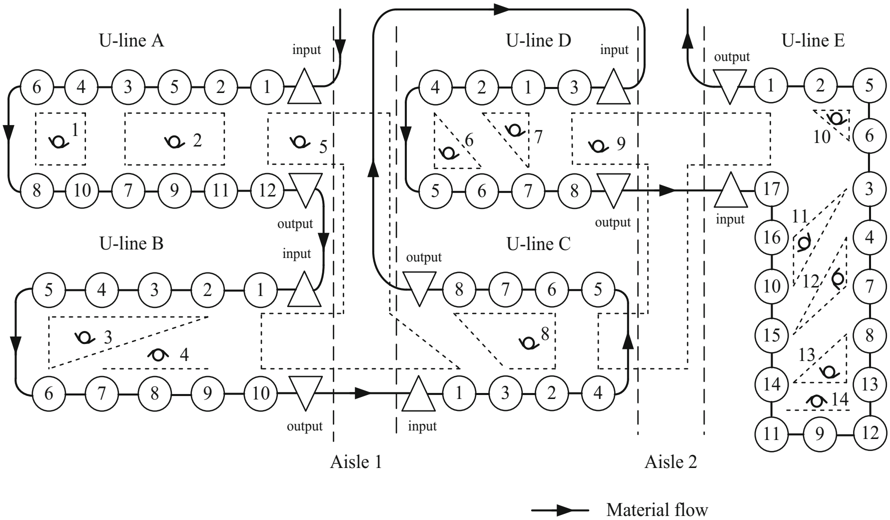


Fig. 79.8 Serail U-lines layout with hybrid type

Material flow is more fluent than one with tail-to-head type and the number of workstations is two less than one with head-to-head type. The hybrid way owns the above two type's advantages.

Discussion and Conclusion

One hypothesis is that the cycle time of all U-lines is same. If all U-lines are part of the same product's manufacturing process, the hypothesis is feasible. There are two other cases in manufacturing. The arrangement of multiline workstations in the two cases is discussed as follows.

1. Semi-finished products manufactured by U-lines are parts of the same end product. The cycle times of all U-lines are proportional. For example, one pieces A and two piece B are assembled to C. $C_A = 2C_B$. Suppose $C_B = x \times C_A$, x > 1 and integer. In multiline workstation, the operating time of tasks from U-line A is t_A and the operating time of tasks from U-line B is t_B. If $\frac{t_A}{C_A} + \frac{t_B}{C_B} \leq 1$, one multiline workstation is feasible and the cycle time of multiline workstation is C_B. During a cycle, the time which an operator works in U-line A is $x \times t_A$; the time which works in U-line B is t_B and the idle time is $C_B - x \times t_A - t_B$. Given $C_A = 1$, x = 3, $t_A = 0.3$, $t_B = 2$. The working time sequence is showed as Fig. 79.9.

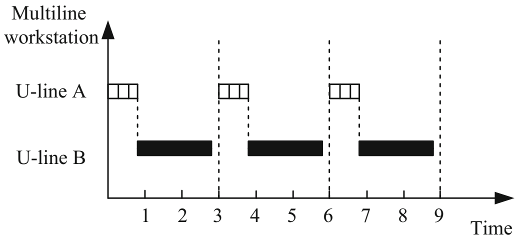


Fig. 79.9 Working time sequence of multiline workstation

2. The cycle times of all U-lines are different and not proportional. $C_B = x \times C_A$, $x > 1$ and not integer. If $\frac{t_A}{C_A} + \frac{t_B}{C_B} \leq 1$, one multiline workstation is feasible. If the cycle time of multiline workstation is C_A, an operator must return to U-line B every x cycle. Because x is not an integer, the operator can not return to U-line B in time. In that situation, a buffer should be set in U-line B to aviod line down. The operator needs to monitor the buffer and decide to work on which line based on production situation.

Therefore, it recommends to combine multiple U-lines with the same or proportional cycle time in serial. Among the three combination type, serial U-lines with tail-to-head type are more efficient to reduce manpower and serial U-lines with head-to-head type are more convenient of material flow. With the restriction of production environment such as factory building, it is not possible to use tail-to-head type or head-to-head type simply, but use the hybird of two types flexibly. The hybrid way owns the above two type's advantages and is recommended.

Acknowledgment This work is partially supported by National Science Foundation of China Grand (No. 71071059) and the scientific research fund of personnel from China Three Gorges University. (No. KJ2011B035).

References

Baykasoglu A, Dereli T (2009) Simple and U-type assembly line balancing by using an ant colony based algorithm [J]. Math Comput Appl 14(1):1–12

Boysen N, Fliedner M, Scholl A (2007) A classification of assembly line balancing problems [J]. Eur J Operat Res 183:674–693

Chiang WC, Kouvelis P, Urban TL (2007) Line balancing in a just-in-time production environment: balancing multiple U-lines [J]. IIE Trans 39:347–359

Deshpande V, Rajaram K, Guignard M (2002) An integer programming based formulation of the U-line balancing problem [R]. Working paper, The Wharton School of the University of Pennsylvania, Philadelphia, 5

Gokcen H, Agpak K (2006) A goal programming approach to simple U-line balancing problem [J]. Eur J Operat Res 171(2):577–585

Gokcen H, Agpak K, Gencer C, Kizilkaya E (2005) A shortest route formulation of simple U-type assembly line balancing problem [J]. Appl Math Model 29:373–380

Hwang RK, Katayama H, Gen M (2008) U-shaped assembly line balancing problem with genetic algorithm [J]. Int J Prod Res 46(10):4637–4649

Kara Y, Paksoy T, Chang CT (2009) Binary fuzzy goal programming approach to single model straight and U-shaped assembly line balancing [J]. Eur J Operat Res 195(2):335–347

Miltenburg J (1998) Balancing U-lines in a multiple U-line facility [J]. Eur J Operat Res 109 (1):1–23

Miltenburg GJ, Wijngaard J (1994) The U-line line balancing problem [J]. Manage Sci 40 (10):1378–1388

Monden Y (1983) Toyota production system [M]. Industrial Engineering Press, Norcross

Sabuncuoglu I, Ozbakir L (2007) Stochastic U-line balancing using genetic algorithms [J]. Int J Adv Manuf Technol 32:139–147

Sabuncuoglu I, Erel E, Alp A (2009) Ant colony optimization for the single model U-type assembly line balancing problem [J]. Int J Prod Econ 120(2):287–3002

Scholl A, Klein R (1999) ULINO: optimally balancing U-shaped JIT assembly lines [J]. Int J Prod Res 37(4):721–736

Urban TL (1998) Note. Optimal balancing of U-shaped assembly lines [J]. Manage Sci 44 (5):738–741

Chapter 80
Parallel Machine Scheduling with Resources Constraint and Sequence Dependent Setup Times

Zheng-liang Hou and Xiu-ping Guo

Abstract This paper considered the scheduling problem of minimizing makespan on parallel machines with multiple resources constraint and job sequence dependent setup times. We proposed a mixed integer programming model to formulate the problem and used commercial software to get the optimal solution and Gantt chart of a small-size case. Then a Genetic Algorithm (GA) was developed to solve the problem in an acceptable time for large-size cases. Computational experiences shown that the proposed GA can achieve high quality solutions comparable to those obtained by commercial software and outperform the schedule rules existing in real manufacturing operation.

Keywords Genetic Algorithm • Makespan • Parallel machine • Resources constraint • Scheduling • Sequence dependent setup times

Introduction

In this paper we studied the parallel machine scheduling problem with multiple resources constrain and job sequence dependent setup times (RSPS), which is encountered in many manufacturing environment, such as the semiconductor wafer and final test operation, plastic forming plant and computer operating systems.

The RSPS can be formulated as follows. We are given a set $N = \{J_1, J_2, \ldots, J_n\}$ of jobs that have to be processed on exactly one machine out of a set $M = \{M_1, M_2, \ldots, M_m\}$ of identical parallel machines. The processing time of job J_j is a positive number denoted as p_j. There are $s \geq 1$ types of renewable resources, and $o_r \geq 1$ units of resource r $(1 \leq r \leq s)$ are available at

Z.-l. Hou • X.-p. Guo (✉)
Department of Management Science and Engineering, School of Economics and Management, Southwest Jiaotong University, Chengdu, China
e-mail: maxgxp@gmail.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_80,

any time. Job J_j requires q_{jr} units of resource r at any time of its processing and different jobs can be processed simultaneously only when their total consumption of resources does not exceed the resources capacity. Moreover, the setup times between consecutive jobs of different produce type are sequence dependent, that is, st_{jk} can be different from st_{kj}.

No machine can process more than one job at a time, that means, the machines considered here are not batch processing machines. Furthermore, we assume that machine breakdown will not happen and no job can be preempted.

Normally, the scheduling problem was denoted by a three-field notation $\alpha/\beta/\gamma$, where α describes the machine environment, β indicates the characteristics of job, and γ denotes the optimizing objective. J. Blazewicz et al. gave out a classification scheme $res\lambda\sigma\rho$ in β field to specify the resources constraint. Detail description was introduced in Blazewicz et al. (1983). Based on the three-field notation, RSPS can be expressed as $Pm/res\ldots, sdst/C_{\max}$, in which, $sdst$ indicates the job sequence dependent setup times and $res\ldots$ means the s, o_r and q_{jr} of the resources can be a random generated positive integer.

The rest of this paper is organized as follows. In section "Literature Review", we review the literatures related to RSPS. Section "Proposed MIP" provides a mixed integer programming (MIP) model. Then a GA is proposed in section "Genetic Algorithm" and computational experiences are shown in section "Computational Experiments". At last, section is the "Conclusions".

Literature Review

Scheduling problems subject to resources constraint was firstly proposed by Blazewicz et al. (1983). In that paper, they gave out a classification scheme for the resources constraint and discussed about the computational complexity of the extended problems.

Then scheduling problems related to resources constraint was widely studied by researchers. T.R. Chen et al. formulated an integer programming model and proposed a Lagrangian Relaxation (LR) approach (Chen and Hsia 1994). Another integer programming model considered resource constraints and preemption was proposed in Chen et al. (1995), LR was used to solve the problem. E.B. Edis and C. Oguz developed a LR based constraint programming method (Edis and Oguz 2011) and H. Tamaki et al. developed a binary representation for the schedules, then applied four search methods, including simulated annealing (SA), GA, a local search method and a random search method, to solve the problem (Tamaki et al. 1993). In Chen (2005), J.F. Chen developed a heuristic and made a comparison with the SA proposed in Tamaki et al. (1993), the constrains considered including resource constraints and setup times. In Ventura and Kim (2003), a zero–one integer linear programming model was proposed and a LR was used to get the lower bounds, the objective in which was a reflection of the JIT philosophy. H. Kellerer and V.A. Strusevich proposed a computational complexity classification for the parallel dedicated machines and gave out a number of polynomial-time algorithms (Kellerer and Strusevich 2003). Several lower bounds and two different GA were developed in Li et al. (2003). K.G. Kempf et al. studied the scheduling problem on a single batch machine with job families and secondary resource constraints (Kempf et al. 1998). J.Z. Wu and C.F. Chien presented a GA and an assignment algorithm to solve the scheduling problem in semiconductor manufacturing, where the constraints considered including resource constraints, job reentrant, sequence constraint and setup times (Wu and Chien 2008). A bi-vector encoding GA was developed and the results were compared with that achieved in Wu and Chien (2008) by Wu et al. (2012). F.T.S. Chan et al. divided the resource constraints flexible job-shop scheduling problem into an assignment problem and a sequencing problem, and proposed a two-stage GA (Chan et al. 2006).

However, there is not so much researches considered the job sequence dependent setup times. In Vallada and Ruiz (2011), a genetic algorithm including a local search and a local search enhanced crossover operator was developed. R. Tavakkoli-Moghaddam et al. presented a two-level MIP model and then used a genetic algorithm to solve the bi-objective parallel machine scheduling problem (Tavakkoli-Moghaddam et al. 2009). A hybrid meta-heuristic was designed in Chen and Chen (2009) to minimize the weighted number of tardy jobs.

As stated above, a lot of researches only concerned the resource constraints or sequence dependent setup times separately. The parallel machine scheduling subjected to multiple resources constraint and job sequence dependent setup times simultaneously has not been studied sufficiently.

Proposed MIP

Based on the model proposed in Wu and Chien (2008), we present a mixed integer programming model (MIP) for the RSPS in this section. This MIP not only can be used to solve the RSPS with identical parallel machines, but also can be applied on uniform parallel machines and unrelated parallel machines by merely changing several parameters.

All parameters including processing time, setup time, available quantities of each type of resources and requirement of resources for each job are assumed to be given and deterministic. T is a time horizon that is long enough to process all jobs. The optimizing objective is to minimize the maximum completion time or makespan, denoted by $C_{\max}$. Other notations are defined in the following section.

Notations

- x_{jit}: equals to one if job j $(j \in N)$ is processing on machine i $(i \in M)$ at time t or zero otherwise.
- y_{jki}: equals to one if jobs j and k $(j, k \in N)$ are consecutive jobs that are assigned on the same machine i, and k is going to be processed after j or zero otherwise.

- z_{ji}: equals to one if job j $(j \in N)$ is assigned on machine i $(i \in M)$ or zero otherwise.
- α_{jit}: equals to one if job j $(j \in N)$ begins processed on machine i $(i \in M)$ at time t or zero otherwise.
- β_{jit}: equals to one if job j $(j \in N)$ is processed on machine i $(i \in M)$ at time t and not processed on machine ii at time $t+1$ or zero otherwise.
- e_j and c_j is the beginning time and completion time of job j $(j \in N)$ respectively.

The Objective Function and Constraints

Objective function:

$$\min \ C_{\max} \tag{80.1}$$

$$\text{s.t.} \ \sum\nolimits_{i=1}^{m} z_{ji} = 1 \quad \forall j \in N \tag{80.2}$$

$$\sum\nolimits_{j=1}^{n} x_{jit} \leq 1 \quad \forall i \in M, t = 1, 2, \ldots, T \tag{80.3}$$

Constraint (80.2) restricts that one job should be assigned on a single machine, while constraint (80.3) restricts that one machine can only process one job at each time.

$$x_{jit} - x_{jit-1} = \alpha_{jit} - \beta_{jit-1} \quad \forall j \in N, \forall i \in M, t = 1, 2, \ldots, T \tag{80.4}$$

$$x_{ji0} = 0 \quad \forall j \in N, \forall i \in M \tag{80.5}$$

$$\beta_{ji0} = 0 \quad \forall j \in N, \forall i \in M \tag{80.6}$$

$$x_{ji1} = \alpha_{ji1} \quad \forall j \in N, \forall i \in M \tag{80.7}$$

$$x_{jiT} = \beta_{jiT} \quad \forall j \in N, \forall i \in M \tag{80.8}$$

$$\sum\nolimits_{t=1}^{T} \alpha_{jit} = z_{ji} \quad \forall j \in N, \forall i \in M \tag{80.9}$$

$$\sum\nolimits_{t=1}^{T} \beta_{jit} = z_{ji} \quad \forall j \in N, \forall i \in M \tag{80.10}$$

Constraints (80.4, 80.5, 80.6, 80.7, and 80.8) describe the relationship between $\alpha_{jit}, \beta_{jit}$ and x_{jit}, while constraint (80.9 and 80.10) restrict the correspondence between $\alpha_{jit}, \beta_{jit}$ and z_{ji}. Combined with constraint (80.2), we can get that the job preemption is prohibited.

$$e_j = \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{m} t * \alpha_{jit} \ \forall j \in N \tag{80.11}$$

$$c_j = \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{m} t * \beta_{jit} \ \forall j \in N \tag{80.12}$$

Constraints (80.11) and (80.12) define the beginning time and the completion time of each job.

$$\sum\nolimits_{j=0}^{n} y_{jki} = z_{ki} \quad \forall k \in N, \forall i \in M \tag{80.13}$$

$$\sum\nolimits_{k=1}^{n} y_{jki} \le z_{ji} \quad \forall j \in N, \forall i \in M \tag{80.14}$$

$$\sum\nolimits_{k=1}^{n} y_{0ki} \le 1 \quad \forall i \in M \tag{80.15}$$

$$y_{jji} = 0 \quad \forall j \in N, \forall i \in M \tag{80.16}$$

$$e_k \ge c_j - \sum\nolimits_{i=1}^{m} M * (1 - y_{jki}) \quad j,k \in N, j \ne k \tag{80.17}$$

Constraints (80.13), (80.14), and (80.15) restrict the number of prior jobs and post jobs for each job, in which job $0\ (j = 0)$ is a virtual job to represent the beginning. In constraint (80.16), the condition of one job being the post job of itself is not allowed. Constraint (80.17) restricts the post job could begin only when the prior job finished its procession, where M is a large number using to make the constraint to be a linear one.

$$\sum\nolimits_{t=1}^{T} x_{kit} = z_{ki} * p_k + \sum\nolimits_{j=0}^{n} st_{jk} * y_{jki} \quad k \in N, i \in M \tag{80.18}$$

Constraint (80.18) confirms the time length of each job equals to the correspondent processing time, in which, p_k is the processing time of job k, and st_{jk} is the setup time between k follow j.

$$\begin{gathered} \sum\nolimits_{i=1}^{m} \sum\nolimits_{j=1}^{n} x_{jit} * q_{jr} \le o_r \\ t = 1, 2, \ldots, T, \ r = 1, 2, \ldots, s \end{gathered} \tag{80.19}$$

This is the resources constraint, where q_{jr} is the requirement of resource r for processing job j, and o_r is the capacity of resource r.

$$C_{\max} \ge C_j \quad \forall j \in N \tag{80.20}$$

A linear determination of the objective $C_{\max}$ is presented in constraint (80.20).

A numerical case was used to test the feasibility of the MIP. ILOG CPLEX 9.0 (2003) was used to perform the computation and determined that at least 26 time units should be used to process all the jobs. Then a Gantt chart could be drawn based on the solution, shown in Fig. 80.1.

Genetic Algorithm

As problem $P3/res1\ldots, p_j = 1/C_{\max}$ is NP-hard in the strong sense (Blazewicz et al. 1983), problem $Pm/res\ldots, sdst/C_{\max}$ is NP-hard too. For the purpose of finding the optimal or near-optimal solutions in practice, we propose a GA to solve the large-size RSPS in this section. What need to be underlined is, the proposed GA can be easily extended to the RSPS with uniform or unrelated machines, like the MIP proposed in section "Proposed MIP" did.

Representation of Solutions

An adaptive encoding and decoding method of Li et al. (2003) is used here to represent the solutions, illustrated in Fig. 80.2. Each chromosome was comprised by two segments. The first one records a machine id, which is going to process the corresponding job. While the second segment is the priority of each job, the smaller number denotes a higher priority.

From the priority and the machine assignment, we can give out the job sequence on each machine. The decoding method can be described as follows:

Step 1: Initialize three arrays, two of them have one dimension and the last one have several dimensions, depending on the number of the resource types. The first array keeps the available starting time of each machine (initial value is set to 1), the second one saves the last job processed on each machine (initial value is set to 0) and the last array records the available quantity of each resource at each time epoch (initial value is set to the original capacity of the resource).

Step 2: Find out the job having the highest priority, say j, and get its processing time, resources requirement, and corresponding machine id, denoted by p_j, $Q_j = \{q_{j1}, q_{j2}, \ldots, q_{js}\}$, and m respectively.

Step 3: According to the last job processed on machine m (denoted by j'), we can get the corresponding setup time ($st_{j'j}$). Therefore, we have got the total processing time of job j, $pt_j = p_j + st_{j'j}$.

Step 4: From the available starting time of the corresponding machine, check whether the following successive pt_j time units have enough resources for job j. If not, defer the starting time until reaching an epoch t with enough successive pt_j time units of resources capacity. Modify the last job and available starting time of machine m to j and $t + pt_j$, and reduce the resource capacity by Q_j for time epochs from t to $t + pt_j - 1$. Delete j from the job list.

Step 5: Schedule all the jobs, take the largest available starting time among all machines as the value of $C_{\max}$.

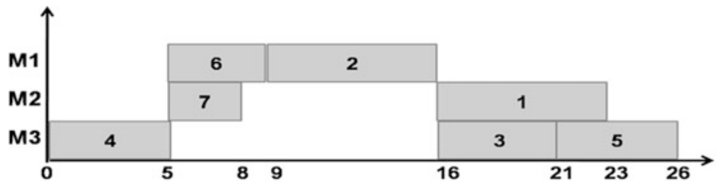


Fig. 80.1 Gantt chart of the numerical case

Fig. 80.2 An example of the chromosome

JOB ID	1	2	3	4	5	6	7
MACHINE	2	1	3	3	3	1	2
PRIORITY	0.494	0.062	0.311	0.036	0.747	0.053	0.796

Fitness Function and Initialization Method

The fitness function transformed the results of chromosomes to fitness values. In this paper, we use a non-linear function, Eq. (80.21). Where a and b are two parameters to determine the selection pressure.

$$f = a * \exp(-b * C_{\max}) \tag{80.21}$$

The first chromosome is initialized by using the longest processing time first (LPT) rule, the job with the longest processing time have the highest priority while the machine is assigned by sequence. For the other chromosomes, machine assignment and job priority is generated randomly according to a uniform distribution in $\{1, 2, \ldots, m\}$ and $(0, 1)$.

Recombination Operators

According to a probability, p_c, the crossover operation repeat several times. In each time, a number of chromosomes (determined by tournament size, t_s) are selected randomly from the population to join a tournament. The best two chromosomes are chosen to perform a one-point crossover operation.

Mutation rate, p_m, decides whether a given gene mutate. For each gene of the chromosomes, we make a comparison between p_m and a randomly generated number from uniform $(0, 1)$. If p_m is larger than that number, an offspring will be generated by replace the corresponding gene with a randomly generated number according to the initialization distribution. The selection operator in this paper is a fitness based "roulette wheel" sampling.

Table 80.1 Factors in small-size

Factors	Level 1	Level 2
Number of jobs (n)	5	7
Number of machines (m)	2	3
Procession time (p)	[5,7]	[2,10]
Setup time (s)	[2,4]	[0,6]
Resources requirement (q)	[1,9]	[4,6]
Resources capacity (c)	5*m*	7.5*m*

Computational Experiments

Two sizes of problems, small-size and large-size, have been conducted to evaluate the performance of GA. Furthermore, some scheduling rules, including LPT (longest procession time first), SPT (shortest procession time first), SST (shortest setup time first) and RND (schedule job randomly) were coded for comparison. In LPT, SPT and SST, the priorities were generated according to the rule. For example, the job with the longest processing time had the highest priority in LPT. And the machine assignment was produced by sequence. As for the RND, job priorities and machine assignment was both generated randomly according to the initialization distribution.

In the small-size problem, 6 factors were used to generate the test cases, shown in Table 80.1. The procession time, setup time and resources requirement in each level were all generated from the correspondent discrete uniform distribution. Resources capacity had two levels: the tight level, equals to 5 times of *m*, and the slack level, equals to 7.5 times of *m*. Therefore we have a total of 64 small-size test cases. The number of resources type in all cases was set to 3.

Computational experiences were taken on a Core I3 CPU 2.4 GHz computer with 2 GB of RAM. GA and scheduling rules were all coded in Visual C++ 6.0. DOE was used to determine the parameters of GA. After a series of exhaustive computational experiments, we set the population size, a, b, t_s, p_c and p_m as 50, 1000, 0.15, 10, 0.95 and 0.15. Each case was computed 50 times by GA. Owing to space constraints, we only present results for case 5J2M (case with 5 jobs 2 machines) and 7J3M (case with 7 jobs 3 machines) in Tables 80.2 and 80.3, where B&B denotes the solution found by commercial software.

Then we generated 16 large-size cases. Where we have 100 jobs to be processed on 5 machines and require 5 types of resources. Resources requirement and capacity were the same as that in Table 80.1. Two levels of procession time were generated from discrete uniform distribution [2,30] and [13,19], while two levels of setup time from discrete uniform distribution [0,20] and Kellerer and Strusevich (2003) and Wu et al. (2012). Each case was computed ten times by GA. Results was shown in Table 80.4.

Computational results showed that GA can find out the optimal solutions in small-size cases and outperformed the rules in all of the cases. Moreover, we can get the improvement percentage from the average of GA to the best of other

Table 80.2 Results of case 5J2M

		GA						
id	B&B	Best	av.	Worst	LPT	SPT	SST	RND
1	32	32	32	32	35	37	39	44
2	27	27	27	27	37	37	30	38
3	37	37	37	37	51	53	43	42
4	21	21	21	21	23	25	28	31
5	32	32	32	32	36	38	45	46
6	26	26	26	26	29	29	28	50
7	20	20	20	20	33	26	32	36
8	20	20	20	20	24	21	23	26
9	29	29	29	29	33	31	35	42
10	23	23	23.1	24	27	29	27	34
11	24	24	24.24	25	31	33	38	29
12	18	18	18	18	25	22	25	19
13	29	29	29	29	32	34	32	41
14	24	24	24	24	28	28	35	51
15	32	32	32	32	40	38	44	49
16	18	18	18	18	27	27	32	24

Table 80.3 Results of case 7J3M

		GA						
id	B&B	Best	av.	Worst	LPT	SPT	SST	RND
1	31	31	31.6	32	35	37	39	45
2	23	23	23.04	24	28	26	28	29
3	21	21	22.02	23	28	36	30	35
4	19	19	19.66	20	27	22	26	29
5	30	30	30.02	31	33	35	34	34
6	22	22	22	22	27	28	25	25
7	22	22	22.42	23	29	32	34	52
8	19	19	19	19	27	24	28	38
9	31	31	31	31	41	41	38	50
10	21	21	21.12	22	29	30	23	40
11	20	20	20.38	22	29	30	29	38
12	16	16	16.88	18	21	28	30	32
13	19	19	19.74	21	27	27	28	36
14	19	19	19.26	21	29	24	22	26
15	22	22	22.5	25	34	34	33	50
16	17	17	17.42	19	24	21	24	29

heuristics for each level (12.02% in 5J2M, 12.13% in 5J3M, 15.75% in 7J2M, 17.61% in 7J2M and 19.58% in 100J5M). Obviously, the improvement was larger as the problem size increased. As for the time consuming, GA consumed average 488 s for 100J5M, which is acceptable in practice.

Table 80.4 Results of case 100J5M

id	GA Best	av.	Worst	LPT	SPT	SST	RND
1	474	491.4	512	722	757	760	769
2	355	361.2	370	559	547	592	585
3	606	613.6	618	716	733	727	723
4	513	514.6	517	559	570	564	637
5	447	460.4	472	644	668	683	693
6	385	391.2	396	553	579	580	723
7	573	579.4	586	638	641	635	722
8	492	493.2	495	533	536	566	664
9	526	543.2	558	763	757	789	826
10	373	383.2	389	559	582	581	630
11	619	630.2	645	732	766	763	783
12	497	499.5	503	532	549	541	655
13	443	454.3	470	668	635	673	759
14	362	370.8	380	529	512	557	554
15	580	584.8	593	634	650	641	726
16	498	498.6	499	535	537	537	725

Conclusions

We studied the parallel machine scheduling problem with multiple resources constraint and sequence dependent setup times in this paper, taking the objective of minimizing makespan. A mixed integer programming model was proposed and commercial software was used to obtain the optimal solution. Then we coded a GA and some other heuristics in Visual C++ 6.0 to solve the problems in practice. Computational experiences showed the proposed GA outperformed the other heuristics and can solve the large-size problem effectively and efficiently in reasonable time. Furthermore, the MIP and GA proposed in this paper can be easily extended to the RSPS with uniform or unrelated parallel machines too. Future researches may be extended to the parallel batch processing machines or dedicated machines. It is also worthwhile to consider some other objectives, for example, the total number of tardy jobs.

Acknowledgments This research was supported by National Natural Science Foundation of China (70901064/G010301), Program for New Century Excellent Talents in University (NCET-11-0709) and Fundamental Research Funds for the Central Universities (SWJTU12CX002).

References

Blazewicz J, Lenstra JK, Rinnooy Kan AHG (1983) Scheduling subject to resource constraints: classification and complexity. Discrete Appl Math 5(1):11–24

Chan FTS, Wong TC, Chan LY (2006) Flexible job-shop scheduling problem under resource constraints. Int J Pro Res 44(11):2071–2089

Chen JF (2005) Unrelated parallel machine scheduling with secondary resource constraints. Int J Adv Manuf Technol 26(3):285–292

Chen CL, Chen CL (2009) Hybrid meta-heuristics for unrelated parallel machine scheduling with sequence dependent setup times. Int J Adv Manuf Technol 43:161–169

Chen TR, Hsia TC (1994) Job shop scheduling with multiple resources and an application to a semiconductor testing facility. In: Proceedings of the 33rd IEEE conference on decision and control, Lake Buena Vista, FL, IEEE Press, Los Alamios, pp 1564–1570

Chen TR, Chang TS, Chen CW, Kao J (1995) Scheduling for IC sort and test with preemptiveness via Lagrangian relaxation. IEEE Trans Syst Man Cybern 25(8):1249–1256

Edis EB, Oguz C (2011) Parallel machine scheduling with additional resources: a lagrangian-based constraint programming approach. In: Achterberg T, Beck JC (eds) CPAIOR, LNCS 6697, Berlin, Germany. Springer, Berlin/Heidelberg, pp 92–98

ILOG Inc. ILOG CPLEX 9.0 user manual (2003)

Kellerer H, Strusevich VA (2003) Scheduling problems for parallel dedicated machines under multiple resource constraints. Discrete Appl Math 133(1–3):45–68

Kempf KG, Uzsoy R, Wang CS (1998) Scheduling a single batch processing machine with secondary resource constraints. J Manuf Syst 17(1):37–51

Li Y, Wang F, Lim A (2003) Resource constraints machine scheduling: a genetic algorithm approach. In: The 2003 congress on evolutionary computation. IEEE Press, Los Alamios, pp 1080–1085

Tamaki H, Hasegawa Y, Kozasa J, Araki M (1993) Application of search methods to scheduling problem in plastics forming plant: a binary representation approach. In: Proceedings of the 32nd IEEE conference on decision and control. San Antonlo, Texas. IEEE Press, Los Alamios, pp 3845–3850

Tavakkoli-Moghaddam R, Taheri F, Bazzazi M, Izadi M, Sassani F (2009) Design of a genetic algorithm for bi-objective unrelated parallel machines scheduling with sequence-dependent setup times and precedence constraints. Comput Oper Res 36(12):3224–3230

Vallada E, Ruiz R (2011) A genetic algorithm for the unrelated parallel machine scheduling problem with sequence dependent setup times. Eur J Oper Res 211:612–622

Ventura JA, Kim D (2003) Parallel machine scheduling with earliness–tardiness penalties and additional resource constraints. Comput Oper Res 30(13):1945–1958

Wu JZ, Chien CF (2008) Modeling semiconductor testing job scheduling and dynamic testing machine configuration. Expert Syst Appl 35:485–496

Wu JZ, Hao XC, Chien CF (2012) A novel bi-vector encoding genetic algorithm for the simultaneous multiple resources scheduling problem. J Intell Manuf 23(6):2255–2270

Chapter 81
Exploring the Relationship Among the Enterprise Operation Ability, Profitability and Development Ability

Tong Liu and Ya-juan Han

Abstract The paper explores the relationships among enterprise operation ability, profitability and development ability by applying cluster analysis and canonical correlation methods which are performed on a dataset of 30 listed household electrical appliance enterprises. The study shows that enterprise profitability and development ability are affected by operation ability, and assets turnover should be focused. Besides, the relationship between enterprise profitability and development ability is not apparent. In other words, not only profitability should be focused, but also do think about the enterprise development ability.

Keywords Cluster analysis • Canonical correlation • Development ability • Enterprise competitiveness • Operation ability • Profitability

Introduction

The enterprise competitiveness is such ability that in a competitive market, an enterprise can provide more effective products or services than other companies and make profitability and self-development (Porter 1985; Zhang et al. 2003). How to evaluate the enterprise competitiveness effectively, many scholars made positive explorations. Chen and Chen believed that the evaluation of the enterprise competitiveness had a fuzzy character, and adopted fuzzy comprehensive evaluation (FCE) to make a quantitative evaluation and construct an index system (Chen and Zhang 1999; Chen 2005). Liu and Zong applied the data envelopment analysis (DEA) to study the enterprise competitiveness (Liu 2001; Zong et al. 2002). Yin and Zhang brought the factor analysis into the evaluation of the enterprise competitiveness by extracting common factors to eliminate multicollinearity and using the model of

T. Liu (✉) • Y.-j. Han
Department of Management Science and Engineering, Shanghai University, Shanghai, China
e-mail: bruce_shu@yeah.net

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_81,

factor scores to make a comprehensive evaluation (Yin and Liu 2004; Zhang et al. 2006). Analytic hierarchy process (AHP) was applied to evaluate the index system of enterprise core competitiveness by Yin et al. (2007). Considering the correlation between indexes, Guo used the analytic network process (ANP) to set up an enterprise soft power evaluation model (Guo and Liang 2008). Zhang investigated the dynamic relationship between the enterprise ability and competitiveness by analyzing the external environment and business processes (Zhang et al. 2011). Sun adopted PCA-PINMAP to calculate the index weights, and set up an enterprise competitiveness evaluation model by using TOPSIS method (Sun et al. 2011). According to the study of the above literatures, we find that many scholars focused on a comprehensive evaluation research, however, few researches focused on the study of the different components of the internal interaction about the enterprise competitiveness. The paper attempts to use cluster analysis and canonical correlation methods to solve this problem.

Enterprise Operation Ability, Profitability and Development Ability

Establishing the Enterprise Competitiveness Evaluation System

The current evaluation of the enterprise competitiveness can be summarized into two dimensions in academia: the market dimension and the internal resources dimension. The competitiveness of the internal resources is the basis for the formation of the market competitiveness and the market competitiveness is the external extension of the internal resources competitiveness. More specifically, the key indexes to measure the internal resources competitiveness are: receivable turnover, inventory turnover, total assets turnover, current asset turnover. The indexes to measure the market competitiveness are: main business profit margins, ratio of profits to cost, return on equity (ROE), sales growth rate of major operation, net asset growth rate, total asset growth rate, see Table 81.1.

Cluster Analysis and Results

According to the similarity between each variable, cluster analysis classifies these variables into several variates which represent a mathematical representation of the selected set of variables. Specifically, by defining the distance or similarity coefficient between the variables, some variables will be gathered into one group, and the other variables will be gathered into another group. The final result shows that different groups exhibit high heterogeneity and on the contrary the internal variables in the same group exhibit high homogeneity (He 2007; Gao 2005).

Table 81.1 Index variables and computing methods

	Index variables	Index variables names	Computing methods
Internal resources competitiveness	X_1	Receivable turnover (times)	Main business net income/Accounts receivable average balance
	X_2	Inventory turnover (times)	Operating costs/Inventory
	X_3	Total assets turnover (times)	Main business net income/Total assets
	X_4	Current asset turnover (times)	Main business net income/Average balance of current assets
Market competitiveness	X_5	Main business profit margins (%)	Profit from main operation/ Main business net income
	X_6	Ratio of profits to cost (%)	Total profit/Total cost
	X_7	Return on equity, ROE (%)	Net profit/Net asset
	X_8	Sales growth rate of major operation (%)	Main business revenue growth/ The previous period main business income
	X_9	Net asset growth rate (%)	This net total asset/The previous period net total asset
	X_{10}	Total asset growth rate (%)	Total asset growth/Total assets of early

Generally, we define C_{ij} as similarity coefficient between variable X_{i} and X_{j}, the cosine formula can be defined as below:

$$c_{ij}(1)=\frac{\sum\limits_{k=1}^{n}x_{ki}x_{kj}}{\sqrt{\sum\limits_{k=1}^{n}{x_{ki}}^2\sum\limits_{k=1}^{n}{x_{kj}}^2}} \tag{81.1}$$

Similarity coefficient was defined as:

$$c_{ij}(2)=\frac{\sum\limits_{k=1}^{n}(x_{ki}-\overline{x}_i)(x_{kj}-\overline{x}_j)}{\sqrt{\sum\limits_{k=1}^{n}(x_{ki}-\overline{x}_i)^2\sum\limits_{k=1}^{n}(x_{kj}-\overline{x}_j)^2}} \tag{81.2}$$

Random samples of 30 enterprises were obtained from the listed household electrical appliance enterprises of Shanghai and Shenzhen which chosen from each

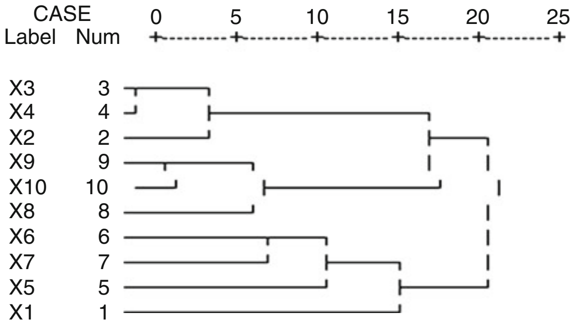


Fig. 81.1 Dendrogram chart

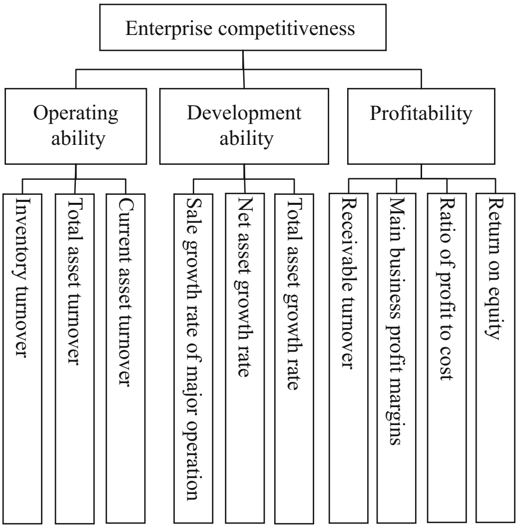


Fig. 81.2 Indexes classification

company's 2010 annual report. After data collected, we used the statistical software SPSS 13.0 to analyze and interpret, the results were showed in Fig. 81.1.

According to the dendrogram chart, the variables can be classified into three groups: the first group contains inventory turnover X_2, total assets turnover X_3 and current asset turnover X_4; the sales growth rate of major operation X_8, net asset growth rate X_9 and total asset growth rate X_{10} constitute the second group, and the third group is composed by receivable turnover X_1, main business profit margins X_5, ratio of profits to cost X_6, return on equity X_7.

These three variates represent the enterprise operating ability, development ability and profitability respectively, actually, the result further proves the rationality of our actual classification. See Fig. 81.2.

Table 81.2 Dimension reduction test

	Wilk's	Chi-SQ	DF	Sig.
1	0.404	22.639	12.000	0.031
2	0.714	8.429	6.000	0.208
3	0.985	0.370	2.000	0.381

Canonical Correlations of the Three Variants

Canonical correlation analysis is a multivariate statistical model that facilitates the study of linear interrelationships between two sets of variables (Hair et al. 2011). Specifically, applying the method of principal component analysis (PCA), we research the correlations of linear composites of two sets of variables. Key terms are used as follows:

1. Canonical correlation coefficient, RC_n
2. Canonical roots, CR_n
3. Canonical weights
4. Canonical loadings, L
5. Shared variance, SV
6. Redundancy index, RI

Correlation Analysis of Operation Ability and Profitability

According to the dimension reduction test, it indicates that the level of model significance is within the 0.1 level, the first canonical function is accepted, therefore, we only analyze the first canonical function, see Table 81.2.

The overall result provides a canonical correlation of 0.658,which provides an estimate of the strength of the relationship between enterprise operation ability and profitability. The amount of shared variance between the canonical variants is 0.433. Redundancy analysis shows that 78.2% of shared variance explained by canonical variants of independent, 7.8% of shared variance explaining the dependent variables. On the other hand, the canonical variate for profitability explains 18.1% of its own shared variance and accounts for 33.9% of its opposite variate for operation ability. The results show that enterprise profitability is mainly affected by operation ability.

The first canonical variate U_1, V_1 is:

$$U_1 = -0.099X_2 + 0.316X_3 + 0.778X_4$$
$$V_1 = -0.103X_1 - 0.113X_5 - 0.62X_6 + 1.279X_7$$

As is discussed earlier, canonical weights may explain the meaning of canonical variate. The first canonical variate mainly stands for current asset turnover, and the

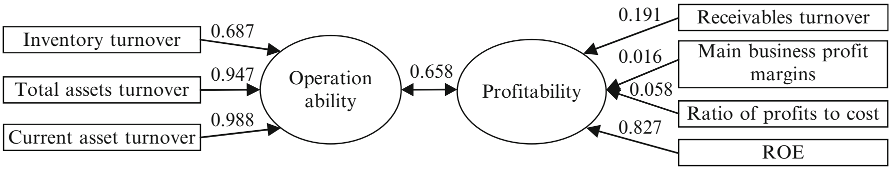


Fig. 81.3 Canonical correlation between operation ability and profitability

Table 81.3 Dimension reduction test

	Wilk's	Chi-SQ	DF	Sig.
1	0.544	15.510	9.000	0.078
2	0.826	4.874	4.000	0.3
3	0.978	0.554	1.000	0.457

second canonical variate mainly stands for ratio of profits to cost and ROE, but the effect of ratio of profits to cost is positive.

The canonical correlation between operation ability and profitability is referred to Fig. 81.3.

The first canonical variate is characterized by total assets turnover and current asset turnover, and the second canonical variate is characterized by ROE.

Correlation Analysis of Operation Ability and Development Ability

Examining Table 81.3, we find that the level of model significance is within the 0.1 level, the first canonical function is accepted, and therefore, to test correlation between operation ability and development ability, we only analyze the first canonical function.

The diagnostic statistics show that canonical correlation of the first function is 0.584 and the canonical roots is 0.341, which provides the amount of shared variance in the canonical variates is 34.1%. Redundancy analysis indicates that proportion of variance of independent explained by its own variate is 68 and 16.9% shared variance explaining the opposite variables. On the other hand, the canonical variate for development ability explains 49.5% of its own shared variance and accounts for 23.2% of the opposite variate of operation ability. The results show that development ability is mainly affected by operation ability.

The first canonical variate U_1, W_1 is

$$U_1 = -0.058X_2 - 1.311X_3 + 0.407X_4$$
$$W_1 = -1.101X_8 + 0.183X_9 + 0.033X_{10}$$

According to the value of variables, we find that the canonical weight of total assets turnover is higher than others, so the first canonical variate mainly stands for

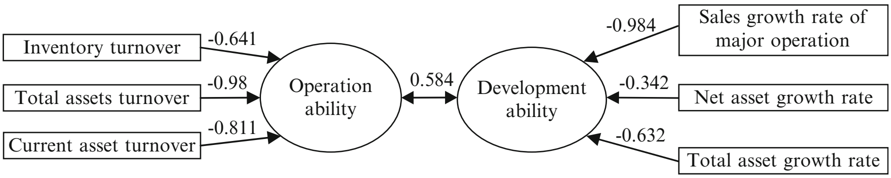


Fig. 81.4 Canonical correlation between operation ability and development ability

Table 81.4 Dimension reduction test

	Wilk's	Chi-SQ	DF	Sig.
1	0.576	13.773	12.000	0.315
2	0.881	3.161	6.000	0.788
3	0.984	0.413	2.000	0.814

Table 81.5 Redundancy analysis of profitability and development ability

Proportion of variance of explained by its own Can. Var.	
SV_1	0.197
SV_2	0.134
Proportion of variance explained by opposite Can. Var.	
$RI_{V_1:U_1}$	0.068
$RI_{U_1:V_1}$	0.041

total assets turnover, conversely, the second canonical variate mainly stands for sales growth rate of major operation.

The canonical correlation between operation ability and development ability is referred to Fig. 81.4.

The first function is between the variate of independent variables characterized by Total assets turnover and current assent turnover and the variate of dependent variables characterized by sales growth rate of major operations.

Correlation Analysis of Profitability and Development Ability

According to the dimension reduction test, Table 81.4, we find that all canonical correlation coefficient of profitability and development ability is not significant, so it is not suitable to make canonical correlation analysis. However, it is considered that the difference between statistic and realistic significance may be existed, meanwhile, the canonical correlation coefficient of the first canonical variate is 0.588, and therefore, we only further analyze the first canonical function.

In order to explore the predictive ability of the first canonical variate and the second canonical variate, the result of redundancy analysis of profitability and development ability is referred to Table 81.5.

Redundancy analysis shows that the first canonical variate shared variance is 0.197 and redundancy index is 0.041, and the second canonical variate shared variance is 0.134 and redundancy index is 0.068. It is indicated that the relationship between enterprise profitability and development ability is not apparent.

Conclusions

The goal of the paper is to empirically study the relationship among enterprise operation ability, profitability and development ability by applying cluster analysis and canonical correlation methods. The study shows that enterprise profitability and development ability is affected by operation ability, and assets turnover should be focused. Besides, the relationship between enterprise profitability and development ability is not apparent. Actually, it is not difficult to understand this conclusion, due to products in short supply, some company short-term profits may be very strong, however, in a long term, because of lacking competitive advantage, such as well-known brand or product innovation, which leads to scarceness of development ability. In other words, not only profitability should be focused, but also do think about the enterprise development ability.

Besides considering enterprise internal resources competitiveness and market competitiveness, industrial structure is another important area requiring attention. In view of this, future research needs to consider the empirical relationship based on the three aspects.

References

Chen JB (2005) Fuzzy comprehensive evaluation of competence of enterprise's competition (in Chinese). Econ Manage 19(6):43–45

Chen MS, Zhang ZT (1999) Applying FCE to explore business competing ability (in Chinese). J Quant Tech Econ 16(1):56–58

Gao HX (2005) Applied multivariate analysis. Perking University Press, Beijing, pp 343–365

Guo D, Liang QH (2008) Research on evaluation system of enterprise's soft power based on ANP (in Chinese). Sci Sci Manage S&T 29(7):184–188

Hair JF Jr, Black WC, Babin BJ, Anderson RE (2011) Multivariate data analysis. China Machine Press, Beijing, pp 235–259

He XQ (2007) Modern statistical method and application. Renmin University of China Press, Beijing, pp 395–408

Liu MF (2001) Application of DEA in evaluating business competing ability (in Chinese). J Jiangxi Univ Financ Econ 16(2):34–35

Porter ME (1985) Competitive advantage. Simon & Schuster Press, New York

Sun H, Sun XP, Fan ZQ (2011) An evaluation and empirical study on competitiveness of civil engineering construction enterprises in Shanghai stock market (in Chinese). Sci Technol Prog Pol 28(13):102–106

Yin ZM, Liu WC (2004) Application of factor analysis in evaluating of business competing ability (in Chinese). Appl Stat Manage 23(3):29–32

Yin HY, Gao P, Deng JC (2007) Research on evaluation system of firm core competitiveness about China's household electrical companies (in Chinese). Manage Rev 19(2):8–14
Zhang XW, Yu W, Hu YQ (2003) A quantitative evaluation method for enterprise competitive capacity (in Chinese). Manage Rev 15(1):32–37
Zhang R, Li E, Tian P (2006) Application of factor analysis method to the evaluation model of corporation competence (in Chinese). Ind Eng Manage 11(3):6–10
Zhang XN, Zhong QY, Mai S (2011) Research on dynamic relationship between enterprise ability and competitiveness (in Chinese). Sci Technol Prog Pol 28(17):72–76
Zong Z, Ma N (2002) Applying DEA to assess industrial enterprise competitiveness (in Chinese). J Quant Tech Econ 19(11):92–95

Chapter 82
Algorithm for Solving the Complicated Maximum Flow in Networks Based on the Interrelationship Tables

Xu-ying Zhu, Kai-hu Hou, Jin-yuan Zhong, and Lin Yang

Abstract In this paper, we focused on the weighted networks system balance relationship between supply and demand to solve the network maximum flow problem under giant complicated environment. A heuristic solution method was proposed which was based on the interrelationship tables. The data was stored in the interrelationship tables according to the method which was defined and discussed on the model whose main part was list structure. The algorithm calculating showed a high efficiency in the condition of many disturbed factors were included while analyzing weighted networks. This algorithm was effectively proved by designed calculating examples. It could improve the visual degree of inherent relationship network and show superiority on solving complex network problems. This algorithm can supply model structure and operating basis on the aspect of solving maximum flow problems with the help of a computer. And it can also expand the researching methods of intelligent network system.

Keywords Heuristic algorithm • Maximum flow • Mutual relationship tables • Weighted networks

Introduction

As we know, many systems include some discharge problems (Yan 2007). For example, the vehicle flow in system in the highway system, the information flow in the control system, the water current in the water supply system and the cash flow in the financial system ,etc. The maximum flow problem requires the maximum flows of logistics, energy flow and information flow in the network.

X.-y. Zhu • K.-h. Hou (✉) • J.-y. Zhong • L. Yang
Department of Industrial Engineering, Kunming University of Science and Technology, Kunming, China
e-mail: 975017746@qq.com; kaihu_kmustie@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_82,

The maximum flow problems have a research history of more than 40 years. During this period, some maximum flow problem theories were established, and a great deal of algorithm were developed as well. They were as follows: Ford & Fulkson increasing track algorithm (Qiao et al. 2005), Dinic Jam flow algorithm, Goldberg heavy label method (Wang et al. 2005; Chen and Li 2005) and two length jams flow method establishing by Goldberg and Rao (1998). These classic algorithm and relevant technology on this problem makes a great contribution to developing the maximum network.

In recent years, with the rapid development of computer techniques in the whole world, more and more people pay attention to the network maximum flow problem and carry on an in-depth research. These studies lead to a great progress in solving the maximum flow problem (Yu and Liu 2003). However, the research work is still far from over. First of all, in the theoretical algorithm study field, people still cannot find the lower bound of the accurate time complexity to the maximum flow problem, or any general algorithm which can achieve the goal or make a closer to the lower bound of the problem (Yongfa Ling 2006). Secondly, the actual function of the algorithm cannot meet the requirements of many application problems and solve giant network system Song et al. (2009) for a computer, either. So it is hard to provide an operation storage model for a maximum flow of operation (Zhang 2004). In order to make a solution on the problems above, we could study the network maximum flow problems based on mutual relation table storage model. Through finding out a unified operation standard, we can carry on checking and seeking operations in procedure and manifest the internal relations of this problem. As a result, the solution method on the network problems was proposed under the giant and complicated circumstance.

Questions

In the large-scale and complicated network diagram, it owns a lot of nodes number and exists uncertain direction in each path. Drawing up a unified standard of these paths can make them more orderly, so that the search rate and computing time were improved. How to improve the flow visualization degree in complex situation? And how to search for the maximum flow model with computer and provide the basis. According to the problems discussed above, this paper provides a kind of heuristic algorithm which utilize mutual relation tables to solve network maximum flow, and the weight coefficient of relevant network maximum flow issues are discussed.

The Definition of the Models

1. P2P (Chen et al. 2005): P2P is short for English peer-to-peer (peer), also known as the “point to point”. It is a point-to-point mutual exchange model. Through the relationship between nodes it achieves resource sharing services and work mode.

2. Network (Weizhen Li and Yingai Gan 2005): Giving a directed graph D = (V, A), one point in the V is designated as the starting point (Vs), while another point is known as the closing point (Vt), the remaining points are the middle points. For each arc (Vi, Vj) ∈A, there is a corresponding C (Vi, Vj) ≥ 0 (or abbreviated as Cij), known as the capacity of the arc. Usually we take such D called network. Remember as D = (V, A, C).
3. The flow on the network: it is defined in the arc set A on a function f = {f(Vi, Vj)}, saying f(Vi, Vj) for arc (Vi, Vj) the flow (sometimes also simply being denoted by fij).
4. Feasible flow (Haichao wang 2001): what meet the following conditions of flow f is called a feasible flow:

   ① Capacity constraints: for each arc (Vi, Vj) ∈ A, 0 ≤ fij ≤ cij
   ② Equilibrium conditions: For the mid-points: the outflow is equal to the inflows that each i (i ≠ s, t)

   $\sum\limits_{(\mathrm{V_i}-V_j)\in A} \mathrm{f_{ij}}-\sum\limits_{(V_j-V_i)\in A} f_{ji}=0$; For the starting point Vs, remember $\sum\limits_{(\mathrm{V_s}-V_j)\in A} \mathrm{f_{sj}}-\sum\limits_{(V_j-V_s)\in A} f_{js}=V(f)$; closing point Vt remember $\sum\limits_{(\mathrm{V_i}-V_j)\in A} \mathrm{f_{ij}}-\sum\limits_{(V_j-V_t)\in A} f_{jt}=-V(f)$ which V(f) is called a feasible flow of traffic, namely the net output of the starting point (or net input of the closing point).

5. The maximum flow: is asking a flow {fij} to make its flow V(f) the maximum and meet:

$$0 \le fij \le Cij \quad (Vt,\ Vj) \in \mathrm{A} \tag{82.1}$$

$$\sum f_{ij} - \sum f_{ji} = \begin{cases} V(f) \Rightarrow & (i = s) \\ 0 \Rightarrow & (i \ne s, t) \\ -V(f) \Rightarrow & (i = t) \end{cases} \tag{82.2}$$

6. The maximum flow problem: for a group of {fij}, V(f) reaches a maximum, while meeting the conditions of (82.1) and (82.2).
7. Flow table: To be able to simply represent the interaction between the size of the flow in all operating points, we modeled the flow from one to the table structure and constructed an operation unit (point) between the interrelationship tables.
8. The directional regulations of flow related table

   ① From the upper left to the lower right for the X direction; from lower left to the upper right for the Y direction. Vested on the X direction, x_s, x_1, x_2. And so on, on the Y direction, y_t, y_1, y_2, and so on. Every Space in the mutual relation table has its own coordinates.

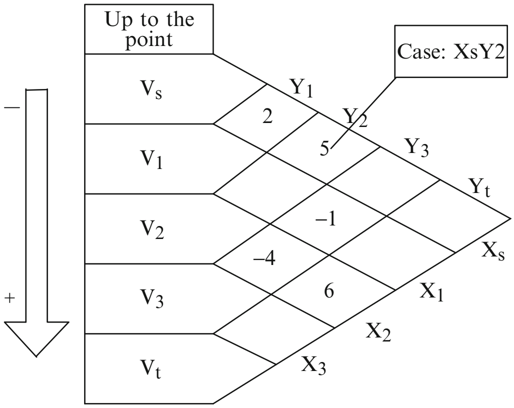


Fig. 82.1 Interrelationship the number of table

② From top to bottom all the points generated positive flow, otherwise negative.
As shown in the Fig. 82.1: the number of $x_s y_2$ is 5, and it means the flow produced from $V_s \rightarrow V_2$ is 5. Whereas the output discharge from $V_2 \rightarrow V_s$ is 5, then at $x_s y_2$ the value is (-5).

(a) $x_s y_1$ is 2, meaning the flow from $V_s \rightarrow V_1$ is 2
(b) $x_s y_2$ is 5, meaning the flow from $V_s \rightarrow V_2$ is 5
(c) $x_1 y_3$ is -1, meaning the flow from $V_3 \rightarrow V_1$ is 1
(d) $x_2 y_3$ is -4, meaning the flow from $V_3 \rightarrow V_2$ is 4
(e) $x_2 y_t$ is 6, meaning the flow from $V_2 \rightarrow V_t$ is 6

Building Up Biggest Flow Model with Mutual Relation Table and Generally Solving Process

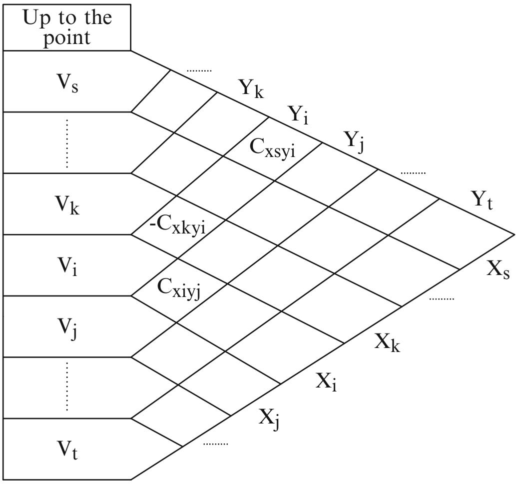
Crunodes Storage Structure

In order to ensure that the original date population and the structure remains the same, this paper put forward a kind of crunodes storage model with heuristic mutual connection structure. Its core thought is: begin with generating a crunode mutual relation table, then solve a routing table structure and do a routing process.

General Solution Process

1. From Fig. 82.2 we can know that the relationship between network diagram and correlation form has the only correspondence determined.

Fig. 82.2 Interrelationship tables



2. Settlement steps:

① Beginning with the starting point Vs, in its line of x_s finding out any C$x_s y_i$ (the value of every point on the line of x_s is respectively positive), then along with C$x_s y_i$'s line of y_i, go to below, and arrive at Vi.

② Again since Vi, along with its line of x_i, go in and find out one positive C$x_i y_j$ (as well along with its line of y_i go in and find out one negative C$x_k y_i$), then go along downward C$x_i y_j$'s line of y_j, and arrive at Vj. (as well go along C$x_k y_i$ 'line of x_k upward, arrive Vk).

③ Thus constantly moving, until it reaches the end point Vt.

④ So we got a thoroughfare like this, using minimum C$x_i y_j$ of this thoroughfare as a basic discharge. Make all flux C on this thoroughfare subtract the basic discharge, and use the new value cover on this path all the traffic, then get a new correlation form.

⑤ Repeat above four steps, until we can not look for any other thoroughfares, stop. Add all basic values, and then get the biggest flow of this network diagram.

Solutions of the Feasibility Analysis and Proof

1. There is one to one relationship between Network diagram and the interrelationship table.
2. The flow and direction of each path on the network diagram have a direct reflection on the crunodes of correlation form. (Namely how many current fluxes there, then how many crunodes values in the correlation form?)

3. Proof the only existence of F_{max}.
   Establish F*being the biggest discharge, so there is thoroughfare in the correlation form of A, make $f_{(c)}$ A's basic discharge. Because $f_{(c)} > 0, f_{(c)}$ + F* > F*. This will have a contradiction with the assumption F* is the biggest discharge.

Data Flow Analysis

A control flow graph (Wu 2010) can be used to make sure which parts may be spread with each variable assignment. The information is used by compiler to Optimize program. The data flow analysis try to acquire every bit of particular information in the procedure. Usually, in the basic block within the limits of can get the information, because it's easy to calculate the basic piece of information. In the forward flow analysis (Markus 2002), the end state of a piece is the function of the start state. The data flow analysis is shown in Fig. 82.3.

$$\min \mathrm{f}_1 = \min\left[\mathrm{C}x_s y_i, \mathrm{C}x_\mathrm{i} y_\mathrm{j} \text{ or } |-\mathrm{C}x_\mathrm{k} y_\mathrm{i}|\ldots\ldots\right] \tag{82.3}$$

$$\max \mathrm{F} = \min \mathrm{f}_1 + \min \mathrm{f}_2 + \min \mathrm{f}_3 + \ldots.. + \min \mathrm{f}_\mathrm{n} = \sum \mathrm{Min\ f}_\mathrm{i} \tag{82.4}$$

The Discussion About Network Maximum Flow Problem with Related to Weight Coefficient (*Wi*)

Using the Whole Layout Thought Gives Corresponding the Weight Coefficient Wi to the Network Path

The weight coefficient (Dalu zhang et al. 2009) shows a index sign item's important degree in the system, it means that under the circumstance of other invariable indexes, the influence of the results can be incurred the change of the index. The magnitude of the weight coefficient is related with the important degree of target. For the different path attribute, the important degree of each index sign item is different, so the weight coefficient of each index sign item should be made reasonable rules according to the actual circumstance, as illustrated in Fig. 82.4.

Data Flow Analysis About Mutual Relation Table with the Weight Coefficient

In the selection of its data flow rules, we use to determine that in accordance with the weighting coefficient for data flow of each short burst. Intercept each of data

Fig. 82.3 Data flow diagram

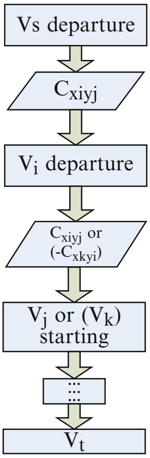
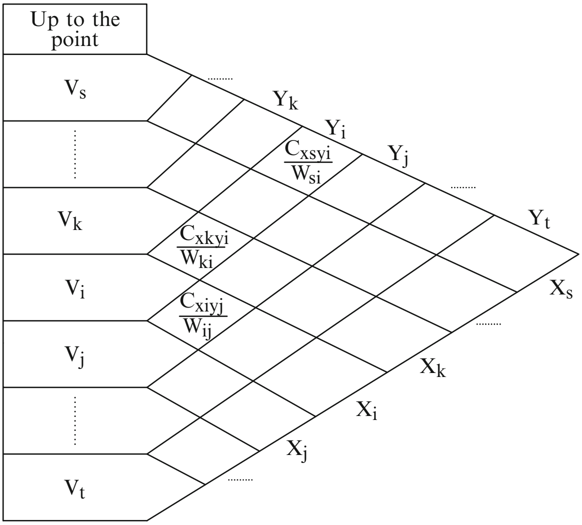
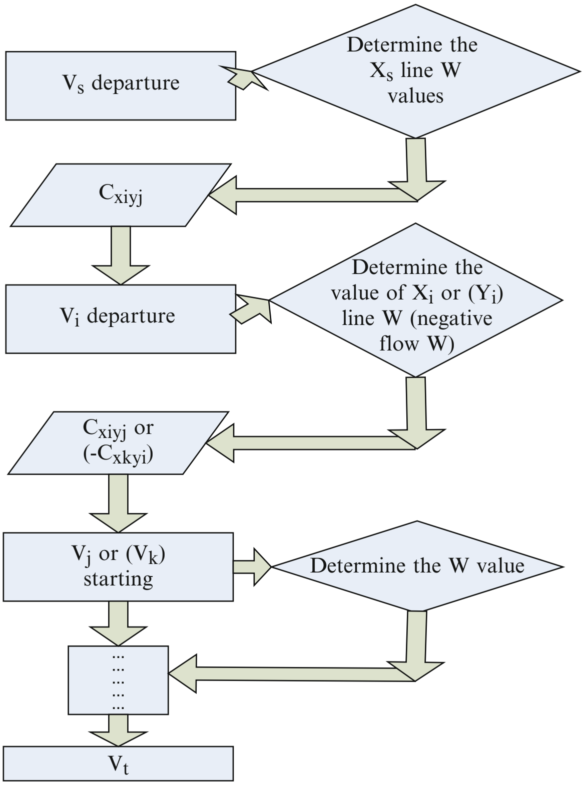


Fig. 82.4 Interrelationship tables



node, determine the weighting coefficient where attainable direction of the node to decide flow direction of the data. Decision in the every up to node every step of the data flow has its basis. So continue to arrive in accordance with the rules and determine, like this you can get an optimal data flow (shown in Fig. 82.5). Unified the optimal data flow which in the entire system that the composition of solution set of the optimal data flow.

Fig. 82.5 With the right to coefficient data stream



Practical Example

Example: As shown in the Fig. 82.6 for the network biggest flow.
Solve:

1. Turn the Network biggest flow diagram into correlation form (such as Fig. 82.7).
2. Set out from the Vs, select point $x_s y_1$; Set out from the V1 again, select point $x_1 y_3$; Set out from the V3 again, select point $x_3 y_t$, arrive at the end point Vt. Namely we get a path: Vs $\rightarrow$ V1 $\rightarrow$ V3 $\rightarrow$ Vt
   Do some Analysis and comparison, take min $(x_s y_1, x_1 y_3, x_3 y_t) = \min(5,2,2) = 2$.
   $\therefore$The minimum discharge of its path is 2, all nodes in the line subtract 2, after that we use the new value cover original form and get new correlation coefficient table 8. It is shown in Fig. 82.8.
3. Set out from the Vs, select point $x_s y_2$; Set out from the V2 again, selection point $x_2 y_4$; Set out from the V5 again, selection point $x_4 y_t$, arrive at the endpoint Vt terminate. Namely get a path: Vs $\rightarrow$ V2 $\rightarrow$ V4 $\rightarrow$ Vt
   Do some Analysis and comparison, take min $(x_s y_2, x_2 y_4, x_4 y_t) = \min(3,4,5) = 3$

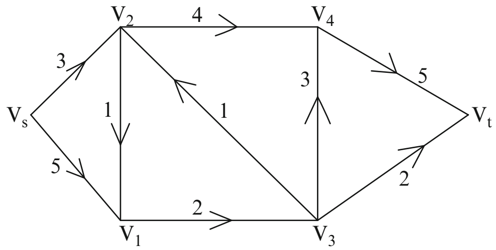


Fig. 82.6 Network diagram

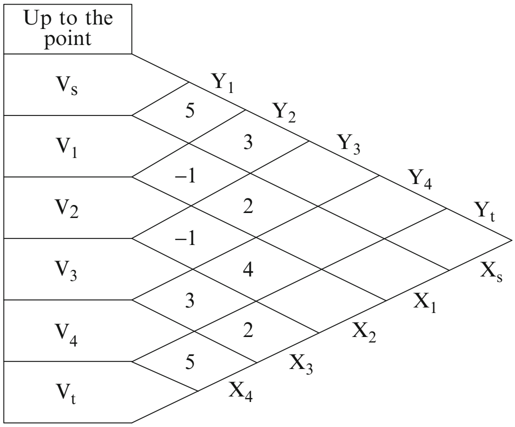


Fig. 82.7 Mutual relational tables 1

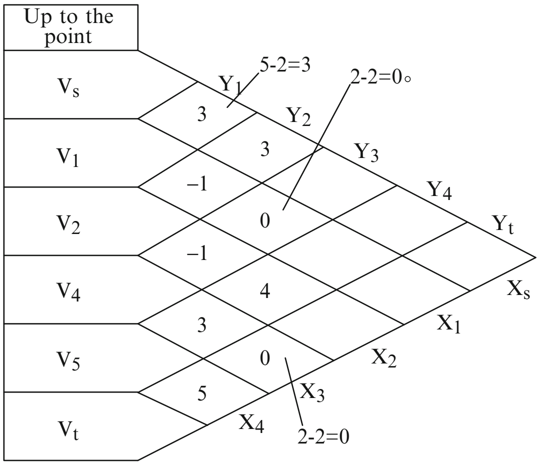


Fig. 82.8 Mutual relational tables 2

∴The minimum discharge of its path is 3, all nodes in the line subtract 3, after that we use the new value cover original form and get new correlation coefficient table 9. It is shown in Fig. 82.9.

4. In the Fig. 82.9 there is no more complete back track, so the biggest discharge on the network is f = 2 + 3 = 5.

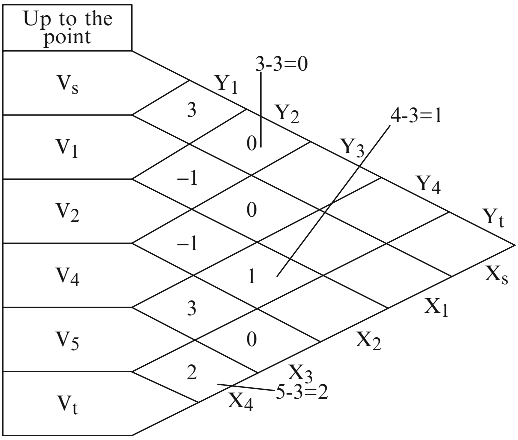


Fig. 82.9 Each other relational tables

Discussions

1. This paper puts forward a solution through solving the network biggest flow problem to meshing the graph, while responding to the large-scale and complicated network diagram structure, among the crunodes, discharge relation and direction can obviously see.
2. According to the model of correlation coefficient form structure, and by guiding into the quantity data and direction, we can turn disorder into order and make the whole process standard while solving the biggest flow problem. The algorithm can provide model structure and operation basis for computer to solve maximum flow.
3. On analysis of the date flow we can see that, there are obvious advantages in the field of date flow rate and correlation. This provide a method basis for our later work about the data correlation analysis of large network structure and data mining.
4. For single point, we can very clearly watch its supply relation (see the X direction as a supply, see the Y direction as a need). For the whole system, it is balanced, and it is important for us to find out the balance point of the biggest discharge. If what we replay to is an intelligent network system, we can realize how to base on this method to optimize it.

References

Chen C, Li T (2005) A hybrid neural network system for prediction and recognition of promoter regions in human genome. J Zhejiang Univ-Sci B (Biomed Biotechnol) 6(5):401–407

Chen M, Yang G, Liu X, Shi S, Wang D (2005) P2P-oriented secure reliable storage system. J Softw 16(10):1790–1797

Dalu Zhang, Zhixiao Wang, Wen Liu, Zhe Yang (2009) Complex network-based ontology structure analysis. J Tongji Univ (Natural Science) (2):120–123

Goldberg AV, Rao S (1998) Beyond the flow decomposition barrier. J Assoc Compute Mach 45 (5):783–797
Haichao Wang (2001) Furthest-flow with reliability of city – Roda network system. J Yanshan Univ (2):153–155
Markus M (2002) A graph-free approach to data-flow analysis. Lect Notes Comput Sci 2304:185–213
Qiao F, Zhang S, Yin X (2005) Study of initial vorticity forcing for block onset by a 4-dimensional variational approach. Adv Atmos Sci 22(2):246–259
Song D, Ruchuan W, Minghui Y (2009) Distributed data mining based on grid services pool. Chin J Electron 18(2):220–224
Wang L, Zhichun M, Guo H (2005) Combining self-organizing feature map with support vector regression based on expert system. Acta Autom Sin 31(4):612–619
Weizhen Li, Yingai Gan (2005) Operational research, 3rd edn. Tsinghua University Press, Beijing, pp 268–271
Wu (2010) Call for papers journal of control theory and applications special issue on wireless sensor networks: from theory to practices and applications. J Control Theory Appl 1:123–123
Yan YY (2007) Recent advances in computational simulation of macro-,-meso-, and micro-scale biomimetics related fluid flow problems. J Bionic Eng 4(2):97–107
Yongfa Ling (2006) An algorithm for the solution to the maximum-flow problem of networks. Comput Sci 2006(6):43–45
Yu S, Liu Y (2003) Algorithm of capacity expansion on networks optimization. Chin Sci Bull 48 (10):1048–1050
Zhang Y (2004) Approximation algorithm for weighted weak vertex cover. J Comput Sci Technol 19(6):782–786

Chapter 83
Job Shop Scheduling with Sequence-Dependent Setup Times Based on Constraint Programming Approach

Yun-fang Peng

Abstract Job shop scheduling problem with sequence-dependent setup times is complicated because machines have to be reconfigured between two consecutive operations. More researchers have attracted attention to this problem. We propose a constraint programming approach to minimize the makespan. Three branching strategies including binary constraint heuristic, variable-based heuristic, task-based heuristic are compared. The constraint model and search strategies are carried out by Xpress-MP. The results showed that binary constraint heuristic is more effective.

Keywords Job shop scheduling • Setup time • Constraint programming

Introduction

How to allocate a set of jobs on distinct machines in predefined time interval is the key work of the job shop scheduling problem, which is widely investigated in literatures. To simplify the problem in job shop scheduling, some researchers studied it with the assumption that the setup time is negligible or considered as part of the process time. However, in real-life production systems, these assumptions are usually not reasonable. Setup times sometimes are dependent on the preceding process on the same machine such as painting, chemical processes. Job shop scheduling problem with sequence-dependent setup times began to attract more and more researchers' attention. However, the existing studies mainly focused on single machine, parallel machines, or flow shop environments because of the difficulty involved in more general environment.

Y.-f. Peng (✉)
School of Management, Shang hai University, Shanghai, China
e-mail: yfpeng@shu.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_83,

Ali Allahverdi has reviewed the scheduling problem with setup times or costs (Allahverdi et al. 2008). It pointed out that some classes of problems and solution methods have received less attention of the research community than the others including the job shop scheduling problem with sequence-dependent setup times. To deal with this problem, Ballicu et al. represented it in terms of disjunctive graphs and a mixed integer linear programming model was derived (Ballicu et al. 2002). Another mixed integer programming model was presented and it was solved by a local search scheme which utilizes a property that reduces computational time in literature (Chio and Chio 2002). Cheung and Zhou proposed a hybrid algorithm based on a genetic algorithm and heuristic rules. The numerical experiments showed that this algorithm is superior to the recently published existing methods (Cheung and Zhou 2001). Egon et al. adapted the shifting bottleneck procedure and incorporated precedence constraints, release times and deadlines (Balas et al. 2008). Artigu and Feillet proposed a branch and bound method to solve the makespan minization problem to optimality (Artigues and Feillet 2008).

Most of these methods solve the jobshop scheduling problem with sequence-dependent setup times by treating single machine problem as traveling salesman problem with time windows (TSPTW) relaxation (Grimes and Hebrard 2010). In this paper, a constraint programming approach is presented which has proven to be efficient to solve combinatorial optimization problem and easily adapted to handle additional constraints.

The rest parts of this paper are organized as follows: section "Constraint Programming Approach" describes the constraint programming approach including the constraint model and three branching strategies. In section "Experimental Evaluation", a numerical example is given to compare these three branching strategies. Some conclusions and further works are discussed in the last section.

Constraint Programming Approach

Constraint programming approach has been identified as a strategic direction and dominant form for the industrial application of production planning and scheduling (Chen et al. 2010). In this part, a constraint model for job shop scheduling problem with sequence-dependent setup times will be given and the search strategy to optimize the problem will be discussed.

Constraint Model for Shop Scheduling Problem with Sequence-Dependent Setup Times

An $n \times m$ job shop problem involves n jobs which need to be scheduled on m machines. Each job consists of a set of m operations. Each operation o_{ij} has an associated duration p_{ij}. Scheduling is the process of deciding the sequence and start time of possible operations on each machine with precedence and disjunctive constraints. The parameters and variables are identified as following:

Parameters:

i: job index;
m: machine index;
o_{ij}: the jth operation of i;
p_{ij}: the duration of operation o_{ij};
s_{mik}: setup time required on machine m for processing job i immediately after job k.

Variable:

t_{ij}: start time of operation o_{ij};
The domain of variable t_{ij} is an integer time interval [0, P], where P is the sum of all process times and setup times.

The constraint model is stated as follows:

$$\text{Min } C_{max} \tag{83.1}$$

S. T.

$$C_{\max} \geq t_{ij} + p_{ij} \quad \forall i, j \tag{83.2}$$

$$t_{ij} + p_{ij} \leq t_{i,j+1} \quad \forall i, \forall j \in [1, m-1] \tag{83.3}$$

$$t_{ij} + p_{ij} + s_{mik} \leq t_{kl} \quad \text{or} \quad t_{kl} + p_{kl} + s_{mki} \leq t_{ij} \quad \forall o_{ij}, o_{kl} \in M_m, o_{ij} \neq o_{kl} \tag{83.4}$$

The objective (83.1) is to minimize the makespan C_{max}, which is the total duration of time of all jobs (83.2). The constraints (83.3) are the precedence constraints for each job, which state that an operation o_{ij+1} cannot start before the end of its preceding operation o_{ij}. The disjunctive Constraints (83.4) imply that if two operations require the same machine, then one cannot start before the end of the other operation plus the necessary setup time.

Above constraints can be expressed by Mosel language in Xpress-MP as follow:

```
forall(i in  JOBS, m in MACH)

    set_task_attributes(task(i,m), DUR(i,m),

res(RES(i,m)))

    forall(i,j in JOBS, m,n in MACH|i<>j)

        if(RES(i,m) = RES(j,n)) then
```

(continued)

(continued)

```
getstart(task(i,m)) + DUR(i,m) + S(RES(i,m),i,j) < =getsta
rt(task(j,n)) or
getstart(task(j,n)) + DUR(j,n) + S(RES(i,m),j,i) < =getstart
(task(i,m))
    end-if
forall (j in JOBS, m in 1..NM-1)
    setsuccessors(task(j,m), {task(j,m + 1)})
```

Search Strategy

The algorithm for solving constraint model can be considered into two categories: inference and search (Rossi et al. 2006). Inference techniques can eliminate large subspaces by local constraint propagation method. Search systematically explores solution, often eliminating subspaces with a single failure. These two basic strategies are usually combined in most applications.

In this paper, the search process is made by a branch and bound algorithm with depth-first exploration of the search tree. At each node, a propagation phase is triggered in order to detect possible inconsistencies and reduce the search space. If this phase detects an inconsistency, the algorithm backtracks and removes the effects of the previous decision. If no inconsistency is detected, a branching process is applied recursively to the child nodes until a solution is found or until all the search space has been explored. We use the default constraint propagation technique to the inference process which will not be discussed here.

We mainly focus on the branching strategy for branch and bound algorithm. Several branching strategies have been proposed for the standard job-shop problem (Jain and Meeran 1999). The branching strategy determines the shape of the search tree which directly influences the search speed. In this section, we will consider three branching strategies.

Strategy 1 (binary constraint heuristic): it creates a binary search tree by branching on the two possibilities defined by a disjunction. Constrain (83.4) defines two possibilities. Consider two operations o_{ij} and o_{kl} share the same machine m. The constraint $t_{ij} + p_{ij} + s_{mik} \leq t_{kl}$ is posted to one branch and the constraint $t_{kl} + p_{kl} + s_{mki} \leq t_{ij}$ corresponds to another branch.

Strategy 2 (variable-based heuristic): we use variable ordering heuristic to select the variable with the smallest domain size. The variables in the constraint model are the start times of each operation. The domain of variable is in the interval of earliest start time and latest start time. We select the variable with the smallest domain size and set the value with increased order (from min to max).

Strategy 3 (task-based heuristic): it consists in the definition of a task selection strategy and a value selection heuristic for the task start times. We selection the task with the smallest latest completion time and choose the value with decreased order (from max to min).

Three strategies are described in Xpress-MP as follow:

```
forall(i in  JOBS, m in MACH)

LS + =getstart(task(i,m))
Strategy(1):=settle_disjunction
Strategy(2):=assign_var
(KALIS_SMALLEST_DOMAIN,
KALIS_MIN_TO_MAX,LS)
Strategy(3):=task_seriliaze(KALIS_SMALLEST_LCT,
 KALIS_MIN_TO_MAX, KALIS_MAX_TO_MIN)
cp_set_branching(Strategy(ALG))

    starttime:= gettime
    if not cp_minimize (getmakespan) then

        writeln("Problem is infeasible")
        exit(1)

    end-if
```

Experimental Evaluation

In this section, we compare the results obtained with the approach discussed in previous sections by a numerical experiment.

A 6 × 6 job shop consists of six jobs and six machines. Each job consists of six operations. Each operation o_{ij} processed on machine M_m has an associated process time p_{ij} (Table 83.1). Setup times denoted s_{mik} are shown in Table 83.2.

The search algorithm for this constraint model is carried out by an OR-optimization software tool called Xpress-MP (by Dash Optimization Inc., UK) on a PC with 2.53 GHz CPU and 4 G RAM. The optimized makespan of above example is 73 and the gant chart for the optimized solution is showed in Fig. 83.1.

We set the maximum computation time as 200 s. The search results and statistics are showed in Table 83.3. Strategy 1 and 3 get the optimal objective in the predefined time, but strategy 2 doesn't get the best solution in 200 s. It is obviously showed that branching strategy 1 is superior to other strategies which in a high computation speed and less backtrack times.

Table 83.1 Process routings and process times

Jobs	(M_m, p_{ij})					
J1	(M3,1)	(M1,3)	(M2,6)	(M4,7)	(M6,3)	(M5,6)
J2	(M2,8)	(M3,5)	(M5,10)	(M6,10)	(M1,10)	(M4,4)
J3	(M3,5)	(M4,4)	(M6,8)	(M1,9)	(M2,1)	(M5,7)
J4	(M2,5)	(M1,5)	(M3,5)	(M4,3)	(M5,8)	(M6,9)
J5	(M3,9)	(M2,3)	(M5,5)	(M6,4)	(M1,3)	(M4,1)
J6	(M2,3)	(M4,3)	(M6,9)	(M1,10)	(M5,4)	(M3,1)

Table 83.2 Sequence-dependent setup times

	M1						M2						M3					
	J1	J2	J3	J1	J2	J3	J4	J5	J6	J1	J2	J3	J4	J5	J6	J1	J2	J3
J1	0	8	4	0	8	3	7	5	1	0	8	4	8	5	1	0	4	4
J2	8	0	6	8	0	5	3	2	1	8	0	6	7	3	1	8	0	7
J3	4	6	0	4	4	0	5	7	1	4	6	0	5	8	1	4	6	0
J4	10	3	5	3	3	1	0	2	2	6	3	6	0	4	1	6	3	6
J5	2	2	2	2	7	7	2	0	3	2	2	5	7	0	3	2	6	2
J6	1	1	1	1	3	5	1	6	0	1	2	4	6	8	0	2	1	7
	M4						**M5**						**M6**					
	J1	J2	J3	J4	J5	J6	J1	J2	J3	J4	J5	J6	J1	J2	J3	J4	J5	J6
J1	0	8	3	7	5	1	0	8	4	8	5	1	0	4	4	10	4	1
J2	8	0	5	3	2	1	8	0	6	7	3	1	8	0	7	3	2	1
J3	4	4	0	5	7	1	4	6	0	5	8	1	4	6	0	6	6	1
J4	3	3	1	0	2	2	6	3	6	0	4	1	6	3	6	0	2	1
J5	2	7	7	2	0	3	2	2	5	7	0	3	2	6	2	4	0	3
J6	1	3	5	1	6	0	1	2	4	6	8	0	2	1	7	9	1	0

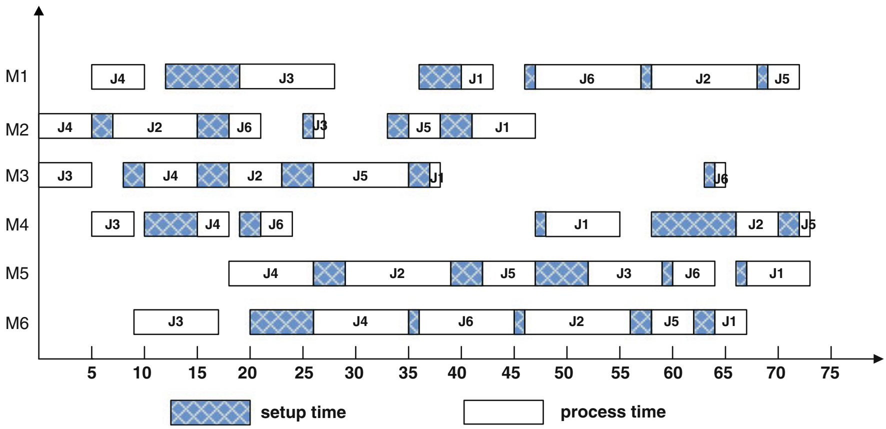


Fig. 83.1 Gant chart for the 6*6 job shop scheduling problem

Table 83.3 Search results and statistic

Branching strategy	Objective	Computation time (s)
1	73	1.69
2	75	200
3	73	11.9

Conclusion and Future Work

We have proposed a constraint programming approach to solve the job shop scheduling problem with sequence-dependent setup times. Three branching strategies for constraint model are compared with a 6 $\times$ 6 job shop example. The results showed that the binary constraint branching strategy is more effective.

This study shows that constraint programming is effective for job shop scheduling problem with sequence dependent setup times problem. Constraint propagation and search strategy are two main techniques for constrain programming method. We mainly focus on the search strategy in this paper. We will combine constraint propagation and search strategy in our future work. Meanwhile more comprehensive numerical experiment will be compared in the future.

Acknowledgement This work has been supported by Shanhai Excellent Young Teachers Porgram (B.37-0129-11-005).

References

Allahverdi A, Ng CT, Cheng TCE, Kovalyov MY (2008) A survey of scheduling problems with setup times or costs. Eur J Op Res 187:985–1032

Artigues C, Feillet D (2008) A branch and bound method for the job-shop problem with sequence-dependent setup times. Ann Op Res 159:135–159

Balas E, Simonetti N, Vazacopoulos A (2008) Job shop scheduling with setup times, deadlines and precedence constraints. J Sched 11:253–262

Ballicu M, Giua A, Seatzu C (2002) Job-shop scheduling models with set-up times. Proc IEEE Int Conf Syst, Man Cybern 5:95–100

Chen YR, Guan ZL, Peng YF, Shao XY, Hassea M (2010) Technology and system of constraint programming for industry production scheduling – part I: a brief survey and potential directions. Front Mech Eng China 5(4):455–464

Cheung W, Zhou H (2001) Using genetic algorithms and heuristics for job shop scheduling with sequence-dependent setup times. Ann Op Res 107:65–81

Chio IC, Chio DS (2002) A local search algorithm for jobshop scheduling problems with alternative operations and sequence-dependent setups. Comput Ind Eng 42:43–58

Grimes D, Hebrard E (2010) Job shop scheduling with setup times and maximal time-lags: a simple constraint programming approach. CPAIOR, LNCS 6120:147–161

Jain AS, Meeran S (1999) Deterministic job-shop scheduling: past, present and future. Eur J Op Res 113(2):390–434

Rossi F, van Beek P, Walsh T (2006) Handbook of constraint programming. Elsevier, Boston/Amsterdam

Chapter 84
Performance Evaluation of State-Owned Enterprises in China: A Case of Petroleum Industry

Xiao-yang Zhu

Abstract This paper suggests that state-owned enterprises have multiple goals including economics and noneconomic targets. State-owned Petroleum Company is a special case. The paper developed a goal-performance model to evaluate the performance of three Chinese state-owned petroleum companies and seven companies from other countries. The findings showed that the three Chinese companies achieved different levels of performance for multiple goals. In addition, the results from comparative analysis showed the performance gaps among these companies.

Keywords Goal-performance model • Multiple-goals • Performance evaluation • State-owned enterprise

Introduction

Prior studies suggested that state-owned enterprises (SOEs) have multiple goals including economic and non- economic targets. In the literature on Macroeconomics, SOE is considered as a special enterprise organization form that is used to directly intervene in economy and make up for market failure by the government. As Monsen and Walters (1979) pointed out, the original goal of establishing SOEs is to become a kind of effective tool that is used to conveniently solve all kinds of political, social and economic problems (Monsen and Walters 1979).

State-owned Petroleum Company is a special case of SOEs with multiple goals. In some countries, the state-owned petroleum company is believed to be "nonprofit organization". The oil is seen as the strategic resources. Petroleum industry could be the supporting industry in some countries. For example, the income from

X.-y. Zhu (✉)
Management and Economy School, Tianjin University, Tianjin, China
e-mail: zhuxiaoyang@petrochina.com.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_84,

petroleum occupies more than 70% of the total governmental revenue in Saudi Arabia. Not only the huge profit is derived from the petroleum industry, but also the employment rate is influenced by the industry. Sometimes, the state-owned petroleum company can be used as political tool to deal with the conflicts of interests among countries. Although the state-owned petroleum company plays a significant role in achieving nonprofit targets, their roles are different in different countries due to the economic development status. Therefore, performance evaluation of state-owned petroleum company may not be consistent with the established theory on SOEs.

China offers a fertile ground for investigating the performance evaluation of state-owned petroleum as emerging economy. China starts to be power house of global economy after years of reform and development. The roles of SOEs are also in transition. In the traditional planned economy era (1949–1978), SOEs were and highly-centralized administrated by the government, and implemented national plans as pure production units. Since 1978, the open door policy and economic reform has been changing the way Chinese companies conduct their business. During the reform era (1979–2000), SOEs experienced a series of reform due to the weak capability in competitiveness. Multiple goals system of SOEs changed accordingly. Overall, in the transition phase from planned economy to market economy, although SOEs still performed functions of providing medical, pension, social security, the goals of providing employment, realizing catch-up and so on is no longer emphasized. Especially SOEs also no longer have the goal of providing government revenue due to large losses. In the new era, large-size SOEs built modern corporate system and took the new responsibility for the country. In this study, three state-owned petroleum companies in China are evaluated with the performance-goal model. In addition, comparative investigation is conduced to demonstrate the competitiveness of the three companies in international market.

Theoretical Background and Framework

Company performance refers to the extent to which the goals are achieved by the company. The SOEs have multiple goals, which is the foundation of the research on company performance and control (Aharoni 1981). Ramanadham (1991) suggested that SOE is a kind of instrument and method by which the government participates and intervenes in the economy in order to solve the problems of market failure (Ramanadham 1991). Sapington and Stiglitz (1987) and Shapiro and Willig (1990) demonstrated that government can sometimes reduce intervention costs by SOEs (Sappington and Stiglitz 1987; Shapiro and Willig 1990). In view of SOEs goal priority, Haririan (1989) further pointed out, the social benefit goal is put in the first place, profit in the second, due of the public nature of SOEs (Haririan 1989). Hansmann and Kraakman (2000) emphasized that besides the goals of profit and shareholder wealth maximization, many other goals are determined by the government (Hansmann and Kraakman 2000).

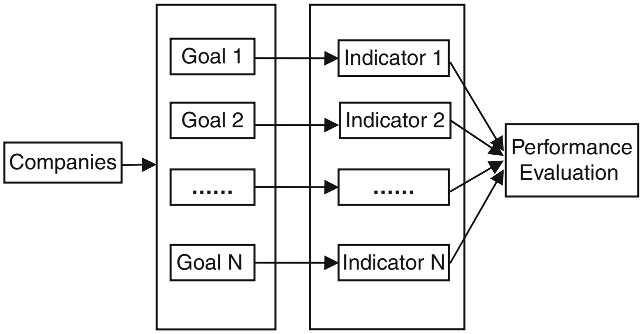


Fig. 84.1 Goal-performance model

While profit maximization is widely regarded as the core goal for private companies, in the case of SOEs, profitability isn't only one goal, and often not the most important one (Aharoni 1981). SOEs may be expected to make unprofitable products in uneconomic plants, create employment (Boycko et al. 1996), hold down price (Bos 1982; Brander 1995; Andrew et al. 2001), promote economic growth (Vernon and Aharoni 1981; Kaldor 1980; Rondinelli and Iacono 1996), make a governmental revenue contribution (World Bank 1991; Swann 1988), help to control macro economy (Krueger 1992), and so on (Boycko et al. 1996; Bos 1982; Brander 1995; Andrew et al. 2001; Vernon and Aharoni 1981; Kaldor 1980; Rondinelli and Iacono 1996; World Bank 1991; Swann 1988; Krueger 1992).

However, Ramamurti (1987) suggested that the economic performance evaluation of the SOEs often influenced the companies' pursuit of economic objectives in spite of social pressures from the government (Ramamurti 1987). Therefore, it is important to build a comprehensive Goal-Performance model to analyze the SOEs in China, especially in petroleum industry. Figure 84.1 depicts the goals and performance evaluation indicators that can be used in further case illustrations.

Illustration Cases

There are three main state-owned petroleum companies in China: PetroChina, Sinopec, and CNODC. Since the reform and merge in 2000, the three companies have been listed in the foreign market. They operate in market economy as the other international petroleum companies. As listed company, they need to emphasize on the shareholder's value and achieve competitive advantage through efficient and effective operations. However, they also take the political and social responsibility as strategic resources of the country. Therefore, the goals of the state-owned petroleum companies are summarized as following.

1. To achieve long term economic value
2. To ensure the energy safety

Table 84.1 Oil self sufficient rate of state-owned petroleum companies' motherland

No.	Name	Country	Ratio of state holder (%)	Self sufficient rate of oil (%)
1	CNOOC	China	66	51.76
2	PetroChina	China	86.29	51.76
3	Sinopec	China	75.84	51.76
4	PTT	Thailand	52.31	49.42
5	Petrobras	Brazil	58	78.97
6	PetroPeru	Peru	100	75.62
7	ETAP	Tunisia	100	86.69
8	Petrobangla	Bangladesh	100	74.43
9	ONGC	India	74.14	38.15
10	OGDCL	Pakistan	85.20	65.22

3. To strengthen the international competitiveness and resource acquisition capability
4. To function as basic industry to support the economic development
5. To contribute to the governmental revenue and support the social development
6. To create employment opportunity

In order to conduct the comparative analysis, seven state-owned petroleum companies from other countries are selected. Their demographic information is listed in Table 84.1. Importantly, the ratio of state holders and self sufficient rate of oil are compared across the ten companies because they would influence the evaluation of the goal achievement.

In this study, the performance evaluation indicators have three levels. The first-tier goals are categorized into micro-economic goals, macro-economic goals, and social and political goals. Each first-tier goals are divided into several second-tier goals. In the end, each the second-tier goals are divided into several third-tier goals. Table 84.2 lists the detail of goals and associated weight. The weight is derived by the method of expert survey.

Secondary data are used to apply the goal-performance model (WorldBank (2008) and BP Company (2010)).

The final scores of each company are listed in Tables 84.3 and 84.4.

Discussions

According to the achievement in microeconomic goals, PetroChina is the best in the three Chinese petroleum companies. It is in the third of the ten companies. However, Sinopec is the worst that it is in the last of the ten companies. Especially, the cost control performance of Sinopec is worse due to the output reduction and increasing difficulties in mining. CNOOC is the sixth of the ten companies. Although CNOOC is not proficient in cost control, it has highest financial

Table 84.2 The weight of performance evaluation indicators for state-owned petroleum companies

Goals	Weight	Sub-goals	Weight	Indicators	Weight
Micro-economic goals	50.00	Cost	12.11	Unit exploration cost	5.99
				Unit operation cost	6.12
		Profit	20.92	ROIC	13.92
				Sales profit ratio	7.00
		Development	16.97	Reserve replacement ratio	6.44
				Petroleum reserve-production ratio	5.97
				Gas reserve-production ratio	4.56
Macro-economic goals	23.47	Financial contribution	8.11	Income-tax ratio	4.31
				Average effective tax rate	3.80
		Economic Promotion	6.69	Economic contribution rate	6.69
		International competition	8.67	Internationalization of E&D	4.59
				Internationalization of reserves	4.08
Social and political goals	26.53	Energy security	17.33	Petroleum Reserves guarantee rate	5.45
				Gas Reserves guarantee rate	4.43
				Petroleum production guarantee rate	4.39
				Gas production guarantee rate	3.06
		Employment	9.19	Assets-Employee ratio	3.64
				Income-Employee ratio	5.56

Table 84.3 Micro-economic performance evaluation scores of state-owned petroleum companies

	Micro-economic performance				
Company	Rank	Score	Cost control performance	Profit performance	Development performance
CNOOC	6	39.35	6.08	18.09	15.18
PetroChina	3	42.25	9.59	16.79	15.87
Sinopec	10	28.64	5.81	10.93	11.90
PTT	9	29.49	8.78	9.07	11.64
Petrobras	2	42.67	9.53	20.05	13.09
PetroPeru	8	29.92	8.78	11.87	9.27
ETAP	1	47.74	12.11	20.92	14.71
Petrobangla	7	31.82	10.31	10.49	11.01
ONGC	5	39.39	8.78	16.74	13.88
OGDCL	4	41.09	10.57	20.92	9.60

Table 84.4 Total performance evaluation scores of state-owned petroleum companies

	Total performance			Macro-economic performance			Social and political performance	
Company	Rank	Score	Micro-economic performance	Financial contribution	Economic Promotion	International competition	Energy security	Employment
CNOOC	6	70.01	39.35	5.44	4.09	8.21	10.16	2.76
PetroChina	3	86.41	42.25	5.86	6.69	6.93	15.50	9.16
Sinopec	8	63.97	28.64	4.83	5.24	4.33	11.93	9.01
PTT	9	62.30	29.49	3.40	6.69	7.13	11.40	4.18
Petrobras	2	88.34	42.67	6.54	6.69	8.67	17.33	6.44
PetroPeru	10	60.48	29.92	2.43	4.69	4.33	12.09	7.02
ETAP	1	88.71	47.74	7.75	6.00	4.33	15.58	7.31
Petrobangla	7	64.73	31.82	8.02	3.96	4.33	7.40	9.19
ONGC	4	82.58	39.39	8.11	2.01	8.67	15.44	8.96
OGDCL	5	80.69	41.09	8.11	6.30	4.33	11.67	9.19

performances among the three Chinese companies. This indicates that CNOOC has high level of operations management.

Considering the governmental revenue contribution, the three Chinese companies are lag behind the other countries. This can be attributed to the low tax on resources in China. However, PetroChina has good performance in facilitate the economic development. It may be explained by the crucial role of strategic resources that PetroChina take in the country. The results are also corroborated by the important role of PetroChina in energy safety (second in the ten companies) and employment (third in the ten companies).

In the results of overall performance, ETAP is the best with Petrobras follows. Among the three Chinese companies, PetroChina is the best and has the third highest performance of the ten companies. CNOOC is in the middle. Sinopec is in the eighth of the ten companies. It is found that the sequence of the overall performance level is consistent with that of the micro-economic performance level. It indicated that the micro-economic performance domain the value orientation of the state-owned petroleum companies. In addition, the micro-economic performance may be the foundation of the other goals achievement. It should be the first priority in the multiple goals of state-owned petroleum companies.

References

Aharoni Y (1981) Performance evaluation of state-owned enterprises: a process perspective. Manag Sci 27:1340–1347

Andrew D, Smith C, Trebilcock MJ (2001) State-owned enterprises in less developed countries: privatization and alternative reform strategies. Eur J Law Econ 12:217–252

Bos D (1982) Public enterprise economics: theory and application. North-Holland, Amsterdam

Boycko M, Shleifer A, Vishny RW (1996) A theory of privatisation. Econ J 106(435):309–319

Brander JA (1995) Government policy toward business, 3rd edn. Wiley, Toronto

BP Company (2010) BP statistical review of world energy [EB/OL]. http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2008/STAGING/local_assets/2010_downloads/statistical_review_of_world_energy_full_report2010.pdf

Hansmann H, Kraakman R (2000) Organizational law as asset partitioning. Eur Econ Rev 44 (4–6):807–817

Haririan M (1989) State-owned enterprises in a mixed economy: micro versus macro economic objectives. Westview Press, Boulder

Kaldor N (1980) Public or private enterprise: the issues to be considered. In: Baumol W (ed) Public and private enterprise in a mixes economy. Macmillan, London

Krueger AO (1992) SOE supply prices have often been maintained at below market levels by many LDC governments in order to control inflation. In: Economic policy reform in developing countries. Oxford, Blackwell

Monsen RJ, Walters KD (1979) A theory of the state-owned firm in a democracy. The State-Owned Enterprise conference, Harvard Business School, Boston, 1979

Ramamurti R (1987) Performance evaluation of state-owned enterprise in theory and practice. Manag Sci 33(7):876–893

Ramanadham VV (1991) The economics of public enterprise. Taylor & Francis, London

Rondinelli M, Iacono M (1996) Strategic management of privatization: a framework for planning and implementation. Public Adm Dev 16(3):247–263

Sappington DEM, Stiglitz JE (1987) Privatization, information, and incentives. J Policy Anal Manag 6(4):567–585

Shapiro C, Willig RD (1990) Economic rationales for the scope of privatization. In: Suleiman EN, Waterbury J (eds) The political economy of public sector reform and privatization. Westview Press, Boulder

Swann D (1988) The retreat of the state: deregulation and privatization in the UK and US. Harvester/Wheatsheaf, New York

Vernon R, Aharoni Y (1981) State-owned enterprise in the western economies. St Martin's Press, New York

World Bank (1991) World development report 1991: the challenge of development. Oxford University Press, New York

WorldBank (2008) A citizen's guide to national oil companies-data directory. [EB/OL]. http://siteresources.worldbank.org/INTOGMC/Resources/NOC_Guide_B_Data_Directory.pdf

Chapter 85
The Innovation and Practice of Three-Dimension Instructional Design in Operations Research

Gang Du, Jun-peng Guo, Jun-yan Zhang, Xiao-tao Zhang, Bai-chen Xie, and Shi-quan Zhong

Abstract Taking the instructional design of National Quality Course—Operations Research in Tianjin University as an example, this paper proposes a concept called three-dimension design space and an idea based on this design space which is called instructional design. Instructional design shows the key dimensions of instructional design factors and provides a systematic instructional frame for integrative optimization and design. This paper builds a three-dimension instructional design procedure that includes dimension division, curricular design, and instructional design. It develops the three-dimension instructional design in Operations Research of Tianjin University. We also compile the *Three-Dimension Instructional Design Handbook of Operations Research in Tianjin University*. These achievements have high practical value and salient application effects.

Keywords Dimension division • Design space • Integrative optimization • Operations research • Three-dimension instructional design

Introduction

At present, instructional design and instructional quality control are still based on syllabus in teaching of undergraduates' curriculum in high education (Du Du Gang and Wu Yuhua 2011; Gagne et al. 2004; Albert et al. 2005; Kalyuga 2009). Therefore, it is necessary to research a more in-depth and systematical instructional design method to satisfy the higher request of personnel training and the young teachers' need to instructional tools (Magidson 2005; Enkenberg 2001;

Foundation: the 12th 5-year education and science plan program in Tianjin (HE4065)

G. Du (✉) • J.-p. Guo • J.-y. Zhang • X.-t. Zhang • B.-c. Xie • S.-q. Zhong
College of Management and Economics, Tianjin University, Tianjin, China
e-mail: tddg@tju.edu.cn

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_85,

Reigeluth 1998,1999). This paper takes the instructional design of a National Quality Course—Operations Research in Tianjin University as an example, to propose a new idea and method of instructional design, which is called three-dimension instructional design basing on philosophy of design space.

Concept of Three-Dimension Instructional Design

Three-dimension instructional design is a curricular and instructional design that takes the key dimensions—knowledge, object and method in instructional design factors as the foundation to generate an instructional design space (Fig. 85.1). The philosophy of design is creative combination and integrative optimization among the three dimensions. There are two general process of the design.

First of all, divide dimensions regarding to cultivating targets and curricular characteristic; secondly, design the curriculum and design the process of teaching in details based on dimension division and instructional characteristics.

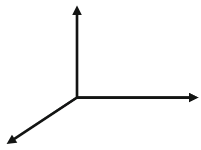
The idea of design space shows the key dimensions of instructional design factors. It regards that any instructional design is a subspace of design space. It is an idea of integrative construction and optimization. The design process based on dimension division provides designers sufficient creating room. Three-dimension instructional design is a systematical guiding frame, based on which can not only design curriculum and instruction, but also make integrative construction and system optimization more convenient.

Three-Dimension Instructional Design of Operations Research in Tianjin University

The guiding ideology of the three-dimension instructional design of Operations Research in Tianjin University is the object dimension satisfying the demands to Operations Research of different majors, which are the knowledge dimension abiding by the knowledge system and scientific disciplines in Operations Research, the method dimension facing the high standards of cultivating innovation capability among high quality talents, and the integrative design emphasizing synergy and seeking for integrative optimization of instruction effects.

1. *Dimension division*: the knowledge dimension consists of introduction and eight knowledge chunks including linear programming, dynamic programming, network analysis, decision analysis, inventory theory, queuing theory, game theory, stochastic simulation. Each chunk can also be divided into some sub-chunks; the method dimension consists of three main patterns which are classroom lectures, participatory case study, and participatory subject research (a new capability cultivating method proposes by the Operations Research course group in Tianjin University, including the content of Operations research philosophy,

Fig. 85.1 Three-dimension instructional design



optimization thoughts in all subfields of Operations Research, basic disciplines, research progress, applicable subjects in management and so on); the object dimension divides into basic, extending and simplified these three levels, which separately corresponds to the knowledge demands of three different majors.

2. *The curricular design*: curricular design on one hand refers to curricular setting based on dimension division and the basic level is commerce financial courses (64 class hours) required in management college, the extending level is engineering information courses (96 class hours) , which is also required in management college, and the simplified level is the selected courses (48 class hours) for non-management specialties in the whole school; on the other hand, it refers to sub-chunks in different kinds of curriculum and the teaching methods design which required to reflect the range of knowledge and the practice background of different majors. An example is as Table 85.1.
3. *Instructional design*: teachers refine the curricular design forming their special curricular design.

Integrating the above designs, our course group compiles a teaching reference material—*Three-Dimension Instructional Design Handbook of Operations Research in Tianjin University* which includes profile, dimension division, curricular design and instructional design four parts (Table 85.2). The handbook is a carrier of three-dimension instructional design of Operations Research and also a significant practical fruit of the course group in these years. It provides an available guiding tool to promote Operations Research in Tianjin University after achieving the honor of National Quality Course and young teachers' capabilities in high-required teaching positions as soon as possible. In fact, the process of compiling this handbook is a procedure of innovation and redesign. The participation of young teachers is important practice helping to improve their teaching ability.

The Application Effects of Three-Dimension Instructional Design of Operations Research in Tianjin University

1. *The dimension division and synergy construct the course platform and series of Operations Research in Tianjin University*

   Three-dimension instructional design is not only a process of dimension division and re-division, but also a process of division, synergy and integrative

Table 85.1 Example of three-dimension curricular design table: dual theory

Knowledge level	Dual problem and model	Characteristics and methods	Economic significance of dual
Extending	Classroom lectures:	Classroom lectures:	Classroom lectures:
	Maximum and minimum problems of dual	Dual theorem	Comprehensive explanation of primal problem and dual problem
	Symmetric model	Complementary slackness theorem	Economic significance of dual optimal solution
	Asymmetric model	KKT theorem	Economic significance of dual constraints
	Geometric significance of dual	Dual simplex method	Economic significance of dual slack variable
			Economic significance of complementary slack relationship
	Case study: comprehensive economic application of linear programming and its dual problem (aimed at engineering information majors)		
	Subject research: applicant subject of rigid complementary linear programming		
Basic	Classroom lectures:	Classroom lectures:	Classroom lectures:
	Maximum and minimum problems of dual	Dual theorem	Comprehensive explanation of primal problem and dual problem
	Symmetric model	Complementary slackness theorem	Economic significance of dual optimal solution
	Asymmetric model		Economic significance of complementary slack relationship
	Case study: comprehensive economic application of linear programming and its dual problem (aimed at commerce finance majors)		
	Subject research: applicant subject of linear programming		
Simplified	Classroom lectures:	Classroom lectures:	Classroom lectures:
	Maximum problems of dual	Relationship of optimal solution and optimal value between primal problem and dual problem	Comprehensive explanation of primal problem and dual problem
	Symmetric model	Complementary slack relationship between shadow price and remained resource	Economic significance of dual optimal solution
	Case study: linear programming and integrative economic application of dual (aimed at engineering majors)		

Table 85.2 Content frame of three-dimension instructional design handbook

Three-Dimension Instructional Design Handbook of Operations Research in Tianjin University
1. Profile
1.1 Key dimensions and design space of curricula design
1.2 General process of three-dimension instructional design
1.3 Three-dimension instructional design of Operations Research in Tianjin University
2. Dimension division design
2.1 Object
2.2 Knowledge
2.3 Method
3. Three-dimension Instructional design
3.0 Introduction
3.1 Linear programming
3.2 Dynamic programming
3.3 Network analysis
3.4 Decision analysis
3.5 Inventory theory
3.6 Queuing theory
3.7 Game theory
3.8 Stochastic simulation
4. Instructional design examples
4.1 Classroom lectures
4.2 Participatory case study
4.3 Participatory subject research

optimization. The three-dimension instructional design itself reflects an idea of assembling and integration. Three-dimension instructional design of Operations Research in Tianjin University pays attention to dimension synergy and integrative effect optimization while dividing the dimensions (Du Du Gang and Wu Yuhua 2011; Zacharia and Constantinou 2008).

The three levels of object dimension in undergraduate instruction synergize transversely to form the course series of undergraduate Operations Research (Fig. 85.2), and it synergize vertically with graduate instruction to make the series based on a same course platform, which realize the benefit optimization of curricular setting.

Curricular design of Operations Research for graduates cooperates with the one for undergraduates. It extends its content on the basis of undergraduate course design. The object dimension divides into two levels, which are the basic and the simplified level. The basic level corresponds to the degree Operations Research course of graduates in college of management and relevant knowledge dimension can be divided into three knowledge chunks, which are nonlinear programming, multiple objective programming and non-zero-sum game theory. It also improves the proportion of subject research.

The common knowledge chunks of course series and the shared teaching resource constructed Operations Research course platform. The course series based on it satisfied the demands of different majors and levels to the max. The

Fig. 85.2 Course series of operations research in Tianjin University

course series realize the effect optimization of curricular setting and make the Operations Research has become an influential and important course in Tianjin University.

2. *The synergetic design of subject research combining with case study forms the new characteristic of Operations Research Quality Course in Tianjin University*

   The "participatory subject research" is a teaching method aimed at cultivating research capability of students, which uses advanced foreign teaching experience for reference (Parchoma 2003; Anderson 1999; Pike et al. 2003; Pike and Kuh 2005; Ryan 2005; Byer 2002). Under teachers' guidance, students study the philosophy and special subject of Operations Research, write literature review or have discussion and reports in groups. The scores of above activities will be counted as part of whole course mark.

   The characteristic of Operations Research course group in Tianjin University is not only to propose and carry out the teaching method of participating subject research, but also to make synergetic design of subject research combining with case study that trains students' ability of solving real management issues and cultivates the capability of extracting scientific problems from reality.

   The subjects of design come from teachers' research projects of the course group, most of which are scientific problems that extracted from real management problems. The instructional design provides real cases including photos of real circumstance in enterprises. After case analysis and building model, teachers lead students extract types of scientific problems and understand relevant current research situation and difficult problems needed to be solved through literature review.

3. *Effects optimization of teaching result and teaching resource*

   Since carrying out the series course teaching that based on three-dimension design, the relationship of common knowledge chunks in platform and variable knowledge chunks of course series becomes clear. Besides, the other teaching resource, such as assembling courseware and so on, provides convenient condition to share resource. These advantages can help to achieve better teaching effect with less teaching resource.

   The only six teachers in the course group undertake the heavy teaching task of Operations Research and related extending courses in the college of management, the whole school and Nankai University. But it turns out that not only the teaching result is outstanding every year, which makes the Operations Research become an influential brand course inside and outside school, but also the scientific research jobs achieve excellent result in course group. All teachers in course group are responsible for high level scientific research project, such as National Science Foundation project and so on, and publish many papers on international high-level journals related to Operations Research.

   Excellent scientific research results in excellent teaching design and teaching efficiency, and the capabilities of students to solve problems have been improved. According to incomplete statistics, there are 25 students doing well in Operations Research course who won awards in international, national and municipal Operations Research competitions. Among them there are five students who won first and second prizes in the Interdisciplinary Contest in Modeling in United States.

4. *Published achievements and popularizing situation*

   In February 2011, the paper, The Integral Optimization of Course Platform and Course Series of Operations Research, which is a teaching and research paper based on three-dimension instructional design of course group, was published in the Operations Research Operations Society of Chinese journal—*Operations Research and Management Science*.

   In March 2010, *the National Interchange Conference of Operations Research Quality Course Construction and Case Teaching in Question Bank*, initiated by the course group, was hosted by Operations Research Operations Society of Tianjin cooperating with Education Working Committee in Operations Research Operations Society of China. More than a hundred representatives from dozens of universities, senior experts in Operations Research and principals or representatives of six national Operations Research quality courses all came to give wonderful reports. Our course group introduced the achievements of building course platform and course series that based on three-dimension instructional design and the situation of question bank construction and case study. Conventioneers shared and praised our reports and experience of question bank construction.

In December 2009, the main textbook, *Foundations of Management Science (the third edition)*, which is related to course series, had been published as the national 11th 5-year plan textbook by Tianjin University Press. This book had been issued more than 65,000 times since its first edition and the matched auxiliary book, *Foundations of Management Science—learning main points, exercises and cases, English and Chinese words, and teaching courseware* also had been reprinted for three times. Another reference textbook, *Operations Research* (the first Operations Research textbook in China and the first person in charge of course group is one of the authors) had issued about 900,000 until now, which is the largest circulation textbook in Operations Research.

Themed as "Operations Research Course Platform and Course Series in Tianjin University", the Operation Research Quality Course Website (http://course.tju.edu.cn/tddg/index.php) has already had around 76,000 visits since the third editing in 2009. The website had successively added columns of audio courseware, bilingual courseware, students' works, students' awards, practice bases outside school and graduates' Operations Research course series etc. Hundreds students learning Operations Research and thousands students taking part in graduate or PHD entrance exams regard it as important learning and review material every year. Operation Research staffs in whole country can understand and consult the teaching experience in Tianjin University. The course website has spread the Operations Research three-dimension instructional design in Tianjin University to all country and world.

Conclusion

The idea and method of three-dimension instructional design are significant in enriching, developing and perfecting curricular and instructional design methods in high education. The *Three-Dimension Instructional Design Handbook of Operations Research in Tianjin University* has practical reference value to Operations Research educators, especially young teachers. The re-promotion of teaching quality in Operations Research Quality Course has significant meaning and makes contribution to cultivating high-quality management talents.

References

Albert WM, Hoogveld FP, Jochems WMG (2005) Training higher education teachers for instructional design of competency-based education: product-oriented versus process-oriented worked examples. Teach Teach Educ 21:287–297

Anderson GL (1999) The politics of participatory reforms in education. Theory Pract 38(4): 191–195

Byer JL (2002) The consistency correlation between student's perceptions of classroom involvement and academic self-concept in secondary social studies classes. J Soc Stud Res 26(l):3–11

Du Du Gang, Wu Yuhua (2011) The integral optimization of course platform and course series of operations research. Oper Res Manag 1:16–20

Enkenberg J (2001) Instructional design and emerging teaching models in higher education. Comput Hum Behav 17:495–506

Gagne RM, Wager WW, Golas KC, Keller JM (2004) Principles of instructional design, 5th edn. Wadsworth Pub Co., Belmont

Kalyuga S (2009) Instructional designs for the development of transferable knowledge and skills: a cognitive load perspective. Comput Hum Behav 25:332–338

Magidson S (2005) Building bridges within mathematics education: teaching, research, and instructional design. J Math Behav 24:135–169

Parchoma G (2003) Learner-centered instructional design and development: two examples of success. J Distance Educ 18(2):35–60

Pike GR, Kuh GD (2005) A typology of student engagement for American colleges and universities. Res High Educ 46(2):185–209

Pike GR, Kuh GD, Gonyea RM (2003) The relationship between institutional mission and student's involvement and educational outcomes. Res High Educ 44(2):241–261

Reigeluth CM (1998) What is the new paradigm of instructional theory. http://itech1.coe.uga.edu/itforum/paper17/paper17.html. Accessed 11 Dec 1996

Reigeluth CM (1999) Instructional-design theories and models: a new paradigm of instructional theory. Routledge 2:324–368

Ryan JF (2005) Institutional expenditures and student engagement: a role for financial resources in enhancing student learning and development. Res High Educ 46(2):235–249

Zacharia ZC, Constantinou CP (2008) Comparing the influence of physical and virtual manipulatives in the context of the physics by Inquiry curriculum: the case of undergraduate students' conceptual understanding of heat and temperature. Am J Phys 76:425–427

Chapter 86
A Novel Vehicle Pre-dispatching Method for Automated Material Handling System in Semiconductor Manufacturing

James T. Lin and Chih-Wei Huang

Abstract As the demand for ultra-clean areas in semiconductor fabrication has increased, the need for more efficient automated material handling system (AMHS) has become imperative. A diffusion tool is characterized by its long processing time of 6–12 h, thus making it a form-batch manufacturing step. Out of necessity with this application, wafer lots are temporarily stored in stocker and are delivered to diffusion tools for processing when the Work-In-Process (WIP) level reaches 4–6 lots. As a result, diffusion tools wait for long wafer delivery time due to the current vehicle assignment method, thus greatly impacting transportation and production efficiency.

In order to improve the transport performance, a novel vehicle assignment method is proposed. Unlike the current methods, which assign idle vehicles to move to load ports sequentially, the novel vehicle pre-dispatching method calls several idle vehicles to move to a load port to simultaneously execute transport jobs with the goal of shortening a vehicle's arrival time. To aid in our research, we performed simulation analysis of an AMHS for a diffusion area. The simulation outcome indicates that a substantial improvement in AMHS transport performance is achieved with applying of the vehicle pre-dispatching method.

Keywords AMHS • Diffusion • Vehicle assignment • Simulation

J.T. Lin (✉) • C.-W. Huang
Department of Industrial Engineering and Engineering Management,
National Tsing-Hua University, Hsinchu, Taiwan, ROC
e-mail: jtlin@ie.nthu.edu.tw

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_86,

Introduction

In semiconductor manufacturing, the wafer travels approximately 10 miles within the fab during the entire processing and typically the wafer visits over 250 processing tools to undergo several hundred individual processing steps (Agrawal and Heragu 2006). Wafer movement occurs between and within different processing area, such as *photo*, *thin-film*, *etching*, and *diffusion*. More specifically, because of characteristics of highly re-entrant processing and larger wafer dimensions, the complexity of material handling and control required by a semiconductor manufacturer has been extensively increasing recently. Over the years with the rapid development of control technology, full-fab automation has become reality in a 300 mm wafer fab. An automated material handling system (AMHS) is a useful solution to fab automation, which is capable of optimizing productivity, improving tool utilization and ergonomics, and reducing particle contamination and vibration shocks to wafers. A typical AMHS consists of track systems, transport vehicles, stocker systems, and a material control system (MCS). Front-opening unified pod (FOUP) with a carrying capacity of 25 wafers is used to transport wafers in a 300 mm wafer fab. These 25 wafers form a manufacturing batch size, called a wafer lot, to be processed in the tool and stored in the stocker. The MCS is a software system used to control vehicle routing and dispatching; it is also used for transport job control of the material and plays an important role in receiving transport jobs from the manufacturing execution system (MES).

In a wafer fab, each wafer lot follows its specific processing steps to be processed in the different tools. Each wafer lot is sequentially moved from the preceding tool to the succeeding one. To complete a wafer lot movement, the MCS has to generate a transport job in the AMHS system. Hence, a transport job is a MCS software command that moves the wafer lot from a source to a destination node. With the analysis of MCS database, the transport jobs demand of each processing area is different. Figure 86.1 shows the transport jobs demand of the diffusion and non-diffusion area. The transport jobs in the diffusion area are 4 jobs in average, with minimum 0 and maximum 15. The transports jobs in the non-diffusion area are 3 jobs in average, with minimum 0 and maximum 7. To compare the difference for these two areas, the variation in the diffusion is higher than the other one. This high variation result in the diffusion area is caused by diffusion tool *form-batch manufacturing* step. The tool requires 4–6 vehicles to transport wafer lots to the tool within a limited time. As an example shown in Fig. 86.2, there are three furnace tools in a diffusion bay. When the tool-A reaches to 6 lots WIP level at time T_5, the MCS generates 6 transport jobs to move these lots to the load port in the tool-A. The AMHS has to assign 6 vehicles to serve these transport demand from stockers to tools. In a practical production fab, many transport jobs in the load ports of a stocker wait for the AMHS vehicle service with a limited time. When vehicles quickly move wafer lots to a furnace tool, the manufacturing system can produce more wafer lots and can minimize tool idle time. Therefore, it is important to manage vehicles assignment and dispatching control to achieve the desired performance measures and costs to procure an optimized AMHS, and much literature is dedicated to this aspect of AMHS.

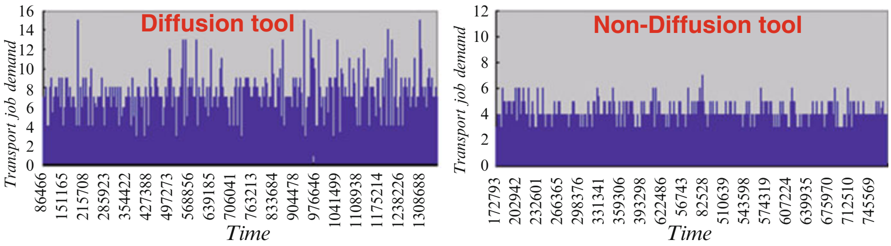


Fig. 86.1 Transport job demand of the diffusion and non-diffusion area

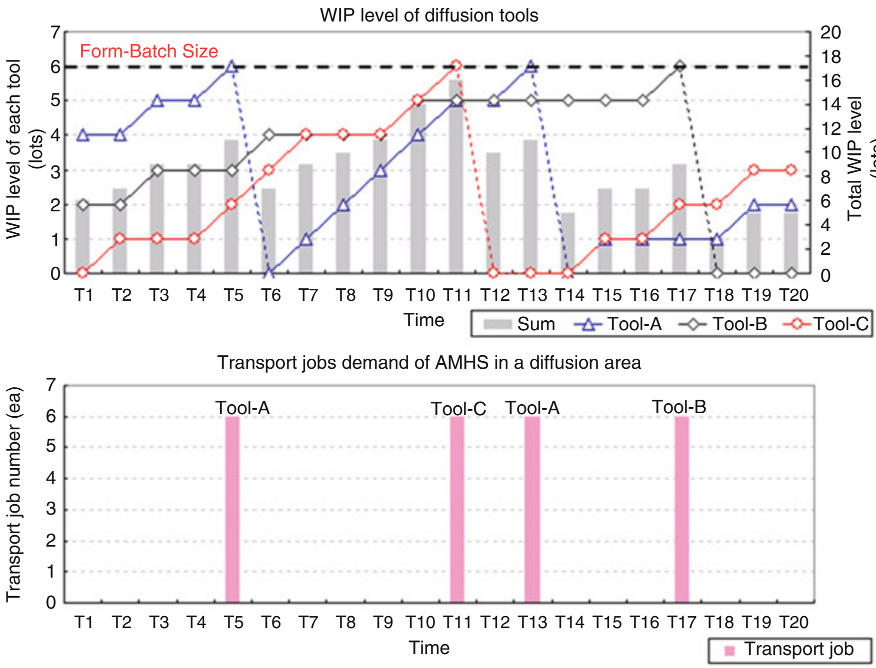


Fig. 86.2 An example of transport job demand analysis in a diffusion area

The AMHS vehicle management problem in these literatures can be categorized into three categories: *vehicle fleet size*, *vehicle dispatching rule*, and *vehicle routing decision*. The vehicle fleet size problem is to determine the minimum number of vehicles required to transport wafer lots in the factory. Maxwell and Muckstadt (1982) formulated the automated guided vehicle (AGV) transport problem into a mathematical model with an objective to minimize the total travelling times of idle vehicles. Their approach found the minimum number of vehicles needed to satisfy a specific demand requirement. The objectives using dispatching rules to control vehicles are minimizing vehicle waiting time and maximizing system throughput. Egbelu and Tanchoco (1984) firstly proposed the AGV vehicle dispatching problems in two aspects: workcenter-initiated versus vehicle-initiated task-assignment problems. Better performances are shown on simulation results on the combination of the modified first-come, first-served (FCFS) rule with the nearest vehicle (NV) or longest idle vehicle (LIV) rules. Lin et al. (2001) presented their performance evaluation of a double loop interbay AMHS, considering the effects of the dispatching rules. The results showed that the combination of the shortest distance with the nearest vehicle (SD-NV) and the foremost-encounter-first-served (FEFS) rule outperform the other rules. The vehicle routing decision problem decides the route a vehicle should take and the sequence of jobs that this vehicle should visit. The objective of the routing of vehicles is to minimize transport time of wafer lots. Kim and Tanchoco (1991) proposed an algorithm based on Dijkstra's shortest-path method to schedule vehicles based on the nodes' time windows. Baker and Ayechew (2003) applied a generic algorithm to solve basic vehicle routing problems and obtained solutions up 0.5% above best known results on average. Renaud et al. (1996) applied meta-heuristics, tabu search, that have been successfully implemented by other researchers in vehicle routing and were reported to perform very well.

As connecting the interbay and intrabay tracks to reduce transport time through stockers, vehicle types and vehicle allocation control in the connecting transport AMHS are widely studied to optimize overall transport performance. Lin et al. (2003) firstly proposed four types of vehicle (A, B, C, and D) to perform the connecting transport tasks by three combinations (A–B, A–C, and A–D) of vehicles. The minimum number of vehicle types was calculated using a simple procedure followed by calculating delivery quantity for all vehicle types. To improve the waiting time of fixed vehicle type proposed in Lin et al. (2003), Lin et al. (2004) continuously proposed a new concept of virtual vehicle to change vehicle type dynamically. Simulation results showed the virtual vehicles outperformed wafer throughput, transport time and waiting time than the fixed vehicle. To avoid congestion or idle time in the intrabay system, Lin et al. (2005) proposed the control of the upper limit or the lower limit on the number of vehicles in the intrabay. Their results indicated that this control significantly affects the travel time, the waiting time and the idle vehicle utilization.

In order to improve the transport performance for a diffusion bay, the concept of a vehicle pre-dispatching method is proposed to solve the high idle vehicles demand with a short time. The objective of this method is to assign idle vehicles at the same time to reducing the vehicle waiting time for each transport job in a diffusion area. Compared with current industry practices, our approach significantly reduces the wafer lots' waiting vehicle time as proven in a simulation study.

Methodology

There are three major tool types located in the diffusion area. These tools include furnaces, cleaners, and metrology tools. In integrated circuit manufacturing process, the diffusion process is characterized by high-temperatures and long-processing time.

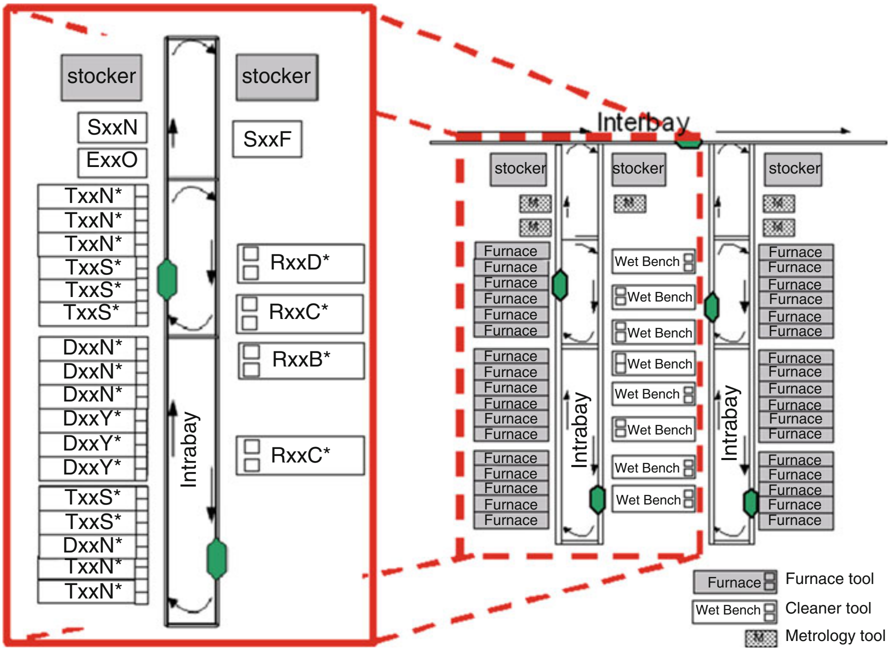


Fig. 86.3 An exemplary layout of a diffusion area

The process flow of a diffusion area includes wafer-cleaning, wafer-oxidizing, and wafer-measuring three steps. Firstly, wafers are processed in the cleaner tools to remove particles, metal ions, organics, and native oxides on the wafers to improve wafer quality. The cleaned wafers are processed in the furnace tools to produce an oxidation or nitride film on the wafer surface. Finally, the wafers are measured in the metrology tools to ensure a satisfactory thickness and uniformity required for the oxidation or nitride film. Figure 86.3 depicts an exemplary layout of a diffusion area in a 300 mm wafer fab that contains 34 furnace tools, 8 cleaner tools, 5 metrology tools, 2 single loop intrabay systems, 3 stockers, multiple shortcuts, and multiple bypasses. The vehicle used is overhead hoist transporter (OHT), which holds the FOUP by its top flange. The vehicle can directly move the wafer lot from one process area to the other area by the interbay and intrabay track system. The information of these tools in this diffusion area is shown in Table 86.1.

The characteristic of a long processing time then arises with furnace tools which are designed to batch-process 4–6 wafer lots to maximize tool throughput at the same processing time. A *form-batch* operation as illustrated in Fig. 86.4 is widely adopted by diffusion tools. Form-batch operation collects the WIP of the furnace tool in the stocker shelf and prohibits wafer lots from being transported to the furnace tool until the WIP level reaches a predetermined size. As shown in Fig. 86.4 status (2) and (3), when Furnace A’s WIP reaches to 4 lots, the system calls AMHS vehicles to move these wafer lots from stocker to tool to complete a form-batch operation.

Table 86.1 The tools information in the diffusion area

Tool group	Type	Max. batch size	Load port quantity	Buffer size	Tool quantity	Lot process time (s)	Throughput rate (pcs/h)
Wet bench	RxxB	2	2	x	1	900	100
	RxxC	2	2	x	2	900	100
	RxxD	2	2	x	2	900	100
Furnace	TxxN*	6	2	18	5	27,000	20
	TxxS*	6	2	18	5	30,000	18
	DxxN*	6	2	18	4	36,000	15
	DxxY*	6	2	18	3	27,000	20
Metrology	ExxO	1	2	x	1	360	250
	SxxF	1	2	x	1	1,059	85
	SxxN	1	2	x	1	600	150

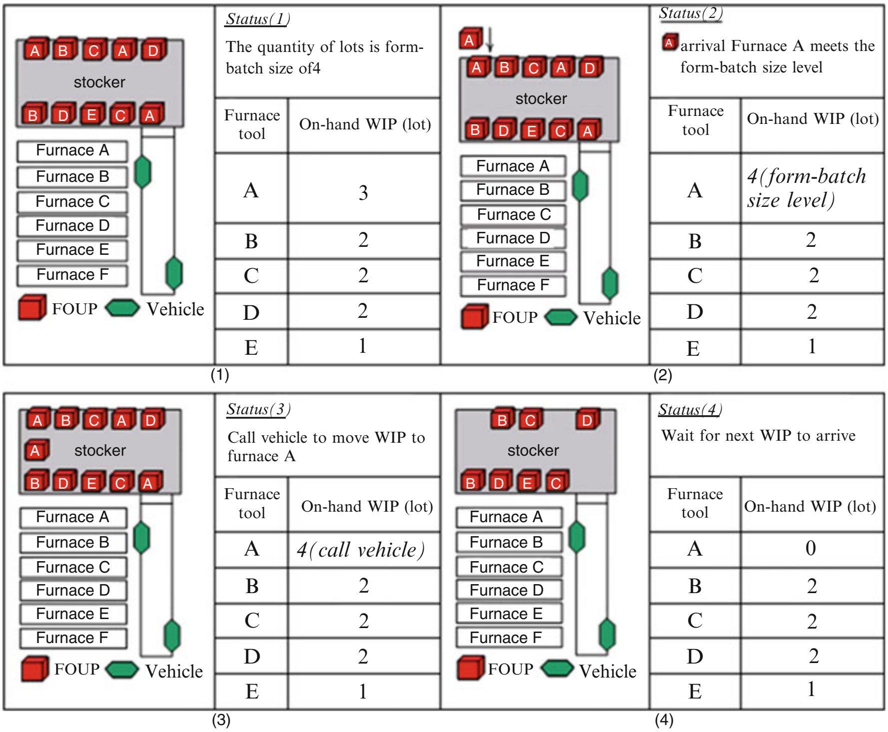


Fig. 86.4 Form-batch manufacturing

In a typical AMHS system, a transport job is triggered either by stockers or tools and then the MCS assigns an idle vehicle, which is selected by the predetermined vehicle dispatching rule, to move the wafer lot from the source to the destination station. With this current vehicle assignment method to generate the transport jobs for stockers or furnace tools, all of transport jobs, which are created from the same

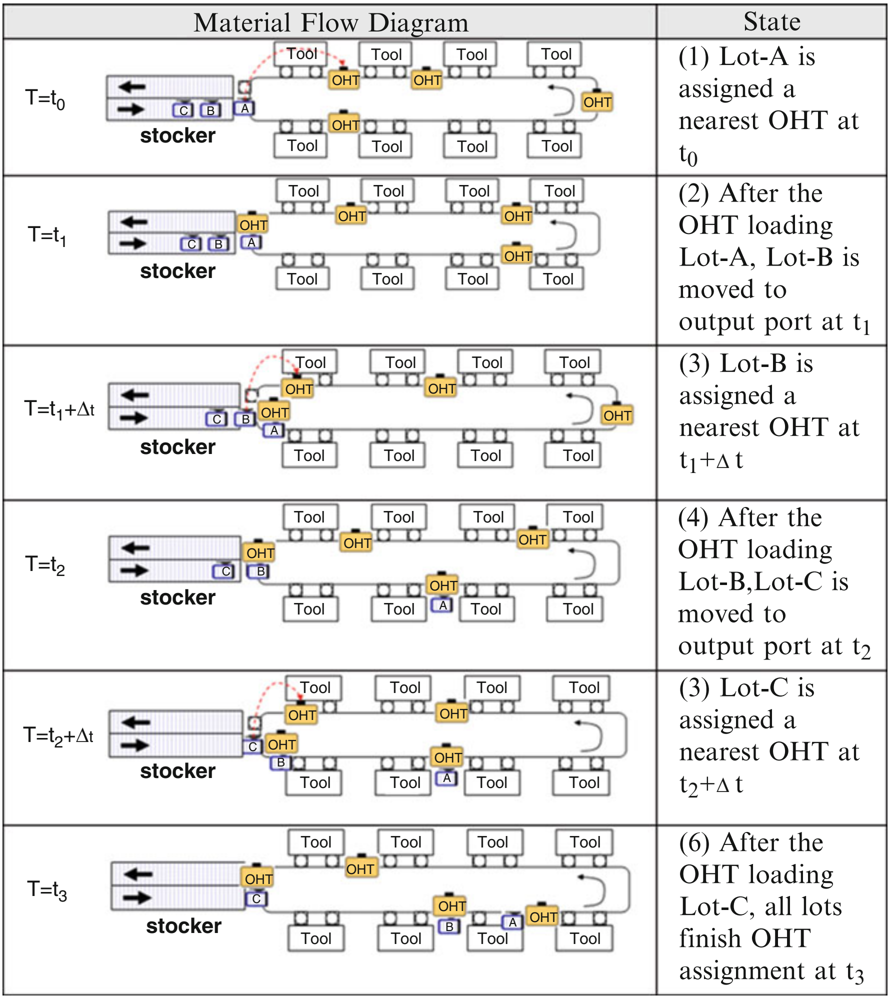


Fig. 86.5 Vehicle assignment by the current method

stations, will be sequentially performed one by one. As shown in Fig. 86.5, there are three wafer lots waiting for vehicles to move from a stocker output port to tools. The MCS assigns an idle vehicle to move the first wafer lot (Lot-A) from a stocker to a tool. After the vehicle finishes the Lot-A movement, the MCS continues to assign an idle vehicle to move the second wafer lot (Lot-B). Finally, the MCS assigns an idle vehicle to move the third wafer lot (Lot-C) after Lot-B is moved out from a stocker to a tool. This one by one vehicle assignment method is designed by each load port of stocker or tool only allowed sending one command to the MCS at one time. However, the transport performance by this current vehicle assignment method is solely determined by waiting for an idle vehicle to arrive. In particular, the form-batch operation of furnace tools requires the AMHS system to transport

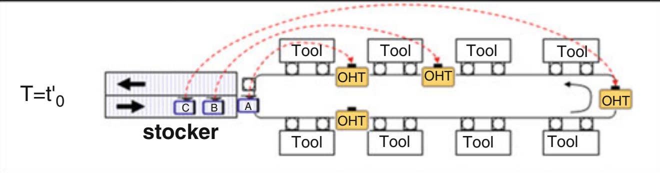
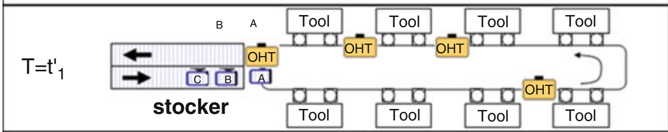
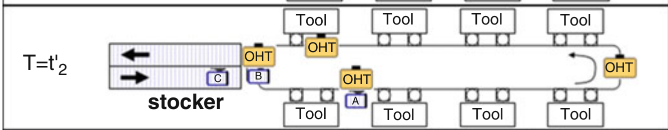
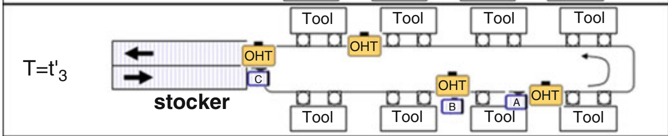
Material Flow Diagram	State
	(1) Lot-A, B, C are assigned a nearest OHT at t'$_0$, respectively
	(2) Lot-A finish OHT loading at t'$_1$
	(3) Lot-B finish OHT loading at t'$_2$
	(4) Lot-C finish OHT loading at t'$_3$

Fig. 86.6 Vehicle assignment by the PDVA method

4–6 jobs within a limited time. With the use of sequential vehicle assignment method, much of the time is spent waiting for idle vehicle's arrival. Hence, a novel vehicle assignment method, named Pre-Dispatching Vehicle Assignment (PDVA), is proposed to improve the above-described phenomenon.

The objective of the PDVA method is to reduce the vehicle waiting time for each transport job in a furnace tool or a stocker. In this proposed method, several idle vehicles are assigned to simultaneously execute transport jobs for the same stations. Figure 86.6 briefly demonstrates the detail behavior by the PDVA method. When there are three wafer lots waiting for vehicles to move from a stocker output port to tools, the MCS assigns three idle vehicles at a time to move these lots simultaneously. After the first wafer lot (Lot-A) is moved out by a vehicle, the second wafer lot (Lot-B) waits for the next vehicle arrival without assigning a vehicle again. Therefore, these three wafers take one time to assign vehicles and these assigned vehicles move to the same station to reduce the vehicle waiting time of these lots.

Features of the PDVA method are presented as follows.

(A) Application scope: Two transport scenarios can be performed by the PDVA method. One is a transport request from the internal buffer to the load port in a furnace tool and the other one is a form-batch operation from a stocker to a furnace tool.

(B) Modification of the current vehicle assignment rule: The PDVA method is a new vehicle assignment strategy based on existing dispatching rules. In the current paper, the vehicle dispatching rule uses the combination of SD–NV (shortest distance and nearest vehicle) and FEFS (the foremost-encounter-first-served) rule. Being based on the existing lot or vehicle dispatching rules, it only replaces the original one by one vehicle assignment method to assigning idle vehicles for the same station at a time.

(C) Determination of a reasonable amount of assigning vehicles: It is essential that a number of vehicles assignments at a time be controlled. Too many assignment vehicles can cause traffic congestion, while too few assignment vehicles can lead to long vehicle arrival time.

Some characteristics of this PDVA method are identified such as an improvement in vehicle arrival time, a reduction in lot waiting time for transport, a reduction in the diffusion tool idle time, and new roles for vehicle dispatching. In general, the load port of a diffusion tool or a stocker can only request a vehicle to transport the wafer lot. If the PDVA mechanism occurs in the load ports, then the wafer lots in these load ports can request several vehicles to a source station at the same time. Thus, the new role for the load ports is better than the sequential method. Hence, the lot waiting time for vehicle's arrival is reduced.

Results

The simulation is the most widely used tool in analyzing AMHS. A simulation experiment was performed by Campbell et al. (2000) to compare effects on cycle time, WIP, and tool utilization due to various factors (e.g., AMHS equipment downtime, number of stockers, etc.). Pierce and Stafford (1994) and Cardarelli and Marcello (1995) developed simulation tools to analyze the AMHS system performance. Their emphasis was on estimating the WIP stocker capacities to provide a smooth operative environment and clean room material handling.

In the current paper, a discrete-event simulation model is used to evaluate the transport performance of an AMHS system for a diffusion area with the PDVA method. The model is built and executed with the *eM-Plant* simulation package. The *eM-Plant* is an object-oriented simulation software with several merits, including hierarchy, inheritance, and concurrent simulation. Basic objects are enabled in the software for immediate use while extended function is also available through coding. In the simulation model, the OHT is constructed by movable objects called "Vehicles". A vehicle acceleration speed of ± 0.2 m/s and a final speed of 1 m/s are given as object attributes. Several real world objects (e.g. diffusion tools, intrabay track and stockers) are also included in the simulation model as Fig. 86.7 shows.

Here, several major performance measures collected from the simulation model are outlined as follows.

(A) *Production performance*: There are four measures: (1) throughput (lots); (2) lot cycle time (seconds); (3) system WIP (lots); and (4) WIP in the stocker (lots).

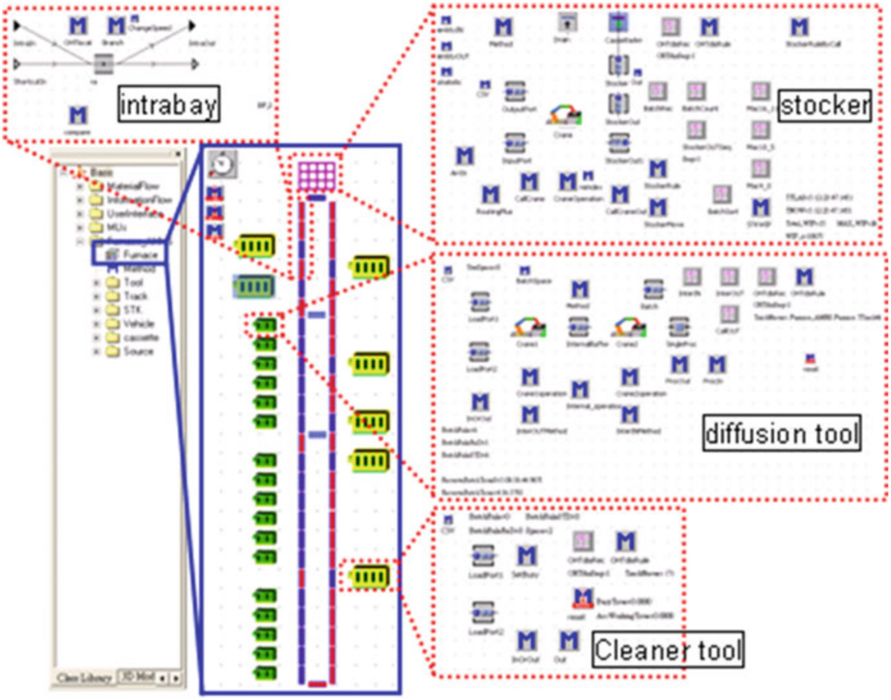


Fig. 86.7 The simulation model of a diffusion bay

(B) *Transportation performance*: Three major categories are included. (1) Delivery time: The time a vehicle is called by a source stocker or from the tool to the time the lot is placed on the load port or shelf of the destination tool or stocker. The time includes transport time and waiting time. (2) 95% Delivery time: The 95% lots can complete the movement at a certain time. (3) Transport time: The amount of time during the placement of the lot of the source tool's output load on a vehicle to the destination tool's input load port.

(C) *Vehicle movement performance*: There are two measures in this category. (1) Transport jobs: The quantity of lots that completes transport in this system during the simulation time. (2) Empty vehicle utilization: The percentage of available working time of an idle vehicle.

The experimental design for this study considers the operational factors such as the arrival rates of the input wafers, the number of vehicles, the form-batch size and the PDVA vehicle quantity. The arrival rate for the input wafers per month can be 18,000 or 25,000. The number of vehicles can be two, four, or six. The form-batch size can be four or six. The PDVA vehicle quantity can be one (without using the PDVA method), two, and four. Here, the combination of the arrival rate, the number of vehicles, the form-batch size, and the PDVA vehicle quantity can be treated as an operational scenario. We verify our model with iterations from simple output checks to a complex walkthrough using an event-list trace through the *eM-Plant* software. We validate our model using a "correlated inspection method". This involved collecting historical data from the wafer fab and comparing the model and system outputs of selected variables after the warm-up period. Using this method, we validate the throughput, cycle time, and WIP levels. Each simulation in our experiment ran for 30 days after a warm-up period of 2 days. Each experiment is replicated 30 times. Thus, the total number of simulation experiments performed is 2(the arrival rates) $\times$ 3(the number of vehicles) $\times$ 2(form-batch size) $\times$ 3 (PDVA vehicle quantity) $\times$ 30(replications) which equals 1,080.

All experimental data are adopted after a statistical residual test and then analyzed with ANOVA. Based on the simulation results, we conclude that production performance is affected by the lot arrival rate, form-batch size, and an interaction of these two factors. The indices of lot movement and vehicle movement performance are both significantly affected by the lot arrival rate, vehicle quantity, form-batch size, and PDVA vehicle quantity. There is further evidence showing that a 60% improvement in delivery time is observed when two to four vehicles are placed in the system, and an additional 30% improvement is reached when four to six vehicles are placed in the system. In addition, the system with a high (25,000 wafers/month) or low(18,000 wafers/month) arrival rate of input wafers could both achieve the best lot's delivery time when there are six vehicles to serve and the PDVA vehicle quantity is set to four instead of one or two. Consequently, the simulation result in transportation and vehicle movement performance shows that the PDVA method can improve vehicle arrival time and reduce lot waiting time for a diffusion bay.

Conclusion

This paper examines the vehicle assignment control problems for an AMHS system in semiconductor manufacturing. A pre-dispatching vehicle assignment (PDVA) method is proposed to assign the vehicles at the same time for a furnace tool or stocker in the diffusion area. The objective is to simultaneously assign idle vehicles for a furnace tool, which has a form-batch manufacturing step that will minimize the long vehicle waiting time of all transport jobs. The discrete-event simulation of an AMHS for a diffusion bay in a 300 mm wafer fab is analyzed, considering the effects of the vehicle assignment method. From the simulation results, we find that the PDVA method revealed substantial improvements in the AMHS transport performance. These simulation results lead to the conclusion that the PDVA method influences lot and vehicle movement performances. This inference is useful for fab managers to further study the PDVA method in other areas and continuously improve transport performance in the entire AMHS system.

References

Agrawal GK, Heragu SS (2006) A survey of automated material handling systems in 300 mm semiconductor fabs. IEEE Trans Semicond Manuf 19(1):112–120

Baker BM, Ayechew MA (2003) A generic algorithm for the vehicle routing problem. Comput Oper Res 30:787–800

Campbell E, Wright R, Cheatham J, Schulz M, Berry JL (2000) Simulation modeling for 300 mm semiconductor factories. Solid State Technol 43:95–104

Cardarelli G, Marcello P (1995) Simulation tool for design and management optimization of automated interbay material handling and storage systems for large wafer fabs. IEEE Trans Semicond Manuf 8:44–49

Egbelu PJ, Tanchoco JMA (1984) Characterization of automated guided vehicle dispatching rules. Int J Prod Res 22:359–374

eM-Plant (2000) Object manual version 4.5. Tecnomatix Technologies, Stuttgart

Kim CW, Tanchoco JMA (1991) Conflict-free shortest time bidirectional AGV routing. Int J Prod Res 29:2377–2391

Law AM, Kelton WD (1999) Simulation modeling and analysis. McGraw Hill, New York

Lin JT, Wang FK, Yen PY (2001) Simulation analysis of dispatching rules for an automated interbay material handling system in wafer fab. Int J Prod Res 39:1221–1238

Lin JT, Wang FK, Wu CK (2003) Simulation analysis of the connecting transport AMHS in a wafer fab. IEEE Trans Semicond Manuf 16:555–564

Lin JT, Wang FK, Young JR (2004) Virtual vehicle in the connecting transport automated material-handling system. Int J Prod Res 42:2599–2610

Lin JT, Wang FK, Young CJ (2005) The performance of the number of vehicles in a dynamic connecting transport AMHS. Int J Prod Res 43:2263–2276

Maxwell WL, Muckstadt JA (1982) Design of automatic guided vehicle systems. IIE Trans 14:114–124

Pierce NG, Stafford R (1994) Modeling and simulation of material handling for semiconductor wafer fabrication. In: The proceedings of winter simulation conference, Phoenix, 1994, pp 900–906

Renaud J, Laporte G, Boctor F (1996) A tabu search heuristic for the multi-depot vehicle routing problem. Comput Oper Res 23:229–235

Chapter 87
A Preliminary Study on Effects of Vision, Standing Posture and Support Surface on Human Balance

Shu-ping Xiong and Mubashir Karim

Abstract A preliminary experimental study on examining the effects of vision, standing posture and support surface on human balance was conducted. Planar deviation (PD), a parameter derived from recordings of center of pressure (CoP) with the aid of a static force platform, was used to assess the body sway and thereby human balance. The experimental results showed that PD had moderate to high short-term test-retest reliability and all main effects from three factors were significant, all interaction effects were not significant except the vision*support surface. The implications of these findings and future research directions were discussed.

Keywords Human balance • Center of pressure • Fall risk • Reliability

Introduction

Due to two thirds of a person's body mass is located at two thirds of body height above the ground, the humans as bipeds are inherently unstable systems unless the body posture is continuously controlling to maintain it (Winter 1995). Human balance is maintained through the integration of at least three major sensory systems: the vision, vestibular, and the proprioceptive systems (Winter 1995; Redfern et al. 1997). The vision system provides vital information about the body's position in relation to the surroundings, and the vestibular system senses linear and angular accelerations. The proprioceptive system senses the position and velocity of all body segments as well as their contact with external objects such as the ground (Winter 1995).

S.-p. Xiong (✉) • M. Karim
Ergonomics and Applied Biomechanics Laboratory, School of Design and Human Engineering, Ulsan National Institute of Science and Technology, Ulsan, South Korea
e-mail: maverickhkust@unist.ac.kr

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_87,

Millions of people experience dizziness and balance problems in their lifetimes, especially for the elderly and certain patients due to the degeneration of the balance control system (Raymakers et al. 2005; Borah et al. 2007). With the increase in our ageing population, injuries and loss of life due to falls in the elderly is becoming a major public health issue. Thus, understanding the affecting factors and the mechanism of human balance control system is important.

Traditionally, the effects of various factors including vision, standing posture, support surface, age, healthy condition, etc. on human balance have been studied independently using different methods (Redfern et al. 1997; Borah et al. 2007; Paulus et al. 1984; Uimonen et al. 1992; Prieto et al. 1996). In general, the ground reaction forces beneath the feet of an individual and moments in different test conditions were recorded by force plates, which were then used to derive the centre of pressure (CoP). Different parameters to characterize the variability of CoP were developed for assessing the human body sway and thereby body balance. For example, planar deviation (PD), a commonly used parameter for measuring human balance from CoP data, was defined as the square root of the sum of variances of CoP displacements in X (sideways) and Y (fore-aft) directions (Raymakers et al. 2005). Consequently, a larger PD value indicated the greater balance difficulty.

One major limitation of the aforementioned one-factor-at-a-time approach is lack of ability to investigate the potential interaction effects among different factors. Since our balance system utilizes information from different sources which may not be always matched with each other (Redfern et al. 1997), this mismatch may induce significant interaction effects on human balance. Consequently, the primary objective of this study was to systematically evaluate the effects (including interaction effects) of vision, standing posture and support surface on human balance. The reliability of using PD as a balance measure was also investigated because in spite of the frequent use of different measures from CoP for assessing the human balance, only a couple of studies have reported on their reliabilities (Condron and Hill 2002; Swanenburg et al. 2008; Ruhe et al. 2010).

Methodology

Participants

Ten young healthy adults were recruited for this experiment. Their ages ranged between 20 and 32 years with an average age of 23.2 years (SD = 4.5 years). The ranges of body stature and weight were from 160 to 190 cm (average: 174.4 cm) and 51 to 89 kg (average: 67.8 kg) respectively. All participants gave informed consent to participate.

Experimental Design, Apparatus, and Procedure

A 2 vision levels (eyes close, eyes open)* 2 standing postures (single-leg stance, two-leg stance) * 2 support surfaces (soft surface, firm surface) within-subject full factorial design was used. Two successive trials with a break of 60 s in between were performed so that all possible interaction effects among different factors can be investigated and the test-retest reliability of PD can be evaluated as well. The presentation sequences were randomized to minimize any order effect. A static force platform (AMTI model OR6-7, USA) was used to record ground reaction forces and moments for 60 s (Carpenter et al. 2000; Clair and Riach 1996) with a sampling frequency of 100 Hz for each experimental condition (Ruhe et al. 2010).

The basic instruction consisted of asking each participant to barefoot stand as steady as possible, with his/her arms at the sides in a comfortable position (Lafond et al. 2004). The outlines of the standing feet were traced in order to obtain standardized individual foot positions for the repeated measurements so that the influence from different positions of feet can be minimized (Uimonen et al. 1992). With eyes open, the participants were required to visually fix a black spot of 10 cm diameter on a portable whiteboard 150 cm before them at their eye heights (Raymakers et al. 2005). A foam seat pad of 4 cm thickness was placed directly on the force platform where the participant stood, in order to simulate the condition when the participant standing on the soft support surface.

Data Analysis

Excel program was used to calculate the CoP data and human balance parameter PD. The intra-class correlation (ICC), a measure for absolute agreement (Shrout and Fleiss 1979), was used to check the test-retest reliability of PD measures from two trials. After that, a three-way repeated measures analysis of variance (ANOVA) was performed to evaluate the effects of vision, standing posture and support surface on human balance using the PD measurement. The software SPSS (v16.0) was used for all statistical analyses. P values less than 0.05 were considered statistically significant.

Results

Test-Retest Reliability of Planar Deviation (PD)

ICC values on planar deviation (PD) were 0.72 for single measure (ICC(2,1)) and 0.84 for average measure (ICC(2,2)) respectively. Since it is generally accepted that moderate ICC value should be above 0.4 and a good ICC value should be larger

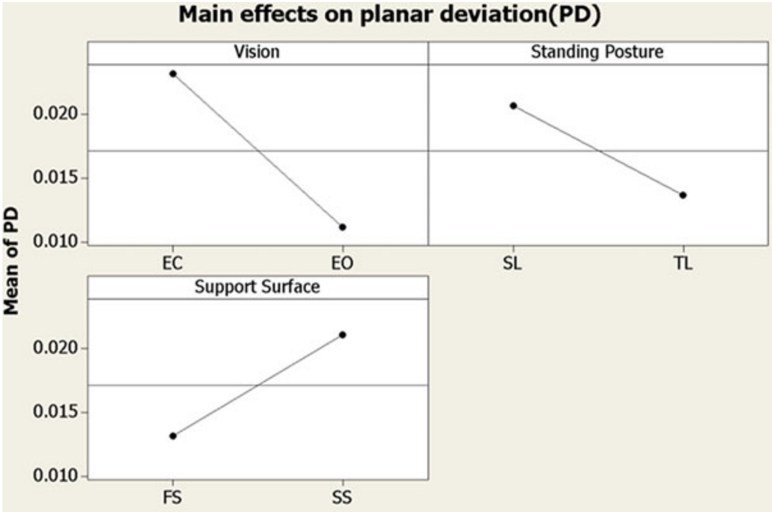


Fig. 87.1 Main effects of three factors on human standing balance measure PD (unit: m) *EC* eyes close, *EO* eyes open, *SL* single-leg stance, *TL* two-leg stance, *FS* firm support surface, *SS* soft support surface

than 0.75 (Ruhe et al. 2010; Carpenter et al. 2000; Clair and Riach 1996; Lafond et al. 2004; Shrout and Fleiss 1979; Xiong et al. 2011), PD can be considered as a reliable parameter for measuring the human balance.

Effects of Vision, Standing Posture and Support Surface on Human Balance

The plots shown in Figs. 87.1 and 87.2 illustrated three factors' main effects and their interactions on PD respectively. The main effect plot indicated that vision ability (eyes open, EO) improved the standing balance and two-leg stance (TL) on the firm support surface (FS) was more stable (Fig. 87.1). Regarding the interaction effects (Fig. 87.2), the lines in each cell of the interaction plot were roughly parallel except the lines for the interaction between vision and support surface, indicating the potential existence of an interaction effect between vision and support surface. ANOVA test (see Table 87.1) further confirmed that there were significant main effects from all three factors ($P < 0.05$), all interaction effects are nonsignificant ($P > 0.05$) except vision*support surface ($P = 0.004$). The vision*support surface interaction (Fig. 87.2) showed that even though the human standing balance on the soft surface (SS) was comparable with that of the firm surface (FS) when vision was available (eyes open, EO), without vision input (eyes close, EC), human standing on the soft surface was much less stable than that of the firm surface.

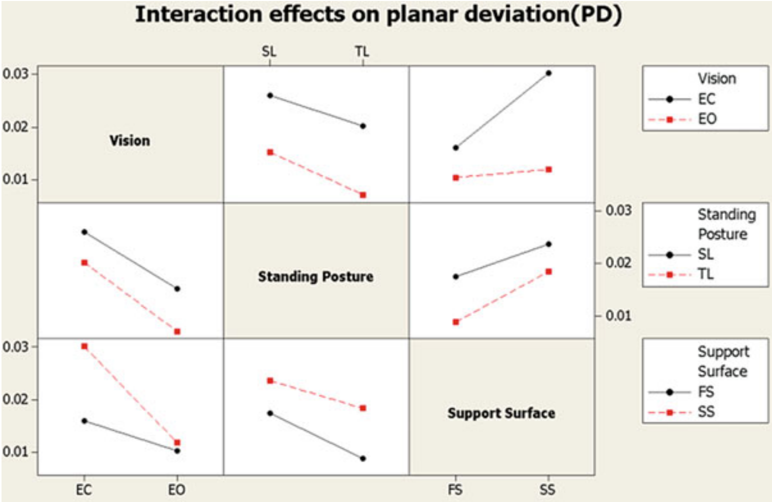


Fig. 87.2 Interaction effects of three factors on human standing balance measure PD (unit: m) (Same abbreviations are used as Fig. 87.1)

Table 87.1 Anova results on human balance measure PD (unit: m)

Source	DF	MS	F	P[a]
Vision (V)	1	0.00576	31.65	**0.000**
Standing posture (P)	1	0.00195	10.71	**0.001**
Support surface (S)	1	0.00248	13.64	**0.000**
Subject (block)	9	0.00106	5.83	**0.000**
V*P	1	0.00005	0.28	0.599
V*S	1	0.00160	8.78	**0.004**
P*S	1	0.00012	0.65	0.422
V*P*S	1	0.00069	3.77	0.054
Error	143	0.00018		**0.000**
Total	159			**0.001**

[a]P values less than 0.05 are shown in bold

Discussion

Even though the evaluation of CoP variability from force platforms is a commonly used method for diagnosing balance problems early and assessing the intervention effects on treating these problems (Chaudhry et al. 2005), the reliability of CoP measures needs to be determined at first if studies using this method are to be considered as valid (Ruhe et al. 2010). In the present study, the test-retest reliability of a commonly used human balance measure PD was investigated. The reliability coefficients (ICC) were above 0.70 for single measure (trial) and above 0.80 for average measure of two trials, which indicated moderate to good test-retest reliability. The ICC values in this study were quite comparable and slightly higher than the corresponding data (around 0.60 and 0.75 for single measure and average measure of two trials respectively) reported in (Lafond et al. 2004). The slight improvement on reliability coefficients from this study could be due to a shorter time interval (1 min) between trials was used in this study when compared with (Lafond et al. 2004) (~5 min). Of course, different experimental protocols may also contribute to the slight difference on reliability coefficients. Nevertheless, the reliability test results were in line with the suggestion of using two or three trials with at least 60 s trial duration for signal stationary and the good reliability of the CoP measures (Lafond et al. 2004).

The experimental results from this study clearly demonstrated that all three investigated factors can significantly affect the human standing balance. As expected and consistent with most previous studies, vision input can improve our balance and two-leg stance is more stable. Regarding the factor of support surface, even though it was reported in the human factors literature that soft support surfaces such as floor mats (so-called anti-fatigue mats) generally resulted in less discomfort and fatigue than on firm support surfaces such as hard concrete floors (Cham and Redfern 2001), this study showed that standing on soft support surfaces negatively affect the standing balance. Compared with the firm support surface, the soft support surface may reduce proprioceptive inputs or provide erroneous proprioceptive cues from feet to the postural control system (Redfern et al. 1997). Furthermore, even though the effect of standing posture on human balance measure PD was independent from different conditions of vision and support surface, the interaction between vision and support surface was significant (Fig. 87.2 and Table 87.1). With open eyes, human standing balance on the soft surface was somewhat comparable with that on the firm surface, but with closed eyes, human standing balance on the soft surface was reduced dramatically. Thus, the effect from different support surfaces on human standing balance was much greater with closed eyes when compared with open eyes.

One implication of aforementioned results is that caution should be taken when placing different floor mats on the ground for the purposes of comfort and anti-fatigue. Even though softer support surfaces are more comfortable and can reduce the potential for fracture neck of femur in the event of a fall, the potential for destabilizing human balance and increasing the risk of fall may cancel out the benefits (Redfern et al. 1997; Raymakers et al. 2005; Borah et al. 2007; Paulus et al. 1984; Uimonen et al. 1992; Prieto et al. 1996; Condron and Hill 2002; Swanenburg et al. 2008; Ruhe et al. 2010; Carpenter et al. 2000; Clair and Riach 1996; Lafond et al. 2004; Shrout and Fleiss 1979; Xiong et al. 2011; Chaudhry et al. 2005; Cham and Redfern 2001). This is true especially for the elderly who generally have poor visibilities and difficulties in motor and muscle control to balance their bodies. Additionally, these findings demonstrated a comprehensive consideration of different factors and their interactions is needed for assessing the human balance.

Several limitations do exist in this preliminary study on human standing balance. Firstly, the sample size ($N = 10$) in this study is relatively small, thus the statistical power of this study may not be sufficient to detect every possible significant effects. Secondly, due to the break between two trials was 1 min only, the test-retest reliability of human balance measure PD in this study can be considered as the short-term reliability only, the long-term reliability should be established further. Thirdly, a follow-up study on the detail configurations (stiffness, thickness etc.) of soft support surfaces should be conducted for finding an appropriate configuration with certain level of comfort and low risk of fall. Additionally, further research into the role of all factors in human balance should include study the human dynamic activities such as walking as well as use different balance parameters.

Conclusion

A preliminary experimental study on examining the effects of vision, standing posture and support surface on human balance was conducted with the aid of a static force platform. The results showed that all three factors have significant main effects on standing balance. In particular, vision ability improves the standing balance and two-leg stance on the firm support surface is more stable. Significant vision*support surface interaction was also found. The implications of the findings were discussed and future research directions were outlined.

Acknowledgment This study was funded by the Basic Science Research Program through the National Research Foundation of Korea (NRF 2011-0022185) and the start-up research fund of Ulsan National Institute of Science and Technology (UNIST 1.110010.01). The support from NSFC (No. 71001066 and 70971084), Ph.D. Programs Foundation from The Ministry of Education of China (20100073120046) and the Shanghai Pujiang Program (PJ[2009]00861) is also appreciated.

References

Borah D et al (2007) Age related changes in postural stability. Indian J Phys Pharmacol 51 (4):395–404

Carpenter MG, Frank JS, Winter DA, Peysar GW (2000) Sampling duration effects on center of pressure summary measures. Gait Posture 13:35–40

Cham R, Redfern MS (2001) Effect of flooring on standing comfort and fatigue. Hum Factors 43 (3):381–391

Chaudhry H et al (2005) Postural stability index is a more valid measure of stability than equilibrium score. J Rehabil Res Dev 42(4):547–556

Clair KL, Riach C (1996) Postural stability measures: what to measure and for how long. Clin Biomech 11(3):176–178

Condron JE, Hill KD (2002) Reliability and validity of a dual-task force platform assessment of balance performance: effect of age, balance impairment, and cognitive task. J Am Geriatr Soc 50:157–162

Lafond D, Corriveau H, Hebert R, Prince F (2004) Intrasession reliability of center of pressure measures of postural steadiness in healthy elderly people. Arch Phys Med Rehabil 85:896–901

Paulus WM, Straube A, Brandt T (1984) Visual stabilization of posture: physiological stimulus characteristics and clinical aspects. Brain 107:1143–1163
Prieto TE, Myklebust JB, Hoffmann RG, Lovett EG, Myklebust BM (1996) Measures of postural steadiness: differences between healthy young and elderly adults. IEEE Trans Biomed Eng 43 (9):956–966
Raymakers JA, Samson MM, Verhaar HJJ (2005) The assessment of body sway and the choice of the stability parameters. Gait Posture 21:48–58
Redfern MS, Moore PL, Yarsky CM (1997) The influence of flooring on standing balance among older persons. Hum Factors 39(3):445–455
Ruhe A, Fejer R, Walker B (2010) The test–retest reliability of centre of pressure measures in bipedal static task conditions – a systematic review of the literature. Gait Posture 32:436–445
Shrout PE, Fleiss JL (1979) Intraclass correlations: uses in assessing rater reliability. Psychol Bull 86(2):420–428
Swanenburg J, Bruin ED, Favero K, Uebelhart D, Mulder T (2008) The reliability of postural balance measures in single and dual tasking in elderly fallers and non-fallers. BMC Musculoskelet Disord 9:162–171
Uimonen S, Laikatari K, Sorri M, Bloigu R, Palva A (1992) Effect of positioning of the feet in posturography. J Vestib Res 2:349–356
Winter DA (1995) Human balance and posture control during standing and walking. Gait Posture 3:193–214
Xiong S, Goonetilleke RS, Jiang ZH (2011) Pressure thresholds of the human foot: measurement reliability and effects of stimulus characteristics. Ergonomics 54(3):282–293

Part III
Management System Innovation

Chapter 88
The Study of the Impact of Knowledge Integration on New Product Development Performance

Jia-Jeng Hou, Jhen-Jhou Wang, and Yu-Chen Hsiao

Abstract The purpose of this study is to explore how external integrative capability (technical integrative capability and customer integrative capability) and internal integrative capability (across-function integrative capability and board-problem solving integrative capability) influence the new product development performance. We find that external and internal integrative capabilities have significant difference on new product development performance. The results demonstrate that higher levels of external integrative capability and internal integrative capability enhance new product development performance.

Keywords Knowledge integration • External knowledge integration • Internal knowledge integration • New product development performance

Introduction

Winners in the global marketplace have been firms that can demonstrate timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competences (Teece et al. 1997). That is, to integrate internal and external knowledge is very important to gain the dynamic capability.

However, in the field of knowledge integration, some scholars suggested the mechanism of knowledge integration (Grant 1996). But others suggested that knowledge integration consists of the two dimensions: external knowledge integration and internal knowledge integration, and each of these different dimensions of

J.-J. Hou (✉) • Y.-C. Hsiao
Department of Business Administration, National Chiayi University, Chiayi City, Taiwan
e-mail: jjhou@mail.ncyu.edu.tw; annahsiao.226@gmail.com

J.-J. Wang
Master of Business Administration, Chung-Yuan Christian University, TaoYuan, Taiwan

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_88,

knowledge integration should impact an organization's dynamic performance (Iansiti and Clark 1994; Petroni 1996).

This paper empirically shows how knowledge integration influences new product development performance. We have focused on two dimensions of knowledge integration, and discerned their influence on new product development performance.

Research Hypotheses

External Knowledge Integration

It is useful to subdivide the capacity for external knowledge integration into two sub-dimensions, customer integration and technology integration. Besides, external (customer and technology) integration capabilities impact the conceptualization stage of each project and therefore are critical drivers of the renewal of the firm's competence base (Iansiti and Clark 1994).

Also, a description of the organizational dimensions of integration (both internal and external) is provided, which represents the basic foundation for the renewal of the organization's dynamic capabilities (Petroni 1996). External integrative capability comprises two elements: internal investments that develop absorptive capacity and an external communication infrastructure to facilitate the transmission of external knowledge. In combination, these elements enable the firm successfully to identify and integrate knowledge outside its boundaries (Tripsas 1997). Our hypothesis was the following:

> H1: High external integrative capability group will be better than low external integrative capability group in the new product development performance.

Furthermore, the review of previous studies revealed that the technical integrative capability could be linked with performance. Iansiti and Clark defined that technical integrative capability is the capacity to link the evolving base of technical knowledge (both inside and outside the firm) to the existing base of capability within the organization (Iansiti and Clark 1994). And, accumulated prior knowledge increases both the ability to put new knowledge into memory, and enhance the absorptive capability (Cohen and Levinthal 1990). That is, accumulated technical knowledge will not only influence absorptive capability and technical integrative capability but improve new product performance. Our hypothesis was the following:

H1-1: High technical integrative capability group will be better than low technical integrative capability group in the new product development performance.

Customer integrative capability will also affect performance on new product. Iansiti and Clark defined that is the capacity to link information and knowledge about future customers and their use of the product to the development process and the details of engineering (Iansiti and Clark 1994). And, capability for customer integration is rooted in the routines and mechanisms that allow the organization to forecast customer requirements (Fujimoto et al. 1991). It involves mechanisms that enable organizational members to interpret current market information and to construct visions of the future market. Moreover, that vision of the market must be translated into precise objectives and implemented in the existing organization. The competence base of the organization must be renewed to enable it to drive the creation of a product that matches future customer expectations (Iansiti and Clark 1994). Our hypothesis was the following:

H1-2: High customer integrative capability group will be better than low customer integrative capability group in the new product development performance.

Internal Knowledge Integration

Iansiti and Clark proved each of these different dimensions of knowledge integration should impact an organization's dynamic performance and defined that internal integrative capability is 'the capacity for extensive coordination between different specialized subunits within an organization, and explicitly targets the implementation of a given project concept' (Iansiti and Clark 1994).

Also, they had found two useful sub-dimensions, across-function integrative capability and board-problem solving integrative capability. Our hypothesis was the following:

•

H2: High internal integrative capability group will be better than low internal integrative capability group in the new product development performance.

Across-functional integrative capability focuses on higher level integration processes such as mechanisms for achieving the coordination of tasks between different functional specialties (Iansiti and Clark 1994). The manufacturers develop across-function integrative capability will improve efficiency in implementation and new product development performance. Other researchers found similar results, across boundaries integration (Clark and Fujimoto 1991a), system composition interface (Iansiti and Clark 1994), and different scientific knowledge base (Henderson and Cockburn 1994) would impact new product development performance. Our hypothesis was the following:

- H2-1: High across-function integrative capability group will be better than low across-function integrative capability group in the new product development performance.

Board-problem solving integrative capability instead characterizes the 'micro' level integration of activities at the individual problem-solving level (Iansiti and Clark 1994). For example, the practice of 'integrated problem solving' (including a complex pattern of skills, routines and organizational processes aimed at the integration of problem-solving activities in subsequent sets of tasks) has been shown to underlie effective practice in the management of major development projects (Fujimoto and Clark 1989; Clark and Fujimoto 1991b; Bowen et al. 1994). Effective development of problem-solving routines has been essential in driving and framing capabilities and performances (Petroni 1996). Our hypothesis was the following:

- H2-2: High board-problem solving integrative capability group will be better than low board-problem solving integrative capability group in the new product development performance.

New Product Development Performance

When we look about the global electronic information industries, there are some uncertainly factors such as shorter PLC and faster product development process. Therefore, new product development (NPD) has become the main source of enterprises' core competitiveness, which makes improving NPD performance the focus of enterprises (Ling and Yang 2009). NPD is an organizational knowledge accumulation and value-added process which takes knowledge as resources and generate new products and new knowledge through knowledge activities such as knowledge acquisition, integration, application and new knowledge sharing (Jing and Hu 2008), so it is a knowledge combination and innovation process (Ling and Yang 2009). Thus knowledge integration is also a key effect factor of NPD performance.

Method

Framework

Based on the prior studies of Iansiti and Clark, the analysis framework is constructed (in Fig. 88.1) (Iansiti and Clark 1994). In this framework, knowledge integration consists of two parts: external knowledge integration and internal knowledge integration.

Measuring Variables

Independent Variables

Two independent variables are measured, including external knowledge integration and internal knowledge integration.

"External integration" was measured from two aspects: index of technical integrative capability and the index of customer integrative capability. Another variable, internal integration index was divided into two sub indexes, a cross-functional integrative capability and board-problem solving integrative capability, to provide consistency with previous work (Iansiti and Clark 1994). Every indicator was evaluated by 7- point Likert scale where 1 was equivalent to very low and 7 to very high.

Dependent Variables

According to the study of Cooper, Olson, Walker and Rueken, the dependent variable "new product development performance" was measured by three indicators: (1) overall relative performance of new product on each project; (2) success ratio of new product development; (3) effect of new product on a company (Cooper 1984; Olson et al. 1995). Every indicator was evaluated by 7-point Likert scale where 1 was equivalent to very low and 7 to very high.

Data

The data collected from electronic manufacturing industry in Taiwan Hsinchu Science Base Industrial Park. The main reason is that electronic manufacturing industry in Hsinchu Science Park is one of the earliest and most important in Taiwan, and its technical projects are most representative. Five hundred and thirty-two companies' data were collected. Excepting the undelivered and

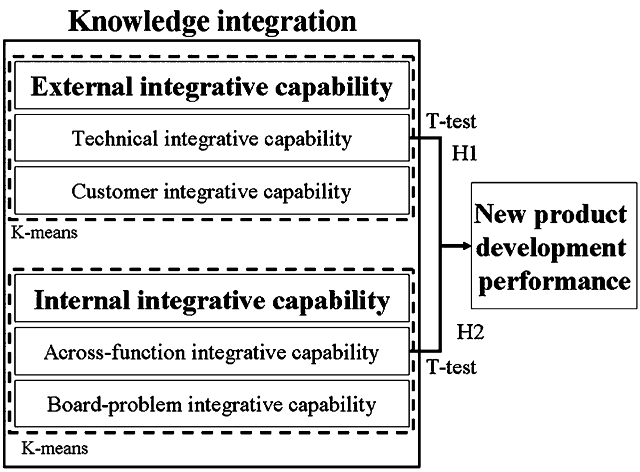


Fig. 88.1 Research framework

overlapped companies, valid questionnaires was 63, its effective rate was 10.1%. Cronbach's alpha value was 0.7.

Results and Analysis

The K-means cluster analysis procedure was adopted. This method requires the expected number of clusters to be input into the analysis. As it turned out, the number of companies was almost evenly divided between the two clusters, with 29 in the high external integrative capability group and 34 in the low external integrative capability group. A two cluster analysis is shown in Table 88.1.

External Integrative Capability Vs. New Product Development Performance

External Integrative Capability

The results of t-tests show (in Table 88.2) the difference between the two groups in the test was significant. The empirical analysis revealed that the manufacturers of higher external integrative capability, the new product development performance are better. This is consistent with the hypothesis H1.

Table 88.1 Cluster analysis for external integrative capability and integrative capability

		Samples	Means	*t*-value
External integrative	High	29	89.86	23.070***
	Low	34	67.74	
Internal integrative	High	24	74.92	22.391***
	Low	39	53.97	
Technical integrative	High	34	54.38	24.324***
	Low	29	41.59	
Customer integrative	High	28	35.21	22.889***
	Low	35	24.80	
Across-function integrative	High	23	47.65	22.325***
	Low	40	33.35	
Board-problem solving integrative	High	28	27.89	22.889***
	Low	35	19.77	

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table 88.2 *t*-Test analysis of external integrative capability on new product development performance

New product development performance	External integrative capability clustering		
	High external integrative capability (n = 29)	Low external integrative capability (n = 34)	*t*-value
	33.0345	26.2059	−7.008***
	Technical integrative capability clustering		
	High technical integrative capability (n = 29)	Low technical integrative capability (n = 34)	
	32.5882	25.5517	−7.408***
	Customer integrative capability clustering		
	High Customer integrative capability (n = 29)	Low Customer integrative capability (n = 34)	
	32.9643	26.4571	−6.411***

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Technical Integrative Capability

Also, results of this experiment have shown (in Table 88.2) that, all technical integrative capability groups (high technical integrative capability and low technical integrative capability) demonstrated significantly difference between the two groups. The *t*-value (=32.5882) of high technical integrative capability group is higher than low technical integrative capability group ($t = 25.5517$). It means the manufacturers have stronger technical integrative capability will perform better new product development performance. This is consistent with the hypotheses H1-1.

Customer Integrative Capability

Then we check the value of two customer integrative capability groups. Results are also presented of empirical tests showing that the difference between the two groups in the test was significant. Higher customer integrative capability will brings better new product development performance. This is consistent with the hypothesis H1-2.

Internal Integrative Capability vs. New Product Development Performance

Internal Integrative Capability

Table 88.3 presents the results of a study that provides support for the hypothesis H2. This result could be explained by the fact that the data shows significantly difference between the two groups (high internal integrative capability and low internal integrative capability). And the score of high internal integrative capability group is much higher than low internal integrative capability group. This study proves that, for company, stronger internal integrative capability will brings high new product development performance.

Across-Function Integrative Capability

Results showed (in Table 88.3) the significant differences in the across-function integrative capability between the two groups. In our survey, the group has higher across-function integrative capability get better performance of new product development and also is consistent with the hypothesis H2-1.

Board-Problem Solving Integrative Capability

The findings show (in Table 88.3) gives us the evidence to prove that the difference between the two groups in the test was significant. Also, the result is consistent with the hypothesis H2-2. Table 88.4 shows that all Hypothesis of this study had been supported.

Discussion and Conclusions

It should be concluded, from what has been said above, that each of these different dimensions of knowledge integration should impact an organization's NPD performance. Analysis revealed significant differences among the six groups. Obviously, high external integrative capability group had better NPD performance than low external integrative capability group; high technical integrative capability group had

Table 88.3 *t*-Test analysis of internal integrative capability on new product development performance

New product development performance	Internal integrative capability clustering		*t*-value
	High internal integrative capability (n = 24)	Low internal integrative capability (n = 39)	
	33.2500	26.9487	−5.864***
	Across-function integrative capability clustering		
	High across-function integrative capability (n = 23)	Low across-function integrative capability (n = 40)	
	32.6087	27.4750	−4.331***
	Board-problem solving integrative capability clustering		
	High board-problem solving integrative capability (n = 28)	Low board-problem solving integrative capability (n = 35)	
	32.3214	26.9714	−4.775***

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table 88.4 Research hypothesis and results

	Hypothesis	Outcome
H1	High external integrative capability group will be better than low external integrative capability group in the new product development performance.	Fully supported
H1-1	High technical integrative capability group will be better than low technical integrative capability group in the new product development performance.	Fully supported
H1-2	High customer integrative capability group will be better than low customer integrative capability group in the new product development performance.	Fully supported
H2	High internal integrative capability group will be better than low internal integrative capability group in the new product development performance.	Fully supported
H2-1	High across-function integrative capability group will be better than low across-function integrative capability group in the new product development performance.	Fully supported
H2-2	High board-problem solving integrative capability group will be better than low board-problem solving integrative capability group in the new product development performance.	Fully supported

better NPD performance than low technical integrative capability group; high customer integrative capability group had better NPD performance than low customer integrative capability group; high internal integrative capability group had better NPD performance than low internal integrative capability group; high across-function integrative capability group had better NPD performance than low across-function integrative capability group; high board-problem solving integrative capability group had better NPD performance than low board-problem solving integrative capability group. Our results agree with those obtained by Iansiti et al., Clark, Petroni, Tripsas, Cohen et al., Fujimoto et al., etc. (Iansiti and Clark 1994; Petroni 1996; Tripsas 1997; Cohen and Levinthal 1990; Fujimoto et al. 1991; Clark and Fujimoto 1991a; Henderson and Cockburn 1994; Fujimoto and Clark 1989).

Company should set up the integration mechanism to link internal R&D and external technical knowledge, also make the connection with information and knowledge about future customers and their use of the product to the development process and the details of engineering.

Furthermore, achieving the coordination of tasks between different functional specialties, and improving efficiency in implementation and new product development performance.

Despite of these meaningful conclusions and implications for Taiwan enterprise, the study still has several limitations. First, the sample size is small. It's obvious that a larger sample would be more representative, and some meaningful conclusion could be verified. Second, because of the resource constraints, we do not deal with these statistical methods of SPSS in this study, but leave them for further research. Finally, future studies could further investigate the effects of few other established moderating variables such as strategic flexibility, absorptive capability, market orientation etc...

References

Bowen HK, Clark KB, Holloway C, Wheelwright SC (1994) The perpetual enterprise machine: high performance product development in the 199Oi. Oxford University Press, New York

Clark KB, Fujimoto T (1991a) Product development performance: strategy, organization, and management in the world auto industry. Harvard Business School Press, Boston

Clark KB, Fujimoto T (1991b) Product development performance. Harvard Business School Press, Boston

Cohen WM, Levinthal DA (1990) Absorptive capacity: a new perspective on learning and innovation. Adm Sci Q 35:128–152

Cooper RG (1984) The performance impact of product innovation strategies. Eur J Mark 18 (5):1–50

Fujimoto T, Clark KB (1989) Organizations for effective product development: the case of the global automobile industry. Unpublished DBA thesis. Harvard Business School, Boston

Fujimoto T, Iansiti M, Clark KB (1991) External integration in product development. Harvard Business School working paper no. 92–025. Harvard Business School, Boston

Grant RM (1996) Prospering in dynamically-competitive environments: organizational capability as knowledge integration. Org Sci 7(4):465–467

Henderson R, Cockburn I (1994) Measuring competence? Exploring firm effects in pharmaceutical research. Strateg Manag J 15:63–84

Iansiti M, Clark KB (1994) Integration and dynamics capability: evidence from product development in automobiles and mainframe computers. Ind Corp Change 3(3):557–605

Jing NN, Hu HH (2008) Knowledge process in new product research and development business flow. Sci Study Sci Technol Manag QS 11:84–87

Ling NN, Yang C (2009) The interrelationship among quality planning, knowledge process new product development performance. In: Industrial engineering and engineering management, 2009, IE&EM 09. 16th international conference proceedings, pp 1051–1055

Olson EM, Walker OC, Ruekert RW (1995) Organizing for effective new product development: the moderating role of product innovativeness. J Mark 59:48–62

Petroni A (1996) The analysis of dynamic capabilities in a competence-oriented organization. Technovation 18:179–189

Teece DJ, Pisano G, Shuen A (1997) Dynamic capabilities and strategic management. Strateg Manag J 18(7):509–533

Tripsas M (1997) Surviving radical technological change through dynamic capability: evidence from the typesetter industry. Ind Corp Change 6:341–377

Chapter 89
Economic Challenges for Taiwan Private Senior High Schools: Performance Evaluation Based on a Revised Indicators Framework

Rong-tsu Wang, Jung-chang Wang, and Li-mei Chen

Abstract This paper evaluates and compares the operational performance of four major private senior high schools in Taiwan. The measure of operational performance is based on the relationship between educational aspect and financial aspect. The education aspect evaluation indicators focus on educational resource, outlay resource, human resource, and school reputation. The financial aspect evaluation indicators focus on benefits of productivity, management capability, solvency, and cash flow. Grey relation analysis (GRA) is used to select the representative indicators, and the TOPSIS method is used for the outranking of PCB firms. It is recommended that it should combine with other applications in the educational industry to improve performance evaluation.

Keywords Performance indicator • Grey relation analysis • Factor analysis • TOPSIS

Introduction

The development of private schools in Taiwan education plays an extremely important role. Due to limited financial resources from government, private schools are set up to assist the government for nurturing talented people and maintaining the great educational diversification. According to the statistics of the Ministry of

---

R.-t. Wang
Department of Marketing and Logistics, Vanung University, Tao-Yuan, Taiwan

Institute of Business and Management, International University of Monaco, Fontvieille, Monaco
e-mail: caroljoe@mail.vnu.edu.tw

J.-c. Wang
Department of Marine Engineering, National Taiwan Ocean University, Keelung, Taiwan

L.-m. Chen
Institute of Business and Management, International University of Monaco, Fontvieille, Monaco

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_89,

Education and Department (Ministry of Education and Statistics 2009), there are 373 private schools nationwide, 37 primary, 17 junior high, 145 senior high, 64 vocational, 12 junior colleges, 35 colleges, 63 university with percent rates as follows: Private school students vs. public school students: primary schools 1.88%, junior high schools 9.65%, senior high schools 32.34%, vocational high schools 63.01%, junior colleges 89.22%, colleges and universities 73.05%.

In the past, school performance evaluation did not adopt the classification of financial ratios; however, in order for private schools to seek sustainable management, it is very important to see that the private schools have good financial performance. Nowadays, it is common to see schools end up financial collapse due to improper or deficient financial management. Hence, this paper covers from financial aspects to educational aspect to analyze the performance of private schools, which is one of the motivations of this paper.

Performance is important as it represents the levels of goals an organization reached and members' satisfaction. Lin (1990) and Seeto (1999) pointed out that lacking of profit as an indicator, non-profit organizations need more effective performance management in order to know whether the missions are achieved, the use of resources is proper and decision-making is correct. Schools are non-profit organizations, and poor organization performance will result in low productivity, low working quality, burnout, and changes in personnel, work absence, etc, and even cause the shutdown of an organization. Smith (2000) pointed out in 2000 that while performance accountability is much diversified (moral, profession, finance, market, social status system and legislation), but overall, it is the school, not taxpayers or government to take the responsibility for reaching high achievement test scores (Huang 2004).

The evaluation indicators is an important basis for schools to know if a school is able to achieve quality education and performance, and to set a good education policy, However, most educational evaluation initiated by the Department of Education is based on public schools standard, and it cannot fully reflect the performance of private schools. Therefore, in this era of global competition and low birth rate, how to establish a high efficiency, performance and competitive evaluation indicators for private schools to meet the characteristics of their development is an urgent matter.

Grey Relation Analysis and TOPSIS

If all performance indicators in the set are placed into the evaluation process, the data would be difficult to collect, arrange and expensive to analyses. The purpose of using GRA in this paper is selecting only those representative indicators for evaluation. In general, the representative indicators can be selected by grouping, which minimizes the differences within a certain group, and maximizes the differences between those groups. If the samples are large enough and normally distributed, some statistical or econometrical methods such as factor analysis, cluster analysis, and discriminate analysis can be used to decide the representative indicators. However, if the sample size is small and distribution of samples is unknown, the grey relation analysis should be used to select the representative indicators. Moreover, the TOPSIS method will be used in conjunction to calculate performance scores and outranking.

Grey system theory was originated by Deng (1982). The fundamental definition of "greyness" is information being incomplete or unknown, thus an element from an incomplete message is considered to be of "grey" element. "Grey relation" means the measurements of changing relations between two systems or between two elements that occur in a system over time. The analysis method, which measures the relation among elements based on the degree of similarity or difference of development trends among these elements, is called "grey relation analysis". More precisely, during the process of system development, should the trend of change between two elements be consistent, it then enjoys a higher grade of synchronized change and can be considered as having a greater grade of relation, otherwise, the grade of relation would be smaller. Grey relation analysis will be applied in the selection of representative indicators. Its definition and model in mathematics are as follows:

Let X be a factor set of grey relation, where $x_0 \in X$ represents the referential sequence and $x_i \in X$ represents the comparative sequence. $x_0(k)$ and $x_i(k)$ represent the respective values at point k for x_0 and x_i. If the average relation value $\gamma(x_0(k), x_i(k))$ is a real number, then it can be defined as (Deng 1988, 1992):

$$\gamma(x_0, x_i) = \frac{1}{n}\sum_{k=1}^{n}\gamma(x_0(k), x_i(k)) \tag{89.1}$$

$\gamma(x_0, x_i)$ is designated as the grade of grey relation in x_i correspondence to x_0. $\gamma(x_0(k), x_i(k))$ is said to be the grey relational coefficient of the same at point k. Professor Deng has proposed a mathematical equation that will satisfy these four axioms of grey relation, which is as follows:

$$\gamma(X_0(k), X_i(k)) = \frac{\min_{i\in I}\min_k|X_o(k) - X_i(k)| + \zeta\max_{i\in I}\max_k|X_o(k) - X_i(k)|}{|X_o(k) - X_i(k)| + \zeta\max_{i\in I}\max_k|X_o(k) - X_i(k)|} \tag{89.2}$$

where ζ is the distinguished coefficient ($\zeta \in [0, 1]$), the function of which is to reduce its numerical value by $\max_{i\in I}\max_k|X_o(k) - X_i(k)|$ increasing, so as to effect its loss-authenticity and to heighten the significance of difference among relation coefficients.

The performance indicators can be divided into several groups according to the calculation of all indicators by the grey relation coefficient. A representative indicator has to be selected from each group and the principal of selection depends on the degree of the relationship between an indicator and the other indicators in the same group. This approach is called "relative total score" (Wang 2001).

After the selection of representative indicators, the next stage is to calculate the performance score of a private senior high school and to rank it. There are many different ways to calculate the performance score and ranking. TOPSIS, developed by Hwang and Yoon in 1981(Hwang and Yoon 1981), will be used as the ranking method in this paper. The advantage of this method is simple and yields an indisputable preference order. But it does assume that each indicator takes monotonic (increasing or decreasing) utility.

TOPSIS is based on the concept that the chosen indicator should have the shortest distance from the ideal solution and the farthest from the worst solution. The ideal solution is the one that enjoys the largest benefit indicator value and the smallest cost indicator value among each of the substitutive private senior high school. The worst solution is the one that enjoys the smallest benefit indicator value and the largest cost indicator value among each of the substitute private senior high school. The steps involved in carrying this out are:

Step 1: Normalization of indicator values. Normalization aims at obtaining comparable scales. This procedure is usually utilized in TOPSIS using:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$$

Where i is the ith private senior high school, j is the jth evaluation indicator, $\mathbf{r}_{ij}$ is the indicator value after vector normalization for the ith private senior high school and jth evaluation indicator, $\mathbf{x}_{ij}$ is the original value of indicators for the ith private senior high school and jth evaluation indicator, and m is the number of private senior high schools.

Step 2: To determine ideal (A^+) and worst (A^-) solution.

$$\begin{aligned} A^+ &= \left\{ \left(\max_i r_{ij} | j \in J \right), \left(\min_i r_{ij} | j \in J' \right) | i = 1, 2, \ldots, m \right\} \\ &= \left\{ A_1^+, A_2^+, \ldots . A_j^+, \ldots, A_k^+ \right\} \\ A^- &= \left\{ \left(\min_i r_{ij} | j \in J \right), \left(\max_i r_{ij} | j \in J' \right) | i = 1, 2, \ldots, m \right\} \\ &= \left\{ A_1^-, A_2^-, \ldots . A_j^-, \ldots, A_k^- \right\} \end{aligned}$$

Where: J = {j = 1,2,. . .,k|k} positively relates to the benefit criteria, **J'** = {j = 1,2, . . .k|k} positively relates to the cost criteria.

Step 3: To calculate the separation measure. The separation of each private senior high school from the ideal airport ($\mathbf{S}_i^{+}$) and the worst airport ($\mathbf{S}_i^{-}$) uses:

$$s_i^+ = \sqrt{\sum_{j=1}^{k} (r_{ij} - A_j^+)^2}; \quad s_i^- = \sqrt{\sum_{j=1}^{k} (r_{ij} - A_j^-)^2}$$

$$i = 1, 2, \ldots, m$$

Step 4: To calculate the relative closeness to the ideal solution (C_i^*). It is defined as

$$c_i^* = \frac{s_i^-}{s_i^+ + s_i^-} \qquad 0 < c_i^* < 1$$

Step 5: To rank the preference order according to the descending order of C_i^*.

Research Design and Conceptual Framework

The education funding for private schools are from parents and the charges are restricted by the competent authorities. Therefore, it is necessary to make the most appropriate allocation of resources within limited funds to avoid misallocation of resources that might bring up failed performance and further affect school operations, or even get closed down, which is no news in the field. The elements for "Performance" are two: "effectiveness" and "efficiency". The so-called efficiency is the extent of using resources and capacity, like human, material, financial resources, and time to do the proper allocation of those. Effectiveness is the extent to achieve their goals, since the use of resources is the result, and those who complete shall achieve the target performance (Cheng 2002). Simply put, efficiency is the degree of input into output, which is the ratio of input and output; effectiveness is the result obtained to achieve target output level. The relationship of effectiveness and efficiency can be expressed in Fig. 89.1.

As shown in Fig. 89.1, the performance depends on the achievement of effectiveness and efficiency, and effectiveness required efficiency to be achieved, which is to achieve goals for organizational effectiveness. In terms of a combination of both input and output levels of education, the organization have no efficiency representing the organization's incapacity for the utilization of resources, waste of resources, and income or output not being able to achieve the desired best results, which fails to reach expected output and the performance of the organization is considered ineffective. Therefore, the performance of school efficiency and

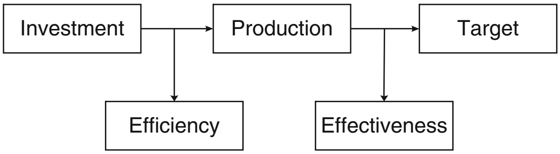


Fig. 89.1 Relationship between effectiveness and efficiency

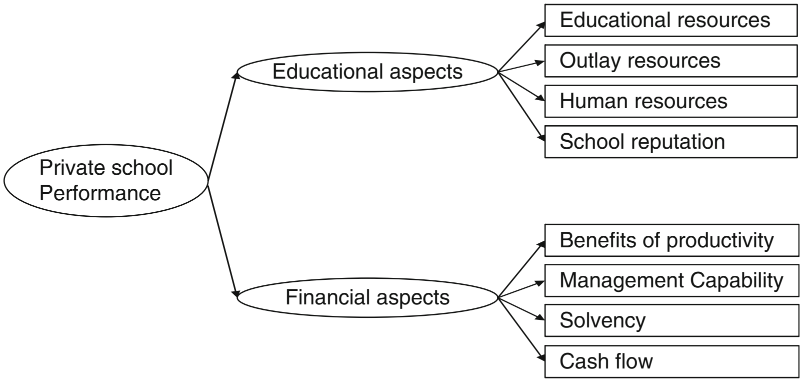


Fig. 89.2 Private schools performance evaluation framework

productivity are the important factors that affect school's effectiveness and performance. This study will divide the performance evaluation of private school into two parts: (1) Educational aspect, (2) financial aspect, respectively. In the aspect of education, it includes educational resources, outlay resources, human resources, school reputation; in financial aspects, it includes benefit of productivity, management capacity, solvency and cash flow, as shown in Fig. 89.2.

Most of the research articles on school performance evaluation focus on educational levels. The education resources inputs contain the school grounds, school floor area, library area and the books total amount. Outlay resources include the equipment and other expenditures. Human resources include full-time teachers with a master's degree and the number of qualified teachers and administrative support, and the number of administrative staff support devoted onto the number of per students, each full-time teachers. School reputation includes the number of extra-curricular prestigious awards that students win, reasonable charges and the degree of satisfaction from educational authority.

According to source profile data from Department of Education, in Taipei City Government (2010), the total amount of public and private senior high schools are 48 schools with 77,011 students until July 2010. As shown in Table 89.1, there are 26 public schools with 55,808 students; 22 private senior high schools with 21,203 students. For junior high schools, there are 98,774 students in total with 88,948 students' public junior high schools and 9,826 students in private junior high schools. The total numbers of student in junior high and senior high schools in Taipei are 175,785.

Table 89.1 Taipei municipal and private high school students enrollment in 2009

	Senior high		Junior		Total	
Schools	School	Student	School	Student	School	Student
Public	26	55,808	59	88,948	85	144,756
Private	22	21,203	3	9,826	25	31,209
Total	48	77,011	62	98,744	110	175,755

22 Taipei private complete secondary schools were selected in (including junior high and high) the research targets on four schools among them. The select of the schools is according to the basic information shown in conformity with 12 secondary schools in Taipei, Due to the difficult to acquire information resources, this paper choose the four schools with the closest student's number for assessment for evaluation.

Results

In this paper, the initial construction of the adjusted performance indicators for private high school are put into 8 major categories with total of 38, as shown in Tables 89.2 and 89.3. The operational definition is based on "Department of Education 2010 award grants on the overall development of private primary and secondary schools implementation plan" published by Department of Education Statistics, Educational Statistics of Taipei City (2009); partly is based on financial statement analysis showed (Hsu 2006; Wang and Chang 2009; Tien 2010); and another part of the system in accordance with the current high school education assessments indicators from general public communities.

According to the rank order in the same group between the indicators, the researcher calculates the indicator points. The indicator with the highest point over threshold values (0.65) can be chosen as the representative indicator. The results of grouping indicators and selecting representative indicators were shown in Table 89.4 and in Fig. 89.3.

By TOPSIS, the scores and ranking results of private schools with levels of performance level were shown in Table 89.5. Figures in brackets are the relative proximity for the ideal solution. The higher the value in brackets is same important to the closer to the ideal solution and shows better performance. From Table 89.5, 'A' high school shows the best performance in the overall operating performance and 'C' high school is the worst.

Table 89.2 Initial indicators set in educational aspects for Taiwan private high schools

Dimensions	Code	Indicators items	Operational definition
Educational resource	ER_1	1-1 every school area per students	total schools area/total number of school students
	ER_2	1-2 average school floor area per student	total schools construction area/total number of school students
	ER_3	1-3 Library space per student Number of	School Library area/total number of school students
	ER_4	1-4 Number of books per student	Number of books/total number of students
	ER_5	1-5 Library seats per student	Library seats/total number of students
Outlay resource	FR_1	2-1 The average equipment expenditure per student	School yearly funding for the purchase of equipment/total number of school students of schools
	FR_2	2-2 teaching, research and training expenditure per students	Secondary school teaching research and training funding/total number of school students
	FR_3	2-3 The average unit cost per student	Current Account Expenditure/total number of students
	FR_4	2-4 Scholarships per student	School Scholarships/total number of school students
	FR_5	2-5 The average administration and management expenditure per student	School administration and management expenses/total number of school students
Human resource	LR_1	3-1 student-teacher ratio	Total number of students/school total number of full-time teachers
	LR_2	3-2 ratio of full-time teachers with a master's degree	Full-time teachers in schools with a master degree/number of total number of full-time teachers school $\times$ 100%
	LR_3	3-3 ratio of for qualified full-time teachers	Number of full time teachers/school requirements of the total number of teachers $\times$ 100%
	LR_4	3-4 ratio of administrative support per student	School professionals, staff, technicians, security and other administrative support full-time human total number/total number of school students
	LR_5	3-5 ratio of administration human resource support for full-time faculty	School professionals, staff, technicians, security and other administrative support full-time human total number/total number of full-time teachers
School reputation	SP_1	4-1 Awarded rate of students participating in external competitions authority	The number of students awarded in international, national, municipal, county (city) authorities hosted competition/total number of students * 100%
	SP_2	4-2 students admitted to the National Universities	The number of graduates admitted to National Universities/academic year graduates
	SP_3	4-3 growth rate of students admitted to the National Universities	The number of graduates admitted to National University in 2010/The number of graduates admitted to National Universities in 2009
	SP_4	4-4 Satisfaction of supervising authorities	Subsidies, grants/Total subsidies and grants of the four schools
	SP_5	4-5 degree of reasonable charges	Tuition expense/charge upper limit

Table 89.3 Initial indicators set in financial aspects for Taiwan private high schools

Dimensions	Code	Indicators items	Operational definition
Educational resource	LB_1	1-1 Revenue per employee	Total revenue/total staff
	LB_2	1-2 Profit and loss per employee	Net income/total number of staff
	LB_3	1-3 Value added per employee	[total income – (expenses - salary)]/total number of staff
	LB_4	1-4 Value added per employee to salaries ratio	[total income - (expenses - salary)]/Salary
Outlay resource	BA_1	2-1 Assets turnover ratio	Total income/total assets
	BA_2	2-2 Cash flow turnover ratio	Total income/cash
	BA_3	2-3 Fixed asset turnover ratio	Total income/fixed assets
	BA_4	2-4 Equity turnover ratio	Total income/total equity
	BA_5	2-5Capital equity growth ratio	Net income/total equity
Human resource	SA_1	3-1 Debt ratio	Total liabilities/total assets
	SA_2	3-2 Equity ratio	Total equity/total assets
	SA_3	3-3 Ratio of current assets to total assets	Current assets/total assets
	SA_4	3-4 Ratio of fixed assets to total assets	Fixed assets/total assets
	SA_5	3-5 Ratio of current assets to total liabilities	Current assets/liabilities
School reputation	CF_1	4-1 Cash flow ratio	Net cash flow from operation/current liabilities
	CF_2	4-2 Ratio of Cash reinvestment	Net cash flow from operation/fixed assets + long-term investment + other assets + Net working capital
	CF_3	4-3Ratio of Cash flow to debt	Net cash flows from operation/total liabilities
	CF_4	4-4 Ratio of Net cash flow	Net cash flow of operation/net income

Table 89.4 Classification of indicators groups of educational and financial aspects for private schools

Categories	groups	Representative indicators of each group	Indicators within each group
Indicators in educational aspect	**ER-** I	**ER_7** (Average per student funding for education and training auxiliary expenditures)	**ER_4, ER_5, ER_7, ER_8, ER_{13}**
	ER-II	**ER_{11}** (Student-teacher ratio)	**ER_1, ER_{11}, ER_{15}, ER_{16}, ER_{19}, ER_{20}**
	ER-III	**ER_{14}** (Administrative support per student)	**ER_2, ER_3, ER_6, ER_9, ER_{10}, ER_{12}, ER_{14}, ER_{17}**
	ER- IV	**ER_{18}** (Growth rate of graduates admitted to the State University)	**ER_{18}**
Indicators in financial aspects	**FR-** I	**FR_4** (Value-added ratio of salary per person)	**FR_1, FR_2, FR_4, FR_5, FR_9, FR_{16}, FR_{18}**
	FR- II	**FR_6** (Cash turnover ratio)	**FR_6, FR_{13}**
	FR- III	**FR_7** (Fixed asset turnover ratio)	**FR_7, FR_{12}**
	FR-IV	**FR_{10}** (Debt ratio)	**FR_8, FR_{10}**
	FR-V	**FR_{11}** (Equity ratio)	**FR_3, FR_{11}**
	FR-VI	**FR_{15}** (Cash flow ratio)	**FR_{14}, FR_{15}, FR_{17}**

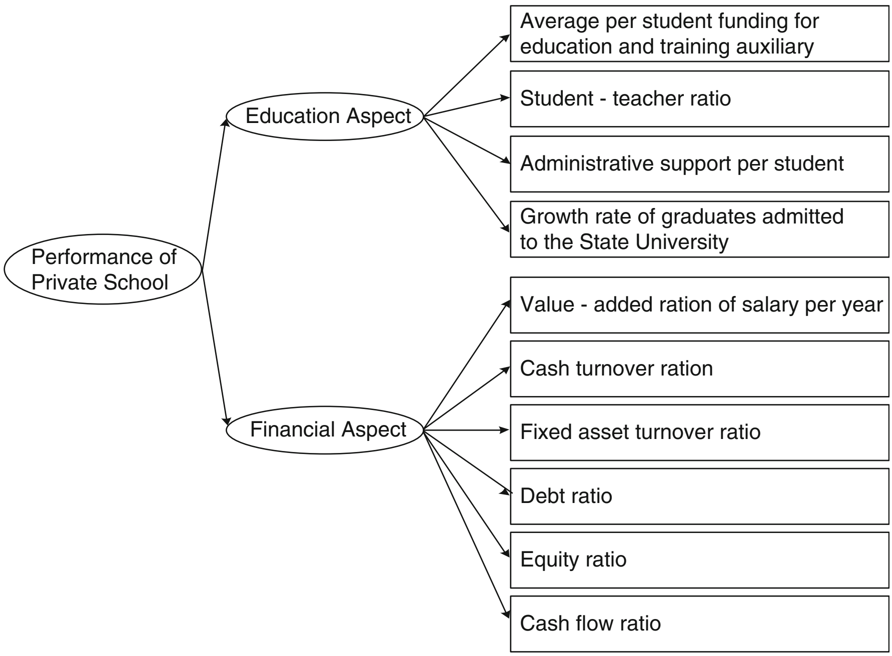


Fig. 89.3 Private high schools performance representative evaluation indicators framework

Table 89.5 Performance ranking of four private high schools

	Ranking			
Items	1st	2nd	3rd	4th
Education aspect	'A'(0.761)	'D'(0.712)	'B'(0.362)	'C'(0.24)
Financial aspect	'B'(0.523)	'A'(0.515)	'C'(0.479)	'D'(0.408)
Overall management performance	'A'(0.633)	'B'(0.508)	'D'(0.507)	'C'(0.405)

( ) indicates the number the proximity of the ideal solution

Conclusion

The purpose of this paper is to completely, practically and operationally provide performance evaluation index set based on operating and financial performance aspects of Taiwan's private high school and then establish the performance evaluation structure and steps of operation and finance of private schools in Taiwan, further improving the quality of education and competitive advantage of each school. In the past researchers only focused on indicators of education to evaluate the performance of education industry and therefore the completeness of the evaluation results were vulnerable to be challenged. This paper proposes a performance evaluation structure which incorporates financial factors into the framework.

Education authorities conduct evaluation for public and private high schools from 2009 to 2012. The difference in the evaluation of public and private schools is that private schools have board of directors, but public schools don't. The education authorities think financial condition of schools is very important for private schools. However, the evaluation about the financial part only focuses on the compliance with laws and regulations. Education authorities should assist private high schools in establishing methods to improve management efficiency, and establishing evaluation indicators for use in corporate financial management.

Schools can show uniqueness by setting up evaluation indicators in the management of private schools. Since the official departments do not pre-dominate the system of performance indicators for private high schools, it is recommended that private high schools can take the performance evaluation indicators of school management constructed in our research into consideration and then collect and publish related information on a regular basis. It can not only provide external stakeholders of private high schools with important references for decision-making, but also provide a basis for internal operation management and for comparison with other schools.

References

Cheng CC (2002) Schools evaluation and knowledge management. World Teach 117:21
Deng JL (1982) Control problems of grey systems. Syst Control Lett 5:288–294
Deng JL (1988) Grey control system. Hua Chung University of Science and Technology, Wuhan

Deng JL (1992) A course on grey system theory. Hua Chung University of Science and Technology, Wuhan
Hsu MC (2006) A study on the construction of evaluation indicators for vocational high schools at Taiwan. Doctoral dissertation, National Kaohsiung Normal University, Kaohsiung, Taiwan
Huang JD (2004) Comparative analysis of American secondary education evaluation Standards vs Evaluation standard of high school, comprehensive high school in Taiwan. Technol Vocat Educ 73:16–20
Hwang CL, Yoon K (1981) Multiple attribute decision making: methods and applications: a state-of-the-art survey. Springer, Berlin/New York
Lin XF (1990) The study of the relationship among leadership of principals, organizational climate and organization performance in Taiwan technique institutes. Doctoral dissertation, National Taiwan Normal University, Taiwan
Ministry of Education, Department of Statistics (2009) Summary of education at all levels. Retrieved 31 July 2010. http://www.edu.tw/files/site_content/b0013/seriesdata.xls
Seetoo DH (1999) Non-profit organization management. Common Wealth, Taipei
Smith LM (2000) Validity and accountability in high-stakes testing. J Teach Educ 51(5):334–345
Taipei City Government, Department of Education (2009) 2009–2012 public and private senior high school evaluation plan – school evaluation handbook. Author, Taipei City
Taipei City Government, Department of Education (2010) Senior high school education. Retrieved 30 Apr 2011, from: http://www.edunet.taipei.gov.tw/, 8 Oct
Tien MH (2010) Practice in accounting reports. Best Wise, Taipei
Wang RT (2001) Framework building and application of the performance evaluation in transport industries – cases of highway buses and domestic airlines. Doctoral dissertation, National Chiao Tung University, Taiwan
Wang YC, Chang CC (2009) Financial statement analysis. Shinlou Book, Taipei

Chapter 90
Assessment of Hydrogen Storage Technologies by Using Compromised Weighting Method

Pao-Long Chang, Chiung-Wen Hsu, and Chih-Min Hsiung

Abstract The purpose of this study is to establish an assessment model for hydrogen storage technologies and examine its applicability. The model is based on multicriteria decision making (MCDM). Evaluation criteria that conform to government policies are adopted. The model involves the use of criteria weights assigned by experts, and a constrained least-squares method to obtain a compromise set of weights; appropriate hydrogen storage technology options are subsequently determined by using the weights. The model indicates that metal hydride technology is the most appropriate for Taiwan. Therefore, this technology should be given top priority for further development in order to promote industrialization.

Keywords Hydrogen storage • MCDM • Compromised weights • Technology assessment

Introduction

Hydrogen is a sustainable energy source. Several technologies are currently being developed, including those pertaining to hydrogen production, storage, and transportation. The storage of hydrogen is an important aspect of the use of hydrogen energy. With the help of government funding, research institutes in Taiwan have developed several hydrogen storage technologies. These technologies involve the

P.-L. Chang (✉)
Department of Business Administration, Feng Chia University, Taichung, Taiwan
e-mail: plchang@fuc.edu.tw

C.-W. Hsu
Graduate Institute of Management of Technology, Feng Chia University, Taichung, Taiwan
e-mail: cwenhsu@fcu.edu.tw

C.-M. Hsiung
Research Center for Industry and Technology Policy, Feng Chia University, Taichung, Taiwan

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_90,

use of metal complex hydrides, carbon nanotube materials, and metal-organic frameworks. However, since the funding provided by the government for technology R&D is very limited—for instance, only USD 28 million was invested from 2005 to 2008 for the development of hydrogen energy technology—identifying the most appropriate technology for further development has become a crucial task. Therefore, the aim of this study is to develop an effective assessment model for choosing the hydrogen storage technology that is the most appropriate for further development in Taiwan.

Since the characteristics, such as energy efficiency, and the cost differ significantly among different hydrogen storage technologies, it is difficult for a decision maker to evaluate the technologies and select the most appropriate technology on the basis of a few criteria. Therefore, it is essential to develop a feasible assessment model that can be used by the Taiwanese government to select the hydrogen storage technology that is the most appropriate for further development. For this type of decision-making problems involving the achievement of multiple goals, the multicriteria decision-making (MCDM) method is widely used (Diakoulaki and Karangelis 2007).

The major hydrogen storage technologies currently available are (Jensen et al. 2007; Hydrogen energy 2006; Hua et al. 2010; Ahluwalia et al. 2010; Edwards et al. 2008) hydrogen storage by compression (compressed hydrogen), low-temperature liquidized hydrogen storage (liquid hydrogen), solid-state hydrogen storage in hydrogen storage alloys (metal hydrides), and chemical hydrogen storage using hydrides (chemical hydrides). In addition, the development of novel hydrogen storage materials (i.e., nanotubes) with the aid of nanotechnology is an important subject of research. Nevertheless, the development of such nanomaterials for use in hydrogen storage is still in the R&D stage. Only the four above-mentioned currently available technologies are selected for the assessment. The main objective of this study is to construct a model for the assessment of the above-mentioned hydrogen storage technologies for the purpose of helping the Taiwanese government make decisions that will promote both energy conservation and the new hydrogen energy industry.

Selection of Evaluation Criteria

When applying the MCDM method, the first question we need to ask is, how should we determine the evaluation criteria? The evaluation criteria must be chosen in congruence with policy and industrial development aims. In Taiwan, there are concerns about energy conservation, CO_2 emission reduction, and promotion of the hydrogen energy industry. On the basis of a literature survey and considering technical, economic, and environmental perspectives, the criteria chosen for the evaluation of the hydrogen storage technologies are as follows:

1. Energy efficiency
   Efficiency is usually defined as the ratio between a system's output power (energy) and the energy consumed by the system (generally in the form of electricity or heat). During the process of hydrogen storage, energy is needed, and it may be supplied by external sources (for example, electricity). In this study, the efficiency criterion is used to evaluate the performance of hydrogen storage technology in terms of energy conservation.
2. Cost
   The hydrogen storage technology with the lowest cost tends to be more competitive; the competitiveness will help promote the development of the technology as well as the associated industry. As an evaluation criterion, cost can be further divided into capital cost (Afgan et al. 2007; Pilavachi et al. 2009), operation and manufacturing cost (Afgan et al. 2007; Pilavachi et al. 2009), and investment cost. In this study, the storage system cost is considered as an evaluation criterion.
3. Volume density (g/L)
   From a technical viewpoint, the focus of current research on hydrogen storage technology is the development a technique that can store a large amount of hydrogen in the least volume and with the smallest weight. Therefore, in this study, the concepts of volume density and gravimetric capacity are adopted to evaluate the hydrogen storage capability. The volume density is defined as the weight (g) of hydrogen stored per unit volume of the hydrogen storage system (L).
4. Gravimetric capacity
   Gravimetric capacity is defined as the weight percentage (wt%) of hydrogen stored in the hydrogen storage system.

Compromised Weights

Kao and Hung (2003) have proposed a two-stage method for calculating a posteriori weights. In the method, expert weights are synthesized through direct explication and decisive weights are obtained objectively through mathematical analysis (indirect explication). In this study, a similar but simpler procedure is used for weight determination. In the first stage, we use the weight assigned by each expert to derive the largest assessment score for each option. In the second stage, a compromised set of weights is determined for all options by minimizing the difference between the largest assessment scores and the scores calculated from the compromised set of weights.

Let S_{ij}, $i = 1, \ldots, \mathrm{n}$ and $j = 1, \ldots, \mathrm{m}$, denote the assessment score of the ith hydrogen storage option determined by considering the jth criterion. Note that the score is standardized to lie between 0 and 1. Let w_{lj} denote the weight assigned to criterion j by expert l. Then, the largest assessment score for option i among all the weights w_{lj} assigned by experts can be calculated as

$$I_i^* = \max_l \left\{ \sum_{j=1}^{m} w_{lj}\ S_{ij} \right\} \tag{90.1}$$

In the second stage, a compromised set of weights that is advantageous to all hydrogen storage options is sought on the basis of a centralized consideration. Let w_j denote the compromised set of weights. Then, $\sum_{j=1}^{m} w_j S_{ij}$ is the compromised composite score of the ith option, and $\left(I_i^* - \sum_{j=1}^{m} w_j S_{ij}\right)^2$ is the squared difference between the largest assessment score and the compromised composite score. A compromised set of weights w_j^* can be obtained by quadratic programming:

$$Min \sum_{i=1}^{n} \left(I_i^* - \sum_{j=1}^{m} w_j S_{ij} \right)^2 \tag{90.2}$$

$$\text{s.t.} \sum_{j=1}^{m} w_j = 1$$

$$l_j \leq w_j \leq u_j, \quad j = 1, \ldots, \mathrm{m}$$

After the compromised weights w_j^* are obtained from model (90.2), the compromised composite score $\sum_{j=1}^{m} w_j^* S_{ij}$ is calculated. In fact, model (90.2) is a compromised programming model used in multiple criteria decision analysis (Yu 1973). Because it involves the least-squares function, the optimal weights w_j^* and the compromised composite score $\sum_{j=1}^{m} w_j^* S_{ij}$ have two important properties in multiple criteria decision analysis: they have a Pareto optimum and a unique solution (Yu 1973). Hence, apart from being more acceptable for all hydrogen storage options, the weighted results prevent ambiguity when the options are compared.

Assessment Matrix

In this study, actual data from the literature were used to evaluate the performance of the four hydrogen storage technologies in terms of energy efficiency, cost, volumetric density, and gravimetric capacity. Results were normalized to produce scores ranging from 0 to 1 for use in the construction of the assessment matrix.

Energy Efficiency

1. Compressed hydrogen
   A substantial amount of energy is required to increase the pressure of hydrogen from atmospheric pressure (1 atm or 14.7 psi) to 350 or 700 bars (about 5,000 psi) in a compressor. Bossel et al. (2003) and Weindorf et al. (2011) have estimated the work of compression in real systems. According to them, compression to 800 bars is possible using 18 or 13% of the lower heating value (LHV). Jensen et al. (2007) estimated that compression to a final pressure of 800 bar would cost 15.5% of the LHV.
2. Liquid hydrogen
   Under atmospheric pressure, a temperature less than 20 K (or −253°C) is required to convert hydrogen from the gaseous state into the liquid state. Therefore, most of the energy provided will be consumed by the equipment used for lowering and maintaining the temperature. The practical energy demand for liquefaction is significantly large and depends on the size of the plant. The energy demand in a modern plant is of the order 40–45% of the LHV (Jensen et al. 2007), and in very large liquefaction plants, the energy demand can reduce to 21–25% of the LHV (Bossel et al. 2003; Weindorf et al. 2011).
3. Metal hydrides
   The temperature at which hydrogen is stored and released is different for different metal hydrides. As a result, energy (electricity or heat) is required to power a compressor as well as heating/cooling equipment. The energy needed ranges from 12.4% of the LHV (interstitial MH) to 30.8% of the LHV (MgH_2) (Jensen et al. 2007).
4. Chemical hydrides
   The release of hydrogen by a chemical hydride involves an exothermic reaction. As a result, the reduction of a reactant to form chemical hydrides, or any other process that involves the conversion of chemicals into chemical hydrides, will require a substantial amount of energy. The amount of energy needed will depend on the type of chemical hydride used and the reduction process involved. For example, in the case of $NaBH_4$, the heat generated by the release of hydrogen upon the addition of water is equivalent to 22% of the LHV. Therefore, the reduction of $NaBO_2$ (formed upon the release of hydrogen) to $NaBH_4$ is theoretically found to require at least 22% of the LHV. In practice, the energy consumed for such a process is twice this value (Jensen et al. 2007).

The energy efficiency assessment values set in this study are shown in Table 90.1; the values have been obtained from the above-mentioned analysis by assuming normal-sized liquefaction plants. For liquid hydrogen, the energy used for storage is 40% of the LHV. If it is assumed that the energy efficiency for the reduction of $NaBO_2$ to $NaBH_4$ is 75%, 29% of the LHV (22% of the LHV/0.75) is required to carry out the process. Since the energy used for storage in metal

Table 90.1 Assessment data for the hydrogen storage technologies

Technology type	Energy used for storage (% LHV)	Volumetric density (g-H_2/L)	Gravimetric capacity (wt%)	Storage system cost ($/kW h)
Compressed hydrogen	15.5	17.6	5.5	15.4
Liquid hydrogen	40.0	44.7	7.1	8.39
Metal hydrides	12.4	48.2	2.0	16.0
Chemical hydrides	29.0	28.7	3.2	4.7

Table 90.2 Assessment scores for the hydrogen storage technologies

Technology type	Energy efficiency S_{i1}	Volumetric density S_{i2}	Gravimetric capacity S_{i3}	Cost S_{i4}
Compressed hydrogen	0.800	0.365	0.775	0.305
Liquid hydrogen	0.310	0.927	1.000	0.560
Metal hydrides	1.000	1.000	0.282	0.294
Chemical hydrides	0.428	0.595	0.451	1.000

hydrides is 12.4% of the LHV, which is the lowest value among the values of the four technologies studied, the score for metal hydrides is set to 1. The scores for the four technologies in Table 90.2 have been normalized by the best value and transformed by using the formula score = 12.4/energy used for storage.

Volumetric Density

1. Compressed hydrogen
   In a compressed-hydrogen storage system, the volumetric density is directly proportional to the hydrogen pressure. In Dynetek's compressed-hydrogen storage system, the volumetric density reaches 11.6 and 18.6 g-H_2/L as the hydrogen pressure reaches 200 and 350 bars, respectively (Hydrogen energy 2006). In Hua et al.'s assessment of compressed-hydrogen storage systems for use in hydrogen cell vehicles (Hua et al. 2010), it was found that volumetric densities of 17.6 and 26.3 g-H_2/L could be reached at hydrogen pressures of 350 and 500 bars, respectively. For a given amount of hydrogen storage (5.6 kg), the total volumes required for a 350-bar system and a 500-bar system were 319 and 212.9 L, respectively.
2. Liquid hydrogen
   In Ahluwalia et al.'s assessment of cryo-compressed hydrogen storage tank systems for use in a fuel cell vehicle (Ahluwalia et al. 2010), it was found that a volumetric density of 41.8–44.7 g-H_2/L could be reached for the Gen-3 prototype tank system developed by the Lawrence Livermore National Laboratory

(LLNL). This system has a hydrogen storage volume of 151 L, and the total system volume is 235 L.

3. Metal hydrides
   Metal hydrides have an extremely high volumetric density, typically around 50–100 g-H_2/L (Edwards et al. 2008). For example, low-temperature MH has a volume% of approximately 0.055, equivalent to 48.2 g-H_2/L (Gardiner and Burke 2002).
4. Chemical hydrides
   Lasher et al. (2006) evaluated sodium borohydride ($NaBH_4$) and sodium alanate ($NaAlH_4$) hydrogen storage systems, and both were found to have a hydrogen storage capacity of 5.6 kg. The total volumes were 195 and 285 L for the sodium borohydride and sodium alanate hydrogen storage systems, respectively; these volumes were equivalent to volumetric densities of 28.7 and 19.6 g-H_2/L, respectively.

The volumetric density assessment values obtained on the basis of the information presented above are shown in Table 90.1; in the table, compressed hydrogen corresponds to a pressure of 350 bars, metal hydrides are represented by interstitial MH, and chemical hydrides are represented by $NaBH_4$. Since the volumetric density of metal hydrides is 48.2 g-H_2/L, which is the highest value among the values of the four technologies studied, the score for this technology is set to 1. The scores for the four technologies in Table 90.2 have been normalized by the best value, i.e., by 48.2.

Gravimetric Capacity

1. Compressed hydrogen
   In the evaluation performed by Hua et al. (2010), the gravimetric capacities for 350- and 500-bar compressed-hydrogen storage systems were 5.5 and 5.2 wt%, respectively. For a given amount of hydrogen storage (5.6 kg), the total weights of the 350- and 500-bar compressed-hydrogen storage systems were 101.1 and 108.6 kg, respectively. The main contributors to the weights of the compressed-hydrogen storage systems were the carbon fiber (CF, 53–62%), the shell of the tank, and the power of the plant (BOP, 17–19%).
2. Liquid hydrogen
   According to the study of Ahluwalia et al. (2010), the maximum amount of hydrogen stored in the case of the LLNL Gen-3 prototype tank system was 10.4 kg, with the gravimetric capacity being 7.1%. The weight of the system included the weights of the shell (34%), liner (27%), CF (15%), and BOP (11%).
3. Metal hydrides
   The gravimetric capacities of the different metal hydrides differ significantly. For instance, the gravimetric capacity of interstitial MH is 1–2 wt%, while that of MgH_2 can be as high as 7.6 wt% (Jensen et al. 2007).

4. Chemical hydrides
   In the study of Lasher et al. (2006), the total weights of the sodium borohydride and sodium alanate hydrogen storage systems were 175 and 350 kg, respectively, assuming that the amount of hydrogen stored in both was 5.6 kg. Therefore, the gravimetric capacities of the two hydrogen storage systems were equivalent to 3.2 and 1.6 wt%, respectively.

In Table 90.1, compressed hydrogen corresponds to a pressure of 350 bars, metal hydrides are represented by interstitial MH, and chemical hydrides are represented by $NaBH_4$. The scores for the four technologies in Table 90.2 have been normalized by the best value, i.e., 7.1.

Cost

1. Compressed hydrogen
   The Boothroyd-Dewhurst Design for Manufacturing & Assembly (DFMA®) software was used by Hua et al. (2010) to estimate the cost of a 350-bar compressed-hydrogen storage system. Depending on the production scale and procurement conditions, the cost was around 10.6–19.7 $/kW h, with an average value of 15.4 $/kW h. The cost of a 500-bar hydrogen storage system was around 13.5–27.2 $/kW h, with an average value of 18.7 $/kW h.
2. Liquid hydrogen
   According to the study of Ahluwalia et al. (2010), the cost of the LLNL Gen-3 prototype tank hydrogen storage system for 10.4 kg of stored hydrogen was around 7.57–10.7 $/kW h, with an average value of 8.39 $/kW h.
3. Metal hydrides
   Since few metal hydrides have been produced, very limited information is available about the system cost. In a study carried out by Chalk and Miller (2006), the cost of a metal hydride system was found to be around 16 $/kW h.
4. Chemical hydrides
   The cost of the sodium borohydride hydrogen storage system is around 4.7 $/kW h and that of the sodium alanate hydrogen storage system is around 11.3 $/kW h (Lasher et al. 2006).

The cost assessment values obtained on the basis of similar arguments and the scores for the four technologies are shown in Tables 90.1 and 90.2.

Assessment Results

In this study, five experts from diverse disciplines, including environmental engineering, chemical engineering, mechanical engineering, and technology policy, were invited to participate in a questionnaire survey. The assessment results for each criterion provided by each expert are shown in Table 90.3.

Table 90.3 Expert weights for the four criteria

Expert weight w_{lj}	Energy efficiency	Volumetric density	Gravimetric capacity	Storage cost
Expert A	0.295	0.166	0.146	0.393
Expert B	0.382	0.127	0.111	0.38
Expert C	0.402	0.142	0.142	0.314
Expert D	0.357	0.143	0.143	0.357
Expert E	0.397	0.103	0.103	0.397
Weight range	0.295–0.402	0.103–0.166	0.103–0.146	0.314–0.397

Table 90.4 Highest assessment scores and corresponding weights for the four storage technologies

Weight w_{lj} for score Ii*	Energy efficiency	Volumetric density	Gravimetric capacity	Storage cost	Largest assessment score I_i^*
Compressed hydrogen	0.402	0.142	0.142	0.314	0.579
Liquid hydrogen	0.295	0.166	0.146	0.393	0.611
Metal hydrides	0.402	0.142	0.142	0.314	0.676
Chemical hydrides	0.295	0.166	0.146	0.393	0.684

For each criterion, we use Eq. (90.1) and consider the score in Table 90.2 and the expert weight in Table 90.3 to determine the highest assessment score for each technology. The highest assessment scores are presented in Table 90.4.

Next, we use model (90.2) to determine the compromised weights as follows:

$$Min\sum_{i=1}^{4}\left(I_i^* - \left(w_1S_{i1} + w_2S_{i2} + w_3S_{i3} + w_4S_{i4}\right)\right)^2$$

$$\text{s.t. } w_1 + w_2 + w_3 + w_4 = 1$$

$$0.295 \leq w_1 \leq 0.402,$$

$$0.103 \leq w_2 \leq 0.166,$$

$$0.103 \leq w_3 \leq 0.146, \quad \text{and}$$

$$0.314 \leq w_4 \leq 0.397$$

The computation can be performed by using *Mathematica* software. The optimal solutions are (1) $w_1^* = 0.335$, (2) $w_2^* = 0.166$, (3) $w_3^* = 0.142$, and (4) $w_4^* = 0.337$. The performance scores and ranks obtained for the four hydrogen storage technologies by using these compromised weights are listed in Table 90.5.

Table 90.5 Performance scores for the four storage technologies, obtained using the compromised weights

Storage technology	Compressed hydrogen	Liquid hydrogen	Metal hydrides	Chemical hydrides
Performance score	0.557	0.595	0.660	0.652
Rank	4	3	1	2

$W_1^* = 0.355$, $W_2^* = 0.166$, $W_3^* = 0.142$, and $W_4^* = 0.337$

Conclusion and Policy Implications

In this study, an assessment model based on the MCDM method was constructed for evaluating hydrogen storage technologies. This model can act as a screening tool for government policy makers, enabling them to select hydrogen storage technologies that conform to the objectives of promotion of energy conservation and industrial development. The research findings indicate that metal hydride technology should be given the top priority in Taiwan. Thus, the country should focus on research and development of this technology, along with its commercialization.

In the development of metal-hydride-based hydrogen storage technologies and products, Taiwan has made significant strides, as evidenced by the following facts. (1) Asia Pacific Fuel Cell Technologies, Ltd., Hsu-Yang Technologies Co., Ltd., and HBank Technologies Inc. are capable of manufacturing hydrogen storage products based on La–Ni and Ti–Mn alloys. (2) The Industrial Technology Research Institute has developed a nanostructure Mg-based hydrogen storage material that can store up to 6 wt% of hydrogen at 150°C. (3) Complex metal hydrides such as LiAl, MgLi, and Li_3N have been developed by the National Central University; among these, Li_3N can store up to 6.2 wt% of hydrogen at 180°C.

In general, the development of metal hydrogen storage technologies in Taiwan lags behind that at the international level. For instance, a gravimetric capacity of 2.3 wt% has been achieved internationally for metal hydrogen storage, whereas that achieved in Taiwan is about 1.0 wt%. This indicates that if Taiwan wishes to develop hydrogen storage technologies that are internationally competitive, sustained efforts and investments will be required.

Acknowledgment The authors appreciate the financial support provided by the National Science Council of Taiwan (NSC 101-3113-P-035-001; NSC 99-2632-E-035-001-MY3).

References

Afgan NA, Veziroglu A, Carvalho MG (2007) Multi-criteria evaluation of hydrogen system options. Int J Hydrog Energy 32:3183–3193

Ahluwalia RK, Hua TQ, Peng JK, Lasher S, McKenney K, Sinha J, Gardiner M (2010) Technical assessment of cryo-compressed hydrogen storage tank systems for automotive applications. Int J Hydrog Energy 35:4171–4184

Bossel U, Eliasson B, Taylor G (2003) The future of the hydrogen economy: bright or bleak? In: 2003 Fuel Cell Seminar, 3–7 Nov 2003. http://www.efcf.com/reports/E08.pdf. Accessed 15 Aug 11

Chalk SG, Miller JF (2006) Key challenges and recent progress in batteries, fuel cells, and hydrogen storage for clean energy systems. J Power Source 159:73–80

Diakoulaki D, Karangelis F (2007) Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece. Renew Sustain Energy Rev 11:716–727

Edwards PP, Kuznetsov VL, David WIF, Brandon NP (2008) Hydrogen and fuel cells: towards a sustainable energy future. Energy Policy 36:4356–4362

Gardiner MG, Burke A (2002) Comparison of hydrogen storage technologies: a focus on energy required for hydrogen input. Fuel Chem Division Prepr 47:794–795

Hua T, Ahluwalia R, Peng JK, Kromer M, Lasher S, McKenney K, Law K, Sinha J (2010) Technical assessment of compressed hydrogen storage tank systems for automotive applications. Argonne National Laboratory, ANL-10/24, Sept 2010. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/compressedtank_storage.pdf. Accessed 10 July 2011

Hydrogen energy (2006) In: Fuel cells for land, sea and air vehicles, chapter 4. NATO, RTO Technical report, RTO-TR-AVT-103, 2006. http://www.sse.gr/NATO/EreunaKaiTexnologiaNATO/2.Fuel_cells_for_land_sea_and_air_vehicles/RTO-TR-AVT-103/TR-AVT-103-04.pdf. Accessed 16 May 2011

Jensen JO, Vestbø AP, Li Q, Bjerrum NJ (2007) The energy efficiency of onboard hydrogen storage. J Alloys Compd 31:723–728

Kao C, Hung HT (2003) Ranking university libraries with a posteriori weights. Libri 53:282–289

Lasher S, Carlson E, Bowman J, Marion M, Yang Y, Unnasch S, Hooks M (2006) Cost analysis of hydrogen storage systems. DOE Hydrogen Program. 2006 Annual Progress Report, pp 535–540

Pilavachi PA, Chatzipanagi AI, Spyropoulou AI (2009) Evaluation of hydrogen production methods using the analytic hierarchy process. Int J Hydrog Energy 34:5294–5303

Weindorf W, Bünger U, Schindler J (2011) Comments on the paper by Baldur Eliasson and Ulf Bossel–the future of the hydrogen economy: bright or bleak? http://www.mpfc.de/pdf/LBSTonBossel.pdf. Accessed 10 Aug 2011

Yu PL (1973) A class of solutions for group decision problems. Manag Sci 19:936–946