Yi-Kuei Lin · Yu-Chung Tsao
Shi-Woei Lin *Editors*

Proceedings of the Institute of Industrial Engineers Asian Conference 2013

Springer

Proceedings of the Institute of Industrial Engineers Asian Conference 2013

Yi-Kuei Lin · Yu-Chung Tsao
Shi-Woei Lin
Editors

Proceedings of the Institute of Industrial Engineers Asian Conference 2013

Springer

Editors
Yi-Kuei Lin
Yu-Chung Tsao
Shi-Woei Lin
Department of Industrial Management
National Taiwan University of Science and Technology
Taipei
Taiwan, R.O.C.

ISBN 978-981-4451-97-0 ISBN 978-981-4451-98-7 (eBook)
DOI 10.1007/978-981-4451-98-7
Springer Singapore Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013943711

Printed on acid-free paper

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

Preface

The organizers of the IIE Asian Conference 2013, held July 19–22, 2013 in Taipei, Taiwan, are pleased to present the proceedings of the conference, which includes about 180 papers accepted for presentation at the conference. The papers in the proceedings were selected from more than 270 paper submissions. Based on input from peer reviews, the committee selected these papers for their perceived quality, originality, and appropriateness to the theme of the IIE Asian Conference. We would like to thank all contributors who submitted papers. We would also like to thank the track chairs and colleagues who provided reviews of the submitted papers.

The main objective of IIE Asian Conference 2013 is to provide a forum for exchange of ideas on the latest developments in the field of industrial engineering and management. This series of conferences were started and supported by the Institute of Industrial Engineers (IIE) in 2011 as a meeting of organizations striving to establish a common focus for research and development in the field of industrial engineering. Now after just 2 years of the first event, the IIE Asian Conference has become recognized as an international focal point annually attended by researchers and developers from dozens of countries around the Asian.

Whether the papers included in the proceedings are work-in-progress or finished products, the conference and proceedings offer all authors opportunities to disseminate the results of their research and receive timely feedback from colleagues, without long wait associated with publication in peer-reviewed journals. We hope that the proceedings will represent a worthwhile contribution to the theoretical and applied body of knowledge in industrial engineering and management. We also hope that it will attract some other researchers and practitioners to join future IIE Asian Conferences.

Finally, the organizers are indebted to a number of people who gave freely their time to make the conference a reality. We would like to acknowledge Dr. Ching-Jong Liao, the president of the National Taiwan University of Science and Technology (Taiwan Tech), and all faculties and staffs in the Department of Industrial

Management at the Taiwan Tech, who have contributed tremendous amount of time and efforts to this conference. The Program Committee would also like to express its appreciation to all who participate to make the IIE Asian Conference 2013 a successful and enriching experience.

Program Committee of IIE Asian Conference 2013

Contents

An Optimal Ordering Policy of the Retailers Under Partial Trade Credit Financing and Restricted Cycle Time in Supply Chain

Shin'ichi Yoshikawa

Abstract The traditional EOQ (Economic Order Quantity) model assumes that retailers' capitals are unrestricting and the retailer must pay for items as soon as the retailer receives them from suppliers. However, this may not be true. In practice, the supplier will offer the retailer a delay period. This period is known as the trade credit period. Previously published papers assumed that the supplier would offer the retailer a delay period and the retailer could sell goods and earn interest or investment within the trade credit period. They assumed that the supplier would offer the retailer a delay period but the retailer would not offer the trade credit period to his/her customer. We extend their model and construct new ordering policy. In this paper, the retailer will also adopt the partial trade credit policy to his/her customer. We assume that the retailer's trade credit period offered by the supplier is not shorter than his/her customer's trade credit period offered by the retailer. In addition, they assumed the relationship between the supplier and the retailer is one-to-one. One thing we want to emphasize here is that the supplier has cooperative relations with many retailers. Furthermore, we assume that the total of the cycle time is restricted. Under these conditions, we model the retailers' inventory system to determine the optimal cycle times for n retailers.

Keywords EOQ model · Partial trade credit · Supply chain

1 Introduction

Inventory management is to decide appropriate times and quantities to produce goods. It has a significant impact on the costs and profitability of many organizations. In general, the EOQ model is still a widely used model to guide the

S. Yoshikawa (✉)
Nagoya Keizai University, Uchikubo 61-1, Inuyama, Aichi Prefecture 484-8504, Japan
e-mail: greatriver-1@nagoya-ku.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_1,

management of inventories in many industrial enterprises and service organizations. The EOQ captures the trade-off between inventory carrying cost and ordering cost for each item with accuracy.

Until now, the EOQ model assumes that the retailer's capitals are unrestricting and the retailer must pay for the items as soon as the retailer receives the items from the supplier. However, this may not be completely true. In practice, the supplier will offer the retailer a delay period. This period is called the trade credit period. During this period, the retailer can sell goods and earn interest or investment (Chang et al. 2001; Chen and Chuang 1999; Kim et al. 1995; Hwang and Shinn 1997).

We extend their model and construct new ordering policy. We reconstruct an ordering policy to stimulate his/her customer demand to develop the retailers' replenishment model. The retailer will adopt the partial trade credit policy to his/her customer (Huang and Hsu 2008). We assume that the retailer's trade credit period M offered by the supplier is not shorter than his/her customer's trade credit period N offered by the retailer ($M \geq N$). Moreover, the problem we want to emphasize here is that the supplier has cooperative relations with n retailers. Furthermore, we assume that the total of the cycle time offered for n retailers is restricted. Under these conditions, we model an optimal ordering policy to determine the optimal cycle times for n retailers. This model can be formulated as a mathematical problem.

2 Model Formulations

2.1 Notation

The notations used in this paper are as follows: D: demand rate per year; A: ordering cost per order; c: unit purchasing price per item; h: unit stock holding cost per item per year excluding interest charges; α: customer's fraction of the total amount owed payable at the time of placing an order offered by the retailer, $0 \leq \alpha \leq 1$, I_e: interest earned per \$ per year; I_k: interest charged per \$ in stocks per year by the supplier; M: the retailer's trade credit period offered by supplier in years; N: the customer's trade credit period offered by retailer in years; T: the cycle time in years; $TCV(T)$: the annual total inventory cost, which is a function of T; T^*: the optimal cycle time of $TCV(T)$.

2.2 Assumptions

(1) Demand rate is known and constant; (2) shortages are not allowed; (3) time period is finite; (4) the lead time is zero; (5) $I_k \geq I_e,\ M \geq N$; (6) when $T \geq M$, the account is settled at $T = M$ and the retailer starts paying for the interest charges on the items in stock with rate I_k. When $T \leq M$, the account is settled at $T = M$ and

the retailer does not need to pay any interest charges; (7) the retailer can accumulate revenue and earn interest after his/her customer pays for the amount of purchasing cost to the retailer until the end of the trade credit period offered by the supplier. That is, the retailer can accumulate revenue and earn interest during the period N to M with rate I_e under the condition of the trade credit.

2.3 Model Formulation

From the above notation and assumptions, we construct a model. First, we must consider all the inventory costs. That is, the annual total inventory cost consists of the following four elements.

1. Annual ordering cost is as follow: $\frac{A}{T}$.
2. Annual stock holding cost (excluding interest charges) is as follow: $\frac{DTh}{2}$.
3. According to Assumption 6, there are two cases to occur in costs of interest charges for the items kept in stock per year. Annual interest payable is as follows

$$\frac{cI_k D(T-M)^2}{2T},\ M \le T, \quad 0,\ N \le T < M,\ T \le N$$

4. According to Assumption 7, there are three cases to occur in interest earned per year. Annual interest earned is as follows:

$$\frac{sI_e D[M^2-(1-\alpha)N^2]}{2T},\ M \le T, \quad \frac{sI_e D[2MT-(1-\alpha)N^2-T^2)}{2T},\ N \le T < M$$

$$sI_e D\left[M-(1-\alpha)N-\frac{\alpha T}{2}\right], \quad 0 \le T < N.$$

From the above arguments, the annual total inventory cost for the retailer can be expressed as $TCV(T)$ = ordering cost + stock-holding cost + interest payable cost − interest earned. That is, it is formulated as follows:

$$TCV(T) = \begin{cases} TCV_1(T) & T \ge M, \\ TCV_2(T), & N \le T \le M, \\ TCV_3(T), & 0 < T \le N, \end{cases}$$

$$TCV_1(T) = \frac{A}{T} + \frac{DTh}{2} + \frac{cI_k D(T-M)^2}{2T} - \frac{sI_e D[M^2-(1-\alpha)N^2)}{2T},$$

$$TCV_2(T) = \frac{A}{T} + \frac{DTh}{2} - \frac{sI_e D[2MT-(1-\alpha)N^2-T^2]}{2T},$$

$$TCV_3(T) = \frac{A}{T} + \frac{DTh}{2} - sI_e D\left[M-(1-\alpha)N\frac{\alpha T}{2}\right].$$

Since $TCV_1(M) = TCV_2(M)$ and $TCV_2(N) = TCV_3(N)$, $TCV(T)$ is continuous and well-defined. All $TCV_1(T), TCV_2(T), TCV_3(T)$ and $TCV(T)$ are defined on $T > 0$. Also, $TCV_1(T), TCV_2(T)$ and $TCV_3(T)$ are convex on $T > 0$. Furthermore, we have $TCV_1'(M) = TCV_2'(M)$ and $TCV_2'(N) = TCV_3'(N)$. Therefore, $TCV(T)$ is convex on $T > 0$.

5. According to Assumption 7, there are three cases to occur in interest earned per year. Annual interest earned is as follows:

$$\frac{sI_eD[M^2 - (1-\alpha)N^2]}{2T}, \ M \le T, \quad \frac{sI_eD[2MT - (1-\alpha)N^2 - T^2)}{2T}, \ N \le T < M,$$

$$sI_eD\left[M - (1-\alpha)N - \frac{\alpha T}{2}\right], \quad 0 \le T < N.$$

From the above arguments, the annual total inventory cost for the retailer can be expressed as $TCV(T)$ = ordering cost + stock-holding cost + interest payable cost − interest earned. That is, it is formulated as follows:

$$TCV(T) = \begin{cases} TCV_1(T), & T \ge M, \\ TCV_2(T), & N \le T \le M, \\ TCV_3(T), & 0 < T \le N, \end{cases}$$

$$TCV_1(T) = \frac{A}{T} + \frac{DTh}{2} + \frac{cI_kD(T-M)^2}{2T} - \frac{sI_eD[M^2 - (1-\alpha)N^2)}{2T},$$

$$TCV_2(T) = \frac{A}{T} + \frac{DTh}{2} - \frac{sI_eD\,[2MT - (1-\alpha)N^2 - T^2]}{2T},$$

$$TCV_3(T) = \frac{A}{T} + \frac{DTh}{2} - sI_eD\left[M - (1-\alpha)N\frac{\alpha T}{2}\right].$$

Since $TCV_1(M) = TCV_2(M)$ and $TCV_2(N) = TCV_3(N)$, $TCV(T)$ is continuous and well-defined. All $TCV_1(T), TCV_2(T), TCV_3(T)$ and $TCV(T)$ are defined on $T > 0$. Also, $TCV_1(T), TCV_2(T)$ and $TCV_3(T)$ are convex on $T > 0$. Furthermore, we have $TCV_1'(M) = TCV_2'(M)$ and $TCV_2'(N) = TCV_3'(N)$. Therefore, $TCV(T)$ is convex on $T > 0$.

3 An Optimal Ordering Policy of the Retailers Under Partial Trade Credit Financing and Restricted Cycle Time

We consider an optimal ordering policy of the retailers for the following problem: (1) inventory problem we propose here is in the EOQ model; (2) the number of the retailers is n; (3) the summation of each cycle time t_i $(i = 1, 2, \ldots, n)$ is restricted to T_0; (4) we allocate the restricted cycle time T_0 to n retailers to minimize the summation of total inventory cost.

To solve the problem, we use the inventory model we have already discussed in previous section. First, we formulate the cost function for each retailer. Next, we lead to all retailers' total cost function.

Let t_i be a cycle time for retailer i $(i = 1, 2, \ldots, n)$. Then we obtain the following total inventory cost function for retailer i:

$$TCV_i(t_i) = \begin{cases} TCV_{1i}(t_i), & t_i \geq M_i, \\ TCV_{2i}(t_i), & N_i \leq t_i \leq M_i, \\ TCV_{3i}(t_i), & 0 < t_i \leq N_i. \end{cases}$$

Here, new subscript i represents the retailer's number i $(i = 1, 2, \ldots, n)$. From the above expression, the summation of total inventory cost is shown as follows:

$$\sum_{i=1}^{n} TCV_i(t_i), \quad i = 1, 2, \ldots, n, \tag{1}$$

Therefore, an optimal ordering policy of the retailers under trade credit financing and restricted cycle time we propose here is represented as follows:

$$Minimize \quad \sum_{i=1}^{n} TCV_i(t_i), \tag{2}$$

$$subject\ to \quad \sum_{i=1}^{n} t_i \leq T_0, \quad t_i > 0 \quad (1 = 1, 2, \ldots, n), \tag{3}$$

Now, our aim is to minimize the objective function [Eq. (2)] under the constraints [Eq. (3)]. We differentiate Eq. (2) with respect to t_i. We obtain as follows:

$$TCV'(t_i) = \begin{cases} TCV'_{1i}(t_i) = -\left[\frac{2A_i + c_i D_i M_i^2 I_{ki} - s_i D_i I_{ei}(M_i^2 - (1-\alpha_i)N_i^2)}{2t_i^2}\right] + D_i\left(\frac{h_i + c_i I_{ki}}{2}\right), & t_i \geq M_i, \\ TCV'_{2i}(t_i) = -\left[\frac{2A_i + s_i D_i (1-\alpha_i) N_i^2 I_{ei}}{2t_i^2}\right] + D_i\left(\frac{h_i + s_i I_{ei}}{2}\right), & N_i \leq t_i < M_i, \\ TCV'_{3i}(t_i) = -\frac{A_i}{t_i^2} + D_i\left(\frac{h_i + s_i \alpha_i I_{ei}}{2}\right), & 0 \leq t_i < N_i \end{cases} \tag{4}$$

Here, we define Δ_{1i} and Δ_{2i} respectively.

Table 1 The retailer's optimal cycle time $\tilde{t}_i^*$ for Lagrange's multiplier λ (Case 1)

The range of λ	Optimal cycle time ($\tilde{t}_i^*$)
$\lambda \geq 0$	$\sqrt{\frac{2A_i}{D_i(h_i+s_i\alpha_i I_{ei})}}$
$-\infty < \lambda < 0$	$\sqrt{\frac{2A_i}{D_i(h_i+s_i\alpha_i I_{ei})-2\lambda}}$

Table 2 The retailer's optimal cycle time $\tilde{t}_i^*$ for Lagrange's multiplier λ (Case 2)

The range of λ	Optimal cycle time ($\tilde{t}_i^*$)
$\lambda \geq 0$	$\sqrt{\frac{2A_i+s_iD_i(1-\alpha_i)N_i^2 I_{ei}}{D_i(h_i+s_i I_{ei})}}$
$\Delta_{2i} \leq \lambda < 0$	$\sqrt{\frac{2A_i+s_iD_i(1-\alpha_i)N_i^2 I_{ei}}{D_i(h_i+s_i I_{ei})-2\lambda}}$
$-\infty < \lambda < \Delta_{2i}$	$\sqrt{\frac{2A_i}{D_i(h_i+s_i\alpha_i I_{ei})-2\lambda}}$

Table 3 The retailer's optimal cycle time $\tilde{t}_i^*$ for Lagrange's multiplier λ (Case 3)

The range of λ	Optimal cycle time ($\tilde{t}_i^*$)
$\lambda \geq 0$	$\sqrt{\frac{2A_i+c_iD_iM_i^2 I_{ki}-s_iD_iI_{ei}[M_i^2-(1-\alpha_i)N_i^2]}{D_i(h_i+c_i I_{ki})}}$
$\Delta_{1i} \leq \lambda < 0$	$\sqrt{\frac{2A_i+c_iD_iM_i^2 I_{ki}-s_iD_iI_{ei}[M_i^2-(1-\alpha_i)N_i^2]}{D_i(h_i+c_i I_{ki})-2\lambda}}$
$\Delta_{2i} \leq \lambda < \Delta_{1i}$	$\sqrt{\frac{2A_i+s_iD_i(1-\alpha_i)N_i^2 I_{ei}}{D_i(h_i+s_i I_{ei})-2\lambda}}$
$-\infty < \lambda < \Delta_{2i}$	$\sqrt{\frac{2A_i}{D_i(h_i+s_i\alpha_i I_{ei})-2\lambda}}$

$$\Delta_{1i} = \frac{-2A_i + D_iM_i^2(h_i + s_iI_{ei}) - s_iD_i(1-\alpha_i)N_i^2 I_{ei}}{2M_i^2},\ \Delta_{2i} = \frac{-2A_i + D_iN_i^2(h_i + s_i\alpha_i I_{ei})}{2N_i^2}$$

where $\Delta_{1i} \geq \Delta_{2i}$ $(i = 1, 2, \ldots, n)$. To solve the problem, we use Lagrange's multiplier λ. The optimal solution $\tilde{t}_i^*$ for our problem is obtained from Tables 1, 2, 3 using $\sum_{i=1}^n t_i \leq T_0$.

For each retailer, we rearrange $\{\Delta_{1i} | 1 \leq i \leq n\}$, $\{\Delta_{2i} | 1 \leq i \leq n\}$, and $\{0\}$ small order, $B_1 \leq B_2 \leq \cdots \leq B_n \leq \cdots \leq B_{2n} \leq B_{2n+1}$. If $B_k \neq B_{k+1}$, the optimal Lagrange's multiplier λ^* only exists in the interval $B_k \leq \lambda^* < B_{k+1}$ $(0 \leq k \leq 2n+1)$ because the objective function is convex, where $B_0 = -\infty$ and $B_{2n+2} = \infty$. In this interval, we allocate the restricted cycle time T_0 to n retailers. Then, the summation of each cycle time has to be equal to T_0. That is to say, using $\sum_{i=1}^n t_i = T_0$, we can find the optimal Lagrange's multiplier λ^*.

Table 4 The parameters for each retailer

Retailer no.	D_i	A_i	c_i	h_i	α_i	I_{ei}	I_{ki}	M_i	N_i
1	6,100	160	100	6	0.3	0.13	0.15	0.11	0.08
2	2,600	100	90	4	0.5	0.12	0.15	0.10	0.06
3	1,500	80	80	3	0.2	0.10	0.15	0.10	0.04
4	6,300	100	110	7	0.3	0.12	0.15	0.11	0.08
5	2,650	75	92	4.5	0.5	0.12	0.15	0.10	0.06
6	1,300	130	79	3	0.25	0.10	0.15	0.10	0.045
7	5,000	100	140	7	0.4	0.09	0.15	0.10	0.08
8	2,650	98	94	4	0.5	0.12	0.15	0.10	0.065
9	1,480	75	80	3.5	0.5	0.10	0.15	0.10	0.06
10	5,950	190	98	6.5	0.5	0.13	0.15	0.11	0.08

Table 5 The optimal cycle time $\tilde{t}_i^*$ for each retailer and the total inventory cost $TCV_i(\tilde{t}_i^*)$

Retailer No.	$\tilde{t}_i^*$	$TCV_i(\tilde{t}_i^*)$
1	0.065281	139.9007
2	0.063961	381.1834
3	0.057087	903.6561
4	0.069594	785.8357
5	0.062986	377.0067
6	0.056952	913.8913
7	0.052168	211.1396
8	0.063189	340.6989
9	0.058609	862.7761
10	0.070176	88.1847
Total	0.620000	5,004.2731

4 Numerical Example

In this section, we show the numerical examples. Here, there are 10 retailers in our model. The parameters for each retailer are shown in Table 4.

4.1 *The Optimal Retailers' Ordering Policy with the Restricted Cycle*

We consider the case of the given T_0 is equal or less than the total of optimal cycle time (0.942389). For example, we set $T_0 = 0.62$. In Table 5, the optimal cycle time $\tilde{t}_i^*$ and the total inventory cost $TCV_i(\tilde{t}_i^*)$ for each retailer are shown. The optimal Lagrange's multiplier $\lambda^* = -19{,}244.2$. The summation of the total inventory costs are 5,004.2731.

5 Conclusion

This note is a modification of the assumption of the trade credit policy in previously published results to reflect realistic business situations. We assumed that the retailer also adopts the trade credit policy to stimulate his/her customer demand to develop the retailer's replenishment model. In addition, their model assumed the relationship between the supplier and the retailer is one-to-one. In this paper, we assumed the supplier has cooperative relations with many retailers for more suiting and satisfying the real world problems and assumed that the summation of each retailer's cycle time is restricted. Under these conditions, we have constructed the retailers' inventory system as a cost minimizing problem to determine the n retailers' optimal ordering policy.

A future study will further incorporate the proposed model more realistic assumptions such as probabilistic demand, allowable shortages and a finite rate of replenishment.

References

Chang HJ, Hung CH, Dye CY (2001) An inventory model for deteriorating items with linear trend demand under the condition of permissible delay in payment. Prod Plan Cont 12:274–282

Chen MS, Chuang CC (1999) An analysis of light buyer's economic order model under trade credit. Asia Pacific J Opns Res 16:23–24

Huang YF, Hsu KF (2008) An EOQ model under retailer partial trade credit policy in supply chain. Inter J Prod Econ 112:655–864

Hwang H, Shinn SW (1997) Retailer's pricing and lot sizing policy for exponentially deteriorating products under the condition of permissible delay in payment. Comp Opns Res 24:539–547

Kim JS, Hwang H, Shinn SW (1995) An optimal credit policy to increase wholesaler's profits with price dependent demand functions. Prod Plan Cont 6:45–50

An Immunized Ant Colony System Algorithm to Solve Unequal Area Facility Layout Problems Using Flexible Bay Structure

Mei-Shiang Chang and Hsin-Yi Lin

Abstract The Facility Layout Problem (FLP) is a typical combinational optimization problem. In this research, clonal selection algorithm (CSA) and ant colony system (ACS) are combined and an immunized ant colony system algorithm (IACS) is proposed to solve unequal-area facility layout problems using a flexible bay structure (FBS) representation. Four operations of CSA, clone, mutation, memory cells, and suppressor cells, are introduced in the ACS to improve the solution quality of initial ant solutions and to increase differences among ant solutions, so search capability of the IACO is enhanced. Datasets of well-known benchmark problems are used to evaluate the effectiveness of this approach. Compared with preview researches, the IACS can obtain the close or better solutions for some benchmark problems.

Keywords Unequal-area facility layout · Ant colony optimization · Clonal selection algorithm · Flexible bay structure · Constrained combinatorial optimization

1 Introduction

Facility layout problems (FLPs) aim to find the optimal arrangement of a given number of non-overlapping departments with unequal area requirements within a facility and certain ratio constraints or minimum length constraints. The common objective is to minimize the total material handling costs among departments.

M.-S. Chang (✉) · H.-Y. Lin
Department of Civil Engineering, Chung Yuan Christian University, 200, Chung Pei Road, Chung Li 32023, Taiwan, Republic of China
e-mail: mschang@cycu.edu.tw

H.-Y. Lin
e-mail: ac-1722@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_2,

Recently, different ACO approaches have been used to solve various versions of FLP problems. Most of them formulate FLP as a quadratic assignment problem (QAP) and obtain promising solutions to several test problems (Baykasoglu et al. 2006; Mckendall and Shang 2006; Nourelfath et al. 2007; Hani et al. 2007). Such approaches need modification in solving FLP. In addition, an ant system approach was first presented to solve the FLP (Wong and Komarudin 2010; Komarudin and Wong 2010). These algorithms use a FBS and a slicing tree structure to represent the FLP respectively. The former also presents an improvement to the FBS representation by using free or empty space. The algorithm can improve the best known solution for several problem instances. The latter one integrates nine types of local search to improve the algorithm performance. No doubt this heuristic shows encouraging results in solving FLP. Moreover, an ACO is proposed to solve the FLP with FBS (Kulturel-Konak and Konak 2011a, b). Compared with meta-heuristics such as GA, TS, AS, and exact methods, this ACO approach is shown to be very effective in finding previously known best solutions and making notable improvements. Then an ACS is used to solve the FLP with FBS (Chang and Lin 2012). Compared with the previously best known solutions, the ACS can obtain the same or better solutions to some benchmark problems. Such interesting results inspire us to further explore the capability of applying ACS to solve the FLP.

Generally speaking, fusion of the computational intelligence methodologies can usually provide higher performances over employing them separately. This study proposes an immunized ant colony system (IACS) approach to solve the FLP with the flexible bay structure (FBS). It is based on clonal selection algorithm (CSA) and ACS.

2 Immunized Ant Colony System Algorithm

2.1 Solution Representation

We adopt the ant solution representation proposed by Komarudin (2009) for solving FLPs. Each ant solution consists of two parts: the department sequence codes and the bay break codes, such as (1-4-5-7-2-3-6)–(0-0-1-0-0-1). The former represents the order of n departments, which will be placed into the facility. The latter is n binary numbers. Here, 1 represents a bay break and 0 otherwise. We assume that bays run vertically and the departments are placed from left to right and bottom to top.

Komarudin (2009) presented this intuitive rule: “A department with higher material flow should be located nearer to the center of the facility.” The heuristic information function was defined by Eq. (3).

$$\eta_{ij} = \left(\sum\nolimits_{k=1}^{N} f_{ki} + \sum\nolimits_{k=1}^{N} f_{ik}\right)\left(\frac{W}{2} - \left|x_j - \frac{W}{2}\right| + \frac{H}{2} - \left|y_j - \frac{H}{2}\right|\right) \tag{1}$$

where f_{ij} is the workflow from i and j; x_j is the x-coordinate of the centroid of the department j; and y_j is the y-coordinate of the centroid of the department j. The rectilinear distance between the centroid of the candidate department and the facility boundary is measured.

2.2 Procedure Steps

Based on the mechanisms of ACS and CSA, we propose a hybrid optimization algorithm and name it immunized ant colony system (IACS) algorithm. The overall procedure of the IACS-FBS is given below. It includes standard procedures of ACS, i.e. parts of Step 0 (except Step 0.2), Step 2 (only N initial ant solutions are needed), Step 3, Step 9, parts of Step 10 (except Steps 10.1, 10.4, and 10.10), Step 13, and Step 14. Basically, we extend the study of ACS-FBS proposed by Chang and Lin (2012) except for several minor modifications. In Step 2, ant solutions are constructed by the space filling heuristic with having the most proper bay number. Such a modification is made for achieving better initial solutions.

The rest of the IACS algorithm is developed according to clone selection algorithm. First, a temporary pool is generated in Steps 1–7. The size of the temporary pool is two times the number of the ant colony. In Step 4, certain ants are reselected because of its diversity with the current best solution in order to maintain the ant diversity. For the same consideration, mutated ants are generated in Step 5. Two mutation operations are performed: swap between a department sequence, which exchanges the positions of two departments in the department sequence and switch of a bay break, which conditional changes the value of a bay break code from 0 to 1 or 1 to 0. The first and the last bay break codes are fixed. Sum of three successive values of bay break codes must be less than or equal to 1.

Next, all solutions in the temporary pool are selected for the ant colony in Step 8. Then the ant colony is further improved by optimization searching in Step 9 and by local searching in Step 10. It is different to the standard ACS in this step. We don't perform a local search to all ant solutions. We regard a local search as a mutation operation. The mutation rate of each ant is inversely proportional to its fitness. After the ant colony is put back a mutated ant pool. According to the mutated ants pool, a memory pool and a candidate pool are updated in Steps 12 and 13 respectively. Note that we don't allow identical ants in the memory pool and the candidate pool in order to increase the ant diversity.

The detailed steps of the IACS-FBS are listed herein.
Step 0: Parameter Setting and Initialization

Step 0.1: Set algorithm parameters of ACS, maximum number of iterations (NI), number of ants (N), pheromone information parameter (α), heuristic information parameter (β), and evaporation rate (ρ).

Step 0.2: Set algorithm parameters of CAS, size of memory pool ($r = N \times b\,\%$), clone number of the best ant-solutions ($s_1 = (N - r) \times d\,\%$), and clone number of the diverse ant-solutions ($s_2 = (N - r) \times (1 - d\%)$).
Step 0.3: Initialize iteration number counter. Set $I := 0$.
Step 0.4: Initialize pheromone information $\tau_{ij}^0, \forall i, j$.
Step 0.5: Initialize the fitness value of the global best solution. Set $z^* = \infty$.

Step 1: Generate an empty memory pool M
Step 2: Generate initial candidate pool P of ant colony (2 N ants) by performing the modified space filling heuristic proposed by Chang and Lin (2012)

Step 2.1: Initialize ant number counter. Set $p = 0$.
Step 2.2: Initialize the fitness value of the iteration best solution. Set $z_I^* = \infty$.
Step 2.3: Update ant number counter $p = p + 1$.
Step 2.4: Perform a procedure of ant solutions construction to create ant p.
Step 2.5: If the number of ants is less than 2 N, then go to Step 2.3; otherwise continue.

Step 3: Evaluate the fitness of the ant colony in candidate pool P

$$z = \sum_i \sum_j f_{ij} c_{ij} \left(d_{ij}^x + d_{ij}^y \right) + \lambda \sum_i \left[Ub_i^w - w_i \right]^+ + \left[Lb_i^w - w_i \right]^+ + \lambda \sum_i \left[Ub_i^h - h_i \right]^+ + \left[Lb_i^h - h_i \right]^+ \tag{2}$$

where c_{ij} is the cost per unit distance from i and j; d_{ij}^x is the rectilinear distance of the centroids from departments i and j on the x-axis; d_{ij}^y is the rectilinear distance of the centroids from i and j on the y-axis; λ is the relative importance of penalty costs and $\lambda = \sum_i \sum_j 10 f_{ij} c_{ij} WH$; $[\,]^+$ denotes returning a positive value of a subtraction expression or zero, i.e. $[\,]^+ = \max\{0, a - b\}$; Lb_i^h is the lower height limit of department i; Lb_i^w is the lower width limit of i; Ub_i^h is the upper height limit of i and Ub_i^w; and Ub_i^w is the upper width limit of i and Ub_i^h.
Step 4: Generate a temporary pool C from the memory pool M and the candidate pool P

Step 4.1: Clone ants in memory pool M (r ants) into the temporary pool C.
Step 4.2: Clone the best ants in candidate pool P (s_1 ants) into the temporary pool C.
Step 4.3: According to Eq. (3), evaluate the diversity measurement of each ant between the best ant in the candidate pool P.

$$\delta = \sum_l \left| b_l - b_l^* \right| \tag{3}$$

where b_l is the current bay widths; b_l^* is the best bay widths.
Step 4.4: Clone the diverse ants in candidate pool P (s_2 ants) into the temporary pool C.

Step 5: Generate a mutated ants pool $C1$ from the temporary pool C

Perform mutation operations of a department sequence and/or of a bay break to all ants in the temporary pool C.

Step 6: According to Eq. (1), evaluate the fitness of all ants in the mutated ant pool $C1$

Step 7: Update the temporary pool C

If the mutated ant is better than the original one, the original ant is replaced.

Step 8: Select ant colony (n ants) from the temporary pool C

Step 9: Optimization searching of ant colony

Step 9.1: Exploit the selected regions by sending the ants for local search by performing a state transition rule.

$$j = \begin{cases} \arg\ \max\left[\tau_{ij}\right]^{\alpha} \cdot \left[\eta_{ij}\right]^{\beta}, & \text{if } q \le q_0 \text{ (exploitation)} \\ S, & \text{otherwise} \quad \text{(exploration)} \end{cases} \tag{4}$$

$$S = P_{ij}^{k} = \begin{cases} \left[\tau_{ij}\right]^{\alpha} \cdot \left[\eta_{ij}\right]^{\beta} \Big/ \sum_{q \in N_i} \left[\tau_{iq}\right]^{\alpha} \cdot \left[\eta_{iq}\right]^{\beta}, & \text{if } j \in N_i \\ 0, & \text{otherwise} \end{cases} \tag{5}$$

where s is a probability to locate department j after department i in the positioning order of departments; τ_{ij} is the pheromone value defined as the relative desirability of assigning department j after department i in the department sequence; η_{ij} is the heuristic information related to assigning department j after department i in the department sequence; q is a random number uniformly distributed in [0, 1]; q_0 is a fixed parameter ($0 \le q_0 \le 1$); α is a parameter which determines the relative weight of pheromone information; and β is a parameter which determines the relative weight of heuristic information; P_{ij}^{k} is a probability of the department j of the department sequence to be chosen by an ant k located in department i and N_i is available alternatives of the department sequence to be chosen by the corresponding ant located in department i.

Step 9.2: Update the local pheromone all the ants according to Eq. (6).

$$\tau_{ij} := (1 - \rho) \cdot \tau_{ij} + \rho \cdot \tau_0 \tag{6}$$

where $0 < \rho < 1$ is the evaporation parameter; τ_0 represents the initial level of pheromone.

Step 10: Mutate the current ant solutions of this iteration by performing the proposed local searching. The mutation rate of each ant is inversely proportional to its fitness, that is, the mutation rate is proportional to the affinity

Step 10.1: Determine the threshold of mutation rate ϕ by Eq. (7).

$$\phi = N \Big/ \sum\nolimits_p z_p \quad (7)$$

Step 10.2: Initialize ant number counter. Set $p = 0$.
Step 10.3: Update ant number counter $p = p + 1$.
Step 10.4: Calculate the mutation rate of ant p, $\phi_p = 1/z_p$. If the value ϕ_p is less than the threshold ϕ, go to Step 10.5; otherwise, go to Step 10.10.
Step 10.5: Perform local search operations of a department sequence (swap, one-insert, or two-opt, Chang and Lin 2012) and of a bay break to the ant solution p.
Step 10.6: Calculate the fitness value $\hat{z}_I$ of the ant p after local search.
Step 10.7: Update the best solution of this iteration z_I^*, once a new best solution is found ($\hat{z}_I < z_I^*$).
Step 10.8: Update the local pheromone of the mutated ant p according to Eq. (6), if its fitness value is improved.
Step 10.9: Update the global pheromone of the mutated ant p according to Eqs. (8) and (9), if its fitness value is not improved.

$$\tau_{ij} := (1 - \rho) \cdot \tau_{ij} + \rho \cdot \Delta\tau_{p \in P} \quad (8)$$

$$\Delta\tau_{p \in P} = \sum\nolimits_{ij \in P} d_{ij}^x + d_{ij}^y \quad (9)$$

Step 10.10: Add ant p or mutated ant p to the mutated ants pool C1.
Step 10.11: If the number of ants is less than N, then go to Step 10.3; otherwise continue.

Step 11: Update the memory pool M

Step 11.1: Clone the best r ants in the mutated ants pool $C1$ into the memory pool M.
Step 11.2: Delete identical ants in the memory pool M
Step 12: Update the candidate pool P
Step 12.1: Delete identical ants in the candidate pool P to maintain the ant diversity.
Step 12.2: Replace those ant solutions in the candidate pool P by the rest ants with better fitness in the mutated ants pool $C1$.

Step 13: Update the global best solution
If z_I^* is less than z^*, update the fitness value of the global best solution $z^* := z_I^*$.
Step 14: Stopping criteria
If the maximum number of iterations is realized, then output the global best solution and stop; otherwise, go to Step 4.

3 Computational Experiments

The proposed algorithm was tested using several problem sets, as listed in Table 1. Note that M11a and M15a were modified to allow the use of FBS representation. The location of the last department is fixed by assigning it to the last position of the facility, but the department fixed size constraint is relaxed. The algorithm was coded with C++ and tested using an Intel(R) Core(TM) i7 CPU processor.

Table 2 provides the previous best-known results of the test problems. The IACS-FBS results are compared to other FBS solutions. The comparative results show that the ACS-FBS approach is very promising. For problem Nug15a5, the IACS-FBS found a new best FBS solution.

4 Conclusions

To prevent the premature convergence problem and to escape from a local optimal solution, clone with affinity-related mutation of the CSA is utilized and combined with the ACS in this algorithm. In this study, an IACS-FBS algorithm is proposed to solve unequal area FLP. We regard local searching as a mutation operation and the mutation rate is inversely proportional to its fitness. In addition, the diversities between the current best solution are measured to help choose clone candidates. Identical ants in a memory pool and a candidate pool are deleted to maintain the diverseness among the ant colony. Furthermore, we revise the ACS-FBS to provide more efficient and comprehensive local exploitation, such as the construction of initial solutions and the local search methods. Compared with existing ACO algorithms, the proposed algorithm obtain better or at least the same solution quality, except for problem Nug15a4. For problem Nug15a5, a new best FBS solution is found.

Table 1 Problem set data

Prob. set	No. of Dpt.	Facility size		Maximum aspect ratio
		Width	Height	
O7	7	8.54	13.00	$\alpha^{max} = 4$
O8	8	11.31	13.00	$\alpha^{max} = 4$
FO7	7	8.54	13.00	$\alpha^{max} = 5$
FO8	8	11.31	13.00	$\alpha^{max} = 5$
O9	9	12.00	13.00	$\alpha^{max} = 4, 5$
vC10a	10	25.00	51.00	$\alpha^{max} = 5$
M11a	11	3.00	2.00	$\alpha^{max} = 4, 5$
M15a	15	15.00	15.00	$\alpha^{max} = 5$
Nug12	12	3.00	4.00	$\alpha^{max} = 4, 5$
Nug15	15	3.00	4.00	$\alpha^{max} = 4, 5$

Table 2 Comparisons of the best FBS solutions with other approaches

Problem	Shape cons.	Konak et al. (2006)	Wong and Komarudin (2010)	Kulturel-Konak and Konak (2011a)	Kulturel-Konak and Konak (2011b)	Chang and Lin (2012)	This study
O7	$\alpha^{\max} = 4$	–	136.58	–	–	134.19*	134.19*
O8	$\alpha^{\max} = 4$	–	–	–	–	245.51*	245.51*
O9a4	$\alpha^{\max} = 4$	–	–	–	–	241.06*	241.06*
O9a5	$\alpha^{\max} = 5$	241.06	241.06	–	–	238.12*	238.12*
FO7	$\alpha^{\max} = 5$	23.12	23.12	–	–	18.88*	18.88*
FO8	$\alpha^{\max} = 5$	22.39*	22.39*	–	–	22.39*	22.39*
vC10a	$\alpha^{\max} = 5$	21,463.07	21,463.1	21,463.07	20,142.13*	20,142.13*	20,142.13*
M11a4	$\alpha^{\max} = 4$	–	–	1,268.55	–	–	1268.55* 1271.56 SingYi
M11a5	$\alpha^{max} = 5$	1,225.00	1,204.15	–	1,201.12*	1,201.12*	1204.15 black
Nug12a4	$\alpha^{max} = 4$	265.5	–	262	257.5*	262	262i7
Nug12a5	$\alpha^{max} = 5$	265.6	262*	–	–	262*	262*
M15a	$\alpha^{max} = 5$	31,779.09	27,545.30	–	27,545.27	–	27701.01*hm
Nug15a4	$\alpha^{max} = 4$	526.72	–	524.75	524.75	–	542.8i7 532.77sil
Nug15a5	$\alpha^{max} = 5$	526.75	536.75	–	–	–	523.67
Approach	–	MIP + FBS	AS + FBS	ACO + FBS	PSO + FBS	ACS + FBS	IACS + FBS

References

Baykasoglu A, Dereli T, Sabuncu I (2006) An ant colony algorithm for solving budget constrained and unconstrained dynamic facility layout problems. Omega 34(4):385–396

Chang MS, Lin HY (2012) A flexible bay structure representation and ant colony system for unequal area facility layout problems. Lecture Notes Eng Comp Sci 2199(1):1346–1351

Hani Y, Amodeo L, Yalaoui F, Chen H (2007) Ant colony optimization for solving an industrial layout problem. Eur J Oper Res 183(2):633–642

Komarudin (2009) An improved ant system algorithm unequal area facility layout problems. Master Thesis, University of Teknologi, Malaysia

Komarudin, Wong KY (2010) Applying ant system for solving unequal area facility layout problems. Eur J Oper Res 202(3):730–746

Konak A, Kulturel-Konak S, Norman BA, Smith AE (2006) A new mixed integer formulation for optimal facility layout design. Oper Res Lett 34:660–672

Kulturel-Konak S, Konak A (2011a) Unequal area flexible bay facility layout using ant colony optimization. Inter J Prod Res 49(7):1877–1902

Kulturel-Konak S, Konak A (2011b) A new relaxed flexible bay structure representation and particle swarm optimization for the unequal area facility layout problem. Eng Optimiz 43:1–25

Mckendall AR Jr, Shang J (2006) Hybrid ant systems for the dynamic facility layout problem. Comp Oper Res 33(3):790–803

Nourelfath M, Nahas N, Montreuil B (2007) Coupling ant colony optimization and the extended great deluge algorithm for the discrete facility layout problem. Eng Optimiz 39(8):953–968

Wong KY, Komarudin (2010) Solving facility layout problems using flexible bay structure representation and ant system algorithm. Exp Syst Appl 37:5523–5527

Characterizing the Trade-Off Between Queue Time and Utilization of a Manufacturing System

Kan Wu

Abstract Characterizing system performance is essential for productivity improvement. Inspired by the underlying structure of tandem queues, an approximate model has been derived to characterize the system performance. The model decomposes system queue time and variability into bottleneck and non-bottleneck parts while capturing the dependence among workstations.

Keywords Queueing systems · Manufacturing systems modeling

1 Introduction

An objective evaluation of the system performance is an essential input for manufacturing system design and productivity improvement. To quantify system performance, performance curves (and their associated variabilities) play a key role since they characterize the trade-off between queue time and utilization. The performance curve is also called a characteristic curve, trade-off curve, operation curve or queueing curve. Bitran and Tirupati (1989) used performance curves to describe the relationship between work-in-process (WIP), cycle time and capacity. Sattler (1996) used performance curves to determine productivity improvements of a semiconductor fab. She assumed variability is independent of utilization and approximated the curve by using a constant to replace the variability term in Kingman's G/G/1 approximation (Kingman 1965).

Since performance curves can be used to quantify the trade-off between queue time and utilization, it would be nice if we can generate the curves analytically. However, due to the complexity of practical manufacturing systems, it is difficult

K. Wu (✉)
Georgia Tech, Atlanta, GA 30332, USA
e-mail: kanwu@gatech.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_3,

to take all the details into account. Hence, people sometimes model a manufacturing system by the aggregation approaches with a macroscopic view. Rather than creating the curve analytically, Rose (2001), Nazzal and Mollaghasemi (2001) and Park et al. (2001) developed the fab performance curve through simulations. Because simulation studies are time consuming, Sattler (1996) attempted to describe the performance curve of a fab based on Kingman's approximation and demonstrated how to enhance productivity through variability reduction. However, rather than a single server, a fab is composed of a sequence of operations executed by a series of workstations. Predicting the performance curve simply based on the G/G/1 queue is not adequate.

Motivated by Kingman's approximation, Yang, et al. (2007) proposed empirical algorithms to generate performance curves through simulation. Two unknown scalars and one unknown vector have to be determined through complex procedures. The algorithm performs well for M/M/1 systems with various dispatching rules, and is extended to predict the performance curve of manufacturing systems by ignoring the dependence among workstations.

It is difficult to compute the performance curve of a practical manufacturing system exactly. Our goal is to have a good approximation of the performance curve by capturing the main underlying structure of a manufacturing system. Rather than assuming stochastic independence, we can capture the dependence among workstations by the intrinsic ratio discovered by Wu and McGinnis (2013). Based on the intrinsic ratio, an approximate model is derived, and it performs very well in the examined cases with complex routing, scheduling, and batching. The objective is to find a model which can describe factory behavior through regression analysis so that we can use only a few known throughput rates and mean queue times to fit the model parameters. After the parameters are determined, the model can be used to predict mean cycle time at any other utilization. Queue time approximation for tandem queues and manufacturing systems are given in Sects. 2 and 3, respectively. Model validation is given in Sect. 4. Conclusion is given at the end.

2 Multiple Single-Server Stations in Series

Wu and McGinnis (2013) identified the nice property of intrinsic ratio in tandem queues, and extended the results to n single-server stations in series with infinite buffers. Their model captures the dependence among tandem queues through so called intrinsic ratios and considerably outperforms the previous approximate models based on parametric-decomposition or diffusion approximations. Based on the concept of intrinsic ratios, system mean queue time can be approximated by

$$\sum_{i=1}^{n} QT_i = f_1\alpha_1\left(\frac{\rho_1}{1-\rho_1}\right)\frac{1}{\mu_1} + f_2\alpha_2\left(\frac{\rho_2}{1-\rho_2}\right)\frac{1}{\mu_2} + \cdots + f_n\alpha_n\left(\frac{\rho_n}{1-\rho_n}\right)\frac{1}{\mu_n}, \quad (1)$$

where QT_i is the mean queue time of station i in steady states, ρ_i is the utilization of station i, μ_i is the service rate of station i, and α_i is the variability of station i in the ASIA system (Wu and McGinnis 2013). f_i is called contribution factor, since it represents the percentage of station i's ASIA system queue time contributing to the overall system queue time as shown in Eq. (1).

Based on the property of intrinsic ratio, Procedure 1 explains how to determine f_i and approximate the mean queue time of n single-server stations in series. It consists of two stages: decomposition and computation. Stage 1 identifies the main system bottleneck first, and then identifies the next bottleneck within each subsystem. A subsystem is composed of the stations from the first station to the newest identified bottleneck (not included). At the beginning, when no bottleneck has been identified, the subsystem is the same as the original system. The subsystem then gradually becomes smaller until it is composed of solely one single station, which is the first station of the tandem queue.

Procedure 1 (System Queue Time for Single Queues in Series):

Stage I: Decomposition by bottlenecks

1. Identify system bottleneck (BN_1), where $\mu_{BN_1} = \min \mu_i$, for $i = 1$ to n. Let $k = 1$.

   - If more than one station has the same minimum service rate, $BN_1 = \min i$, where $=\mu_i = \mu_{BN_1}$.

2. Identify the next bottleneck (i.e., BN_{k+1}) in front of the previous one (i.e., BN_k), where $\mu_{BN_{k+1}} = \min \mu_i$, for $i = 1$ to $BN_k - 1$.

   - If more than one station has the same minimum service rate, $BN_{k+1} = \min i$, where $\mu_i = \mu_{BN_{k+1}}$.

3. If $BN_{k+1} = 1$, stop. Otherwise, let $k = k + 1$, go to 2.

Stage II: Determining the parameters

4. Let $k = n$, $f_i = 1$ for $i = 1$ to k.
5. If station k is marked as a bottleneck, $f_i \leftarrow y_k * f_i$ for $i = 1$ to $k - 1$. Otherwise, $f_k \leftarrow x_k * f_k$. Stop if $k = 2$.
6. Otherwise, let $k = k - 1$, go to 5.

Figure 1 shows the bottleneck decomposition. In Eq. (1), the value of f_i always equals 1 for the system bottleneck, which implies that a unit weight is always given to the system bottleneck. However, there will be a (non-unit) weight on all other stations' ASIA system mean queue times. When both x_k and y_k are smaller than 1, the contribution factor will be smaller than 1 and behaves like a discount factor. In this situation, reducing bottleneck service time SCV brings greater improvement on queue time than reducing non-bottleneck service time SCV.

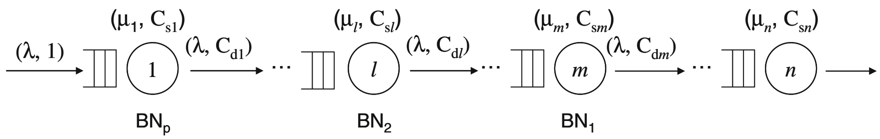


Fig. 1 *n* single queues in series

3 Approximate Models for Manufacturing Systems

A practical factory is much more complex than single-server queues in series. Each workstation may have multiple servers with different capabilities and each server may have complicated configuration and suffer different types of interruptions. Dispatching rules other than work-conserving policies may be used. Modeling the behavior of a factory through analyzing all details is a formidable task.

Since the intrinsic ratio captures the dependence among stations (Wu and McGinnis 2013), our approach is to abstract a simple form from Eq. (1) to describe the behavior of practical manufacturing systems. We hope this simple form can capture the underlying structure of system performance. We assume system stability can be achieved when the utilization of each station is smaller than one.

Because f_i is 1 at the system bottleneck, system mean cycle time can be expressed as

$$\begin{aligned} CT &= \sum_{i=1}^{n} QT_i + PT_f = \sum_{i=1}^{n} f_i \alpha_i \left(\frac{\rho_i}{1-\rho_i} \right) \frac{1}{\mu_i} + PT_f \\ &= \alpha_{BN} \left(\frac{\rho_{BN}}{1-\rho_{BN}} \right) \frac{1}{\mu_{BN}} + \sum_{i \neq BN} f_i \alpha_i \left(\frac{\rho_i}{1-\rho_i} \right) \frac{1}{\mu_i} + PT_f, \end{aligned} \tag{2}$$

where CT is mean cycle time, BN stands for bottleneck. Hence, ρ_{BN} is the bottleneck utilization (or system utilization). PT_f is mean total processing time (of a job in a factory). Total processing time can be approximated by the cycle time of a job in light traffic when the station has no cascading, and there is no batch and assembly. The first term of Eq. (2) is the ASIA system mean queue time of the bottleneck, and the second term is the gross mean queue time of the non-bottlenecks.

Queue time of tandem queues is contributed by all stations and so does its variability. From Eq. (2), system variability is composed of two parts: the bottleneck and non-bottlenecks, with the bottleneck part playing a key role in heavy traffic. The coefficient of the bottleneck (α_{BN}) is the same as the variability in its ASIA system. The coefficients of the non-bottlenecks ($f_i\alpha_i$) are the weighted (by the contribution factors) variabilities in their ASIA systems. When all service times are exponential and the original external arrival process is Poisson, all intrinsic ratios are one. Hence, f_i is 1 and Eq. (2) reduces to the cycle time of a Jackson network. When all service times are deterministic, the intrinsic ratios are zero for the system bottleneck and the stations behind it. Hence, f_i is zero for all non-bottlenecks and Eq. (2) reduces to the cycle time of a Friedman's tandem queue (Friedman 1965).

In Eq. (2), since queue time is dominated by the bottleneck in heavy traffic, we can replace the $(n - 1)$ non-bottleneck performance curves by $(n - 1)$ identical composite non-bottleneck performance curves. Furthermore, within the non-bottleneck performance curves, system queue time is dominated by the performance curve of the second bottleneck (i.e., the one with the highest utilization among all non-bottlenecks) in heavy traffic. Therefore, a reasonable choice is to pick up the second bottleneck performance curve to represent the composite non-bottleneck performance curves. Based on the above observations, Eq. (2) can be simplified as

$$\begin{aligned} CT &= \alpha_{BN}\left(\frac{\rho_{BN}}{1-\rho_{BN}}\right)\frac{1}{\mu_{BN}} + \sum_{i \neq BN} f_i \alpha_i \left(\frac{\rho_i}{1-\rho_i}\right)\frac{1}{\mu_i} + PT_f \\ &\cong k_1\left(\frac{\rho_{BN}}{1-\rho_{BN}}\right)\frac{1}{\mu_{BN}} + (n-1)k_2'\left(\frac{\lambda/k_3}{1-\lambda/k_3}\right)\frac{1}{k_3} + PT_f \\ &= k_1\left(\frac{\rho_{BN}}{1-\rho_{BN}}\right)\frac{1}{\mu_{BN}} + k_2\left(\frac{\lambda}{k_3-\lambda}\right)\frac{1}{k_3} + PT_f, \end{aligned} \tag{3}$$

where λ is the external arrival rate at the first station. In Eq. (3), the first term on the right-hand side corresponds to the bottleneck mean queue time where k_1 is the bottleneck variability. The second term corresponds to the mean queue time of the non-bottleneck stations where k_2 approximates the variability of the composite station (representing the $(n - 1)$ non-bottleneck stations), and k_3 represents the capacity of the composite station. Note that k_1 is the same as α_{BN}, the bottleneck variability in the ASIA system if the system is a tandem queue. Since there are three parameters in Eq. (3), we call it the 3-parameter model. When there is reentry or rework, capacity can be computed as follows,

$$1/\mu_i = \sum\nolimits_{j=1}^{l} w_j \times ST_j, \tag{4}$$

where l is the total reentry or rework frequency at station i, w_j is the rework rate.

In addition to its simplicity, Eq. (3) considerably reduces the burden of data collection in Eq. (2). In order to apply Eq. (2), we assume the service time SCV is available. However, in a setting of complex machine configurations, robot scheduling, interruptions, resource contention, reentry, and product mix, finding out the variance of service time, where service time is the reciprocal of capacity (Wu et al. 2011), can be a formidable task. Wu and Hui (2008) discussed the potential issue when measuring process time in practice. Newell (1979) stated, "In fact, in most applications, one is lucky if one has a good estimate of the service rates (to within 5 % say); the variance rates are often known only to within a factor of 2, seldom to within an accuracy of 20 %." Although SCV of service time is well defined in theory, it may not be accessible in practice.

An easy way to estimate service time SCV is to analyze historical data. Although it is difficult to have a reliable estimate of service time SCV, it is relatively easy if only the mean queue time is needed. In practice, observable mean queue time (first moment estimator) is much more accessible than the intangible service times SCV (second moment estimator). In order to make queueing models more accessible in practice, it is important to have an approach which does not rely on the service time SCV explicitly. The historical mean queue time is a good alternative. Indeed, except for when we construct a brand new factory, the historical performance is commonly accessible in practical applications of queueing theory. Hence, it is practical to develop an approximate model which can predict future performance based on few reliable historical data estimates.

Compared with the approximate model by Wu (2005), Eq. (3) gauges the variability of a manufacturing system from the viewpoint of the bottleneck while adding a correction term to consider the impact from non-bottlenecks.

4 Model Validation

Planning and managing major defense acquisition programs (DAP) requires balancing and synchronizing design, and manufacturing across a network of distributed activities performed by independent commercial entities. To achieve this goal, it is important to have the capability to describe the performance curve of each independent entity accurately. Hence, a simulation model is constructed by one of the manufacturers in a DAP using ARENA®. The model (illustrated in Fig. 2) describes the behavior of a manufacturing facility for a specific product.

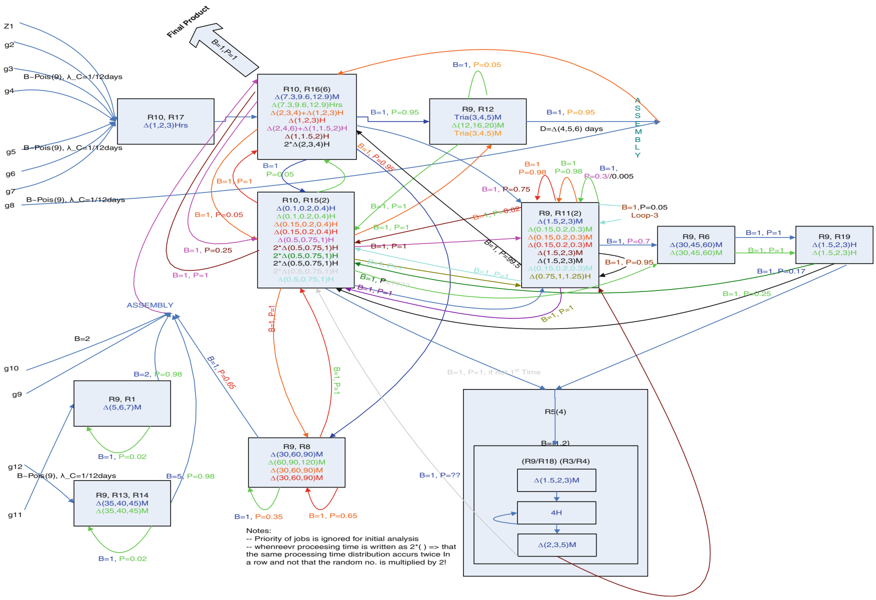


Fig. 2 Process flows of a manufacturing facility in DAP

The output of this facility supplies critical parts to downstream assembly lines in the supply chain. There are 14 workstations (R1, R3, R4, R5, R6, R8, R11, R12, R13, R14, R15, R16, R17, R19) arranged in 11 main process groups (i.e., 9 process groups use 1 workstation, 1 group needs 2 workstations, and 1 group uses 3 workstations). Four workstations have multiple servers (R5 = 4, R11 = 2, R15 = 2, R16 = 6), and the remaining workstations have only a single server. In addition to workstations, each process group requires operators from one of the three operator types (R9, R10 and R18). While the operators have their own shift schedules (i.e., 8 h a day), machines work 24 h a day as long as a job has been loaded by operators. Service times follow triangular distributions. Dispatching rules at critical workstations follow the shortest remaining processing time instead of First-Come-First-Serve (FCFS). Reentry and rework in the system are shown in Fig. 2. 12 different raw parts arrive every 12 days with random batch sizes following a Poisson distribution. System utilization is determined by the mean batch size rather than the arrival intervals. Before the process can be started, raw parts (Z1 and g2–g7) need to be assembled in front of the first process step. Subsequently, an incomplete job has to be assembled again with some other raw parts (g8–g12) in the middle of the process flow.

Due to shift schedule, operator availability, batch arrivals and assembly lines, finding a reliable estimate of inter arrival and service time SCVs is difficult, not to mention computing the cycle time. To get a reliable estimate of cycle time, we resort to simulation. Through experimentation, the system bottleneck has been identified as R8, which is composed of a single server, and system capacity is about 13.7 jobs per 12 days. In total, system performance at 14 different utilizations has been simulated. The performance curve with 99 % confidence intervals is shown in Fig. 3. The cycle time at each utilization is the average of 30 batches

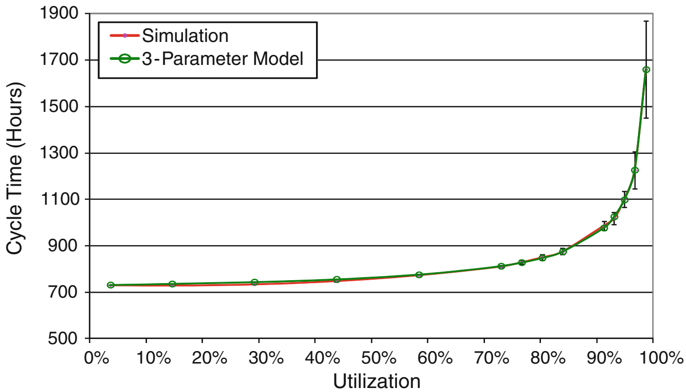


Fig. 3 Performance curve of a manufacturing facility in DAP

from one simulation run. In each simulation run, the first 1,000–10,000 data points are discarded for warm-up, and each batch consists of 1,500–500,000 data points.

The values of k_1, k_2 and k_3 in Eq. (3) (i.e., 3-Parameter model curve in Fig. 3) are 0.356, 422.951 and 14.636, and the largest error is 1.38 % at 29 % utilization. Note that the value of k_3, 14.636, which represents the non-bottleneck capacity, is greater than the bottleneck capacity 13.7 as expected. The results exhibit the accurate prediction capability of Eq. (3) in practical manufacturing systems.

5 Conclusion

Through the nice property of intrinsic ratios, we developed analytical models to quantify the performance of manufacturing systems. From the simulation results, we find the intrinsic ratios discovered in tandem queues can be applied to quantify the performance of manufacturing systems.

Although our models perform well in the examined case, the practical situation can be much more complicated. In real production lines, dispatching rules can be complicated especial when batching exist. Furthermore, there can be multiple products in a production system. They may have different cycle times but share the same resources. Those situations have not been considered in our models and will be left for future research.

References

Bitran GR, Tirupati D (1989) Tradeoff curves, targeting and balancing in manufacturing queueing networks. Oper Res 37:547–564

Friedman HD (1965) Reduction methods for tandem queuing systems. Oper Res 13:121–131

Kingman JFC (1965) The heavy traffic approximation in the theory of queues. In: Proceedings of the symposium on congestion Theory, pp 137–159

Nazzal D, Mollaghasemi M (2001) Critical tools identification and characteristics curves construction in a wafer fabrication facility. In: Proceedings of the winter simulation conference, pp 1194–1199

Newell G (1979) Approximate behavior of tandem queues, Springer

Park S, Mackulak GT, Fowler JW (2001) An overall framework for generating simulation-based cycle time-throughput curves. In: Proceedings of the winter simulation conference, pp 1178–1187

Rose O (2001) The shortest processing time first (SPTF) dispatch rule and some variants in semiconductor manufacturing. In: Proceedings of the winter simulation conference, pp 1220–1224

Sattler L (1996) Using queueing curve approximations in a fab to determine productivity improvements. In: Proceedings of the advanced semiconductor manufacturing conference, 140–145

Wu K (2005) An examination of variability and its basic properties for a factory. IEEE Trans Semicond Manuf 18:214–221

Wu K, Hui K (2008) The determination and indetermination of service times in manufacturing systems. IEEE Trans Semicond Manuf 21:72–82
Wu K, McGinnis L (2013) Interpolation approximations for queues in series. IIE Trans 45:273–290
Wu K, McGinnis L, Zwart B (2011) Queueing models for a single machine subject to multiple types of interruptions. IIE Trans 43:753–759
Yang F, Ankenman B, Nelson B (2007) Efficient generation of cycle time-throughput curves through simulation and metamodeling. Naval Res Logistics 54:78–93s

Using Latent Variable to Estimate Parameters of Inverse Gaussian Distribution Based on Time-Censored Wiener Degradation Data

Ming-Yung Lee and Cheng-Hung Hu

Abstract To effectively assess the lifetime distribution of a highly reliability product, a degradation test is used if the product's lifetime is highly related to a critical product characteristic degrading over time. The failure times, as well as the degradation values, provide useful information for estimating the lifetime in a short test duration. The Wiener process model has been successfully used for describing degradation paths of many modern products such as LED light lamps. Based on this model, the lifetime of a product would follow the Inverse Gaussian (IG) distribution with two parameters. To estimate the parameters, we propose a method using the latent variables to obtain Latent Variable Estimates (LVE) of the parameters of the IG lifetime distribution. The proposed LVEs have simple closed functional form and thus they are easy to interpret and implement. Moreover, we prove the LVEs are consistent estimates. Via simulation studies, we show that the LVEs have smaller bias and mean square error than existing estimates in the literature.

Keywords Latent variable · Time-censored · Wiener process · Inverse Gaussian distribution

M.-Y. Lee (✉)
Statistic and Informatics Department, Providence University,
Taichung 43301, Taiwan
e-mail: mylee@pu.edu.tw

C.-H. Hu
Department of Industrial Engineering and Management, Yuan Ze University, No. 135,
Yuan-Tung Road, Chungli, Taoyuan, Taiwan
e-mail: chhu@saturn.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_4,

1 Introduction

To increase the likelihood of observing failure in a short duration, a degradation test is used if we can associate the lifetime of a product to certain Quality Characteristic (QC). For example, Tseng et al. (2003) presented an example of Light Emitting Diode (LED) lamps, whose life is related to the light intensity.

Suppose the value of the QC of the products degrades over time, the product lifetime can then be defined as the time when the QC crosses a pre-specified critical level. In this paper, we consider the Wiener process to model the degradation path. Under this assumption, it can be shown that the product life follows the Inverse Gaussian (IG) distribution. The Wiener/IG distribution model has found many applications in certain studies. For example, see Doksum and Hoyland (1992), Meeker and Escobar (1998), Tseng and Peng (2004), Park and Padgett (2005), and Wang (2010).

When a degradation test is time-constrained, the failure times and the degradation values of the censored units at time both contain valuable information regarding the lifetime distribution. In this paper, we propose an estimation procedure by using Latent Variables. Closed-form Latent Variable Estimates (LVE) of the parameters of the IG distribution are available and the LVE are proved being consistent in Sect. 3. In addition, to compare the performance of the LVE to some existing estimates, a simulation study is proposed in Sect. 4. We numerically evaluate the performances of the LVE, modified E-M estimates (MEME), and Modified MLE (MMLE), for both IG parameters with different sample sizes (For detailed introduction of MEME and MMLE, one can refer to Lee and Tang (2007)). Results show that the resulting LVEs can reduce the bias and variances than that from other two estimation methods. In Sect. 5, we use our LVE for estimating parameters of the IG distribution to existing degradation data proposed in Lee and Tang (2007). Concluding remarks and future research topics are given in Sect. 6.

2 Model Assumption

We assume that the transformed degradation path of the QC at time t, is $W(t) = \eta t + \sigma B(t)$, $t \geq 0$, where η is the drift parameter, $\sigma > 0$ is the diffusion coefficient, and $B(\cdot)$ is a standard Brownian motion. Under this model, the product's failure time (or lifetime), denoted by T, is the defined as the first-passage time over a constant threshold, a. It is well-known that T follows an inverse Gaussian distribution, denoted by IG (μ, λ), with the location and scale parameters $\mu = a/\eta$ and $\lambda = a^2/\sigma^2$. For detailed introduction and systematic overviews of the IG distribution, one can refer to (Seshadri 1999).

For a given random sample $x_1, x_2, \ldots, x_n$ from the IG(μ, λ) distribution, the maximum likelihood estimates of parameters are:

$\hat{\mu}_{\text{MLE}} = \sum_{i=1}^{n} \left(\frac{x_i}{n}\right)$ and $\hat{\lambda}_{\text{MLE}} = n \Big/ \sum_{i=1}^{n} (1/x_i - 1/\hat{\mu}_{\text{MLE}})$.

The discussion above works on a premise that the failure time of all test units are observable. On the other hand, if part of the random sample is censored, the previous MLE has no closed functional form and thus numerical procedures are required for obtaining the estimates. To overcome this problem, we introduce the latent variable and propose LVE in the next section to obtain simple closed-form estimate of IG parameters.

3 Latent Variable Estimates

Assume that n independent units are tested, and, before a pre-specified test censoring time τ, m of them have failed with failure times $t_1, \ldots, t_m$. The remaining units were censored with degradation values, $w_{m+1}(\tau), \ldots, w_n(\tau)$, at time τ. Using the observed sample of these random values from a time-constrained test, we propose LVE for both parameters by using latent variables.

3.1 The LVE of μ

Suppose one can observed the degradation value of all test units at the censoring time, then by the fact that the degradation path is a Wiener process, the observed degradation value is a random sample of $N(\eta\tau, \sigma^2\tau^2)$. However, for those failed units, the degradation value at the censoring time is unknown. Hence, we would add a latent variable to each of the failed units and obtain a pseudo random sample of degradation data. The following discussion illustrates how we proceed.

For the i-th failed unit ($i = 1, 2, \ldots, m$) with failure time t_i, its degradation value at the failure time is a. If one had measured the degradation value of this failed unit at time τ, the value is a random variable $w_i(\tau)$ and the difference between $w_i(\tau)$ and a (the *latent variable*, $\Delta w_i(\tau)$) follows a normal distribution. That is,

$$\Delta w_i(\tau) \sim N(\eta(\tau - t_i), \sigma^2(\tau - t_i)), \quad i = 1, 2, \ldots, m$$

The latent variable is a random variable independent from failure time, T_i because of the independent increment property of Brownian motion. By adding the latent variable to each failed unit, we then obtain a pseudo random sample of degradation data, $(\tilde{w}_1(\tau), \ldots, \tilde{w}_m(\tau), w_{m+1}(\tau), \ldots, w_n(\tau))$ where $\tilde{w}_i(\tau) = a + \Delta w_i(\tau)$. This pseudo random sample are identical and independently distributed as the normal distribution with mean $\tau\eta$ (also $\tau a/\mu$) and variance $\tau\sigma^2$ (also $\tau a^2/\sigma^2$) by Wiener process property.

However, different from the real random degradation values, the latent variables are not actually observable and thus we would replace them by their conditional expected values (i.e., $\eta(\tau - t_i)$ for $\Delta w_i(\tau)$) and obtain the following closed-form LVE for parameter μ:

$$\hat{\mu}_{\mathrm{LVE}} = \frac{(n-m)\tau + \sum_{i=1}^{m} t_i}{m + \sum_{j=m+1}^{n} w_j(\tau)/a} \tag{1}$$

3.2 The LVE of λ

Notice that since $\tilde{w}_1(\tau), \ldots \tilde{w}_m(\tau), w_{m+1}(\tau), \ldots w_n(\tau)$ are assumed to be identical and independent normally distributed random variables. The MLE for $\tau\sigma^2$ is

$$\tau\hat{\sigma}^2 = \frac{1}{n}\left(\sum_{i=1}^{m} (\tilde{w}_i - \tau\eta)^2 + \sum_{j=m+1}^{n} (w_j - \tau\eta)^2\right).$$

As discussed in Sect. 3.1, each latent variable $\Delta w_i(\tau)$ follows the normal distribution. In other words, we can decompose each $\Delta w_i(\tau)$ as $\Delta w_i(\tau) = \eta(\tau - t_i) + \Delta B_i(\tau)$, where $\Delta B_i(\tau) \sim N(0, \sigma^2(\tau - t_i))$, $i = 1, 2, \ldots, m$. Thus, the original MLE for $\tau\sigma^2$ becomes

$$\tau\hat{\sigma}^2 = \frac{1}{n}\left(\sum_{i=1}^{m} (a - \eta t_i)^2 + \sum_{i=1}^{m} 2(a - \eta t_i)\Delta B_i(\tau) + \sum_{i=1}^{m} \Delta B_i(\tau)^2 + \sum_{j=m+1}^{n} (w_j - \tau\eta)^2\right). \tag{2}$$

The random variables, $\Delta B_i(\tau)$, is also independent from failure time, T_i, by independent increment prosperity of Brownian motion. Similar to the derivation process for $\hat{\mu}_{\mathrm{LVE}}$, since the latent variables $\Delta w_i(\tau)$ (and thus $\Delta B_i(\tau)$) are not observable, we substitute them with their expected values (i.e., $E(\Delta B_i(\tau)) = 0$ and $E\left(\Delta B_i(\tau)^2\right) = \sigma^2(\tau - t_i)$) into the (2) and obtain an estimate for the parameter σ

$$\hat{\sigma}^2 = \left(\sum_{i=1}^{m} (a - \hat{\eta} t_i)^2 + \sum_{j=m+1}^{n} (w_j - \tau\hat{\eta})^2\right) \Big/ \left(\sum_{i=1}^{m} t_i + \tau(n-m)\right).$$

Finally, using the relationships that $\mu = a/\eta$, $\lambda = a^2/\sigma^2$, and the estimates of μ and σ, we have an estimate for λ as

$$\hat{\lambda}_{\mathrm{LVE}} = \left(\sum_{i=1}^{m} t_i + \tau(n-m)\right) \Big/ \left(\sum_{i=1}^{m} (1 - t_i/\hat{\mu}_{\mathrm{LVE}})^2 + \sum_{j=m+1}^{n} (w_j/a - \tau/\hat{\mu}_{\mathrm{LVE}})^2\right). \tag{3}$$

Compare to the estimates in Lee and Tang (2007), advantages of using the LVEs include closed form estimates for both IG parameters are available and thus easier to interpret and implement. In the next section, the comparisons of performance between the LVE and some other estimates are given.

4 Latent Variable Estimates

For comparing the performance of the proposed LVE to some existing parameter estimates in the literature, a simulation study is conducted and presented in this section. Following the parameters used in Lee and Tang (2007), we fix the true parameter values at $\mu = 100$, $\lambda = 2{,}500$ for simulating random IG distributed failure times, as well as the degradation values. Meanwhile, instead of the actual censoring time, we specify the failure probability (denoted as p) before the censoring time for each simulated sample. Three values of p (0.2, 0.5, and 0.8) are used in this simulation. The actual censoring time can be easily calculated by using the CDF of IG distribution. Different sample sizes ($n = 16$, 32, and 64, and 128) are considered for studying the performance of the estimates under small and large sample size scenarios. For each combination of experimental setting, two hundred samples are simulated by using R Software. Each simulated sample contains both failure times and degradation values at the censoring time. The estimates of the IG distribution parameters using three different methods (MEME, MMLE, and LVE) are obtained for each sample of simulated data. We calculate the sample mean and the variance (and thus the Square roots of Mean Square Error (SMSE)) of the 200 obtained estimates for each method. Results are presented in Table 1.

Based on Table 1, both $\hat{\mu}_{\text{LVE}}$ and $\hat{\lambda}_{\text{LVE}}$ estimates are reasonably close to the true parameter values, even for small sample sizes. Moreover, the SMSE of $\hat{\mu}_{\text{LVE}}$ and $\hat{\lambda}_{\text{LVE}}$ decrease as the sample size increases, which provide numerical evidence that the LVEs are consistent. Comparing to the other estimates, the LVE performs better than MMLE and MEME in all cases with respect to both bias and SMSE criteria. In addition, the bias and SMSE of $\hat{\lambda}_{\text{MEME}}$ are very sensitive to the failure probability, p; both bias and SMSE of $\hat{\lambda}_{\text{MEME}}$ are large when p is small. Comparing to others, the LVE would be a better estimate.

5 LED Example

Tseng et al. (2003) considered the problem of determining the termination time for a burn-in test for a LED lamp. The lifetime of a LED lamp is highly related to its light intensity. Hence, one may define a LED lamp *failed* when its light intensity decreases and becomes smaller than certain threshold (e.g., 50 % of its original brightness).

As an illustrative example, we implement the proposed LVE for estimating the lifetime distribution of a LED lamp. The following data was obtained from one of

Table 1 The mean and square root of mean square error of 200 estimates of by using LVE, MMLE, and MEME when $\mu = 100$ and $\lambda = 2{,}500$ with different sample sizes

p	LVE (SMSE)		MMLE(SMSE)	MEME(SMSE)	Observed p
	μ	λ	λ	λ	
$n = 16$					
0.2	100.49	2,494.91	3,063.46	2,866.14	0.19
	(5.46)	(1,002.10)	(1,341.26)	(1,225.07)	
0.5	100.63	2,483.93	3,029.97	2,585.47	0.49
	(5.13)	(959.73)	(1,274.11)	(977.06)	
0.8	100.51	2,529.44	3,119.25	2,533.98	0.79
	(4.94)	(979.39)	(1,337.53)	(966.71)	
$n = 32$					
0.2	100.13	2,503.51	2,771.65	2,874.41	0.19
	(3.69)	(691.32)	(804.84)	(883.87)	
0.5	100.23	2,506.81	2,757.69	2,620.75	0.50
	(3.59)	(641.61)	(733.29)	(675.96)	
0.8	100.25	2,516.02	2,787.99	2,536.86	0.79
	(3.51)	(679.42)	(800.22)	(680.96)	
$n = 64$					
0.2	100.14	2,482.12	2,619.05	2,858.00	0.20
	(2.67)	(459.03)	(494.25)	(646.08)	
0.5	100.22	2,479.82	2,612.54	2,610.57	0.49
	(2.62)	(4,35.83)	(474.44)	(475.06)	
0.8	100.25	2,473.34	2,611.85	2,513.43	0.80
	(2.54)	(448.51)	(487.18)	(462.88)	
$n = 128$					
0.2	100.24	2,496.96	2,567.57	2,869.60	0.19
	(1.93)	(325.53)	(339.71)	(537.98)	
0.5	100.27	2,500.38	2,569.16	2,625.25	0.49
	(1.85)	(300.44)	(320.41)	(345.60)	
0.8	100.34	2,493.22	2,563.30	2,520.05	0.79
	(1.80)	(311.53)	(326.83)	(315.73)	

the leading LED manufacturers in Taiwan. The data contains the failure times and degradation values of LED lamps from an accelerated degradation test using electric current = 10 amperes and temperature = 105 °C. The test censoring time is 6,480 h. The sample size is $n = 24$ and there were $m = 18$ boundary-crossing times (the defined failure times): 6,274.826, 6,164.547, 6,144.000, 6,102.000, 5,430.000, 6,291.087, 6,259.672, 5,261.236, 3,963.600, 6,034.026, 4,866.947, 3,508.613, 5,008.976, 2,893.333, 6,172.000, 6,158.170, 3,494.400, and 4,801.878. The brightness of the 6 censored units at censoring time are: 0.5027, 0.5438, 0.5768, 0.5516, 0.5267, and 0.5639. The original degradation path (denoted as $L(t)$) did not follow a Wiener process. However, as demonstrated in Tseng et al. (2003), the transformed path, $W(t) = -\ell n(L(t^{0.6}))$, can be modeled by the Wiener process. The threshold is then $a = -\ell n(0.5) = 0.6932$. To apply our results, the boundary-crossing times, the censoring time, as well as the degradation values at the censoring time of censored units, are transformed. The resulting LVEs for the IG parameter are $\hat{\mu}_{\text{LVE}}$= 181.39 and $\hat{\lambda}_{\text{LVE}} = 16,569$. Note that distribution of T can be estimated by $F(t|\hat{\mu}_{\text{LVE}},\ \hat{\lambda}_{\text{LVE}})$.

6 Summary

In this paper, a latent variable method for estimating both mean and the scale parameters of the IG distribution is proposed. Comparing to the existing modified maximum likelihood estimate, advantages of our method includes: (1) our estimates has clear closed form solutions and thus easier to compute. (2) Simulation results show that, with the help of the degradation values of the censored units, the performance of LVE is better than MMLE because it has smaller asymptotic variances of the estimators for both IG parameters. A Numerical example is also provided for illustration of our method. A possible direction for future research is to see whether it is better to collect first-passage times of the degradation sample paths over certain non-failure thresholds, instead of collecting degradation values at prescribed time points as we considered in this paper.

Acknowledgments This research was supported by the National Science Council of ROC grand NSC 99-2118-M-126 -002. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Doksum KA, Hoyland A (1992) Models for variable-stress accelerated life testing experiments based on Wiener processes and the inverse Gaussian distribution. Technometrics 34:74–82

Lee MY, Tang J (2007) Modified EM-algorithm estimates of parameters of inverse Gaussian distribution based on time-censored Wiener degradation data. Stat Sinica 17:873–893

Meeker WQ, Escobar LA (1998) Statistical methods for reliability data. Wiley, New York

Padgett WJ, Tomlinson MA Inference from accelerated degradation and failure data based on Gaussian process models. Lifetime Data Anal 10: 191–206

Park C, Padgett WJ (2005) Accelerated degradation models for failure based on geometric Brownian motion and Gamma process. Lifetime Data Anal 11:511–527

Seshadri V (1999) The inverse gaussian distribution: statistical theory and applications. Springer, New York

Tseng ST, Peng CY (2004) Optimal burn-in policy by using integrated Wiener process. IIE Tran 36:1161–1170

Tseng ST, Tang J, Ku IH (2003) Determination of optimal burn-in parameters and residual life for highly reliable products. Naval Res Logistics 50:1–14

Wang X (2010) Wiener process with random effects for degradation data. J Multivariate Anal 101:340–351

Interpolation Approximations for the Performance of Two Single Servers in Series

Kan Wu

Abstract Dependence among servers is the root cause of the analytic intractability of general queueing networks. A tandem queue is the smallest unit possessing the dependence. Understand its behavior is the key to understand the behavior of general queueing networks. Based on observed properties, such as intrinsic gap and intrinsic ratio, a new approximation approach for tandem queues is proposed. Across a broad range of examined cases, this new approach outperforms prior methods based on stochastic independence or diffusion approximations.

Keywords Queueing systems · Manufacturing systems modeling

1 Introduction

In manufacturing systems, the states of the upstream and downstream workstations are mutually dependent in general queueing networks. The dependence plays a critical role in modeling the behavior of manufacturing, computer and communication queueing networks. To understand the impact of dependence, we study the behavior of tandem queues which consists of two single servers in series. It is the simplest queueing system which exhibits dependence among servers.

Virtually all existing tractable results in first-come-first-serve (FCFS) queueing networks only hold exactly under memoryless assumptions, which can be restrictive. An important exception is formed by two early papers that seem forgotten but form a cornerstone for our modeling approach. Specifically, Avi-Itzhak (1965) and Friedman (1965) investigated the behavior of tandem queues with constant service times. In particular, Friedman showed the following important properties. If

K. Wu (✉)
Georgia Technology, Atlanta GA 30332, USA
e-mail: kanwu@gatech.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_5,

customers arrive at the first stage and proceed though the stages in FCFS order with infinite buffers, then: (a) for any sequence of customer arrival times, the time spent in the system by each customer is independent of the order of the stages; and (b) under certain conditions, a tandem queueing system can be reduced to a corresponding system with fewer stages, possibly a single stage. This procedure is called a reduction method. Consequently, the total system queue time is determined solely by the bottleneck workstation, i.e. the queue time of any customer equals the time the same customer would have been waiting in the queue of a single workstation, which is the bottleneck workstation. Therefore, we can analyze such a queueing system exactly even though there is dependence among workstations.

Jackson (1957) and Friedman's results seem totally different at first sight, but indeed share a very important structure: in both, each server sees the initial arrival process directly. In other words, in a Jackson network, all servers see Poisson arrivals, and in a tandem queue with constant service times, the bottleneck sees the initial arrival process. Based on this key insight, we develop new approximate models without directly dealing with the non-renewal departure process. Based on extensive simulations, we argue that this new approach outperforms earlier methods by the parametric-decomposition and diffusion approximation approaches.

The rest of this paper is organized as follows. An introduction to the prior approximate models is given in Sect. 2 and definitions of some critical terms are given in Sect. 3. Section 4 presents the intrinsic gap and intrinsic ratio, along with some important properties and observations of simple tandem queues. The new approximate model is introduced in Sect. 5. In Sect. 6, we draw conclusions and discuss future work.

2 Prior Approach

The parametric-decomposition method (Kuehn 1979) analyzes the nodes in the queueing networks separately by assuming each node is stochastically independent. This dates back to Kleinrocks' independence assumption (Kleinrock 1976). Whitt (1983) developed Queueing Network Analyzer (QNA) based on this assumption, Kingman's G/G/1 approximation (Heyman 1975), and Marshall's equation (Marshall 1968). The essential model for QNA is:

$$E(QT) = \left(\frac{c_a^2 + c_s^2}{2}\right)\left(\frac{\rho}{1-\rho}\right)\frac{1}{\mu}, \tag{1}$$

$$c_d^2 = c_a^2 + 2\rho^2 c_s^2 - (2\rho)(1-\rho)\mu E(QT) = \rho^2 c_s^2 + (1-\rho^2)c_a^2, \tag{2}$$

where ρ is utilization, μ is service rate (or capacity), σ_a is the standard deviation of inter-arrival time, σ_s is the standard deviation of service time, c_d is the coefficient of variation of departure intervals, c_s is the coefficient of variation of service time and QT is queue time.

Reiser and Kobayashi (1974) use the diffusion process approximation to develop analytical models of computing systems by considering service time distributions of a general form. By using multidimensional reflected Brownian motion, Harrison and Nguyen (1990) proposed QNET to approximate queueing networks. Dai and Harrison (1992) developed QNET further to obtain numerical results. QNET is based on a central limit theorem, involving a sequence of networks in which all nodes are assumed to be in heavy traffic. Such a regime may not always be realistic in practice and there is no guarantee on the speed of convergence.

3 Definitions

Throughout this paper, the term bottleneck refers to a throughput bottleneck, which is the server with the highest utilization. Thus the utilization of a tandem queue is its bottleneck server utilization.The following two idealized tandem queue systems are the foundation for the proposed interpolation approach.

Definition 1 *In a fully coupled system (FCS), the system queue time is determined solely by its bottleneck workstation, and is the same as the bottleneck workstation queue time would be if the bottleneck workstation sees the initial arrival process directly.*

For a given tandem queue, a fully coupled system results from assuming the service times are deterministic. Since Friedman's results are applicable to tandem queues with any specified arrival process, it should be noted that an FCS may have either renewal or non-renewal arrival processes.

Definition 2 *An ASIA system is one in which it is assumed that for the workstations in the system, "all see initial arrivals" (ASIA) directly.*

If the initial arrival process is renewal, the ASIA system queue time can be computed by Kingman's approximation. It should be noted that, for a tandem queue, a Jackson network is a special case of an ASIA system, since all servers in Jackson networks see exponential inter-arrival times.

Definition 3 *For a given tandem queue, the intrinsic gap (IG) is the queue time difference between its ASIA and fully coupled system models, i.e.,*

$$Intrinsic\,Gap = QT\ in\,ASIA\,System - QT\ in\,Fully\,Coupled\,System. \tag{4}$$

Based on the intrinsic gap, two important ratios are defined.

Definition 4 *For a given tandem queue, the intrinsic ratio (IR) is defined as*

$$Intrinsic\,Ratio = \frac{Actual\,QT - QT\ in\,Fully\,Coupled\,System}{Intrinsic\,Gap}. \tag{5}$$

Definition 5 *For a given tandem queue, the intrinsic gap ratio (IGR) is the ratio of its IG to its AISA system queue time, i.e.,*

$$Intrinsic\,Gap\,Ratio = \frac{Intrinsic\,Gap}{Queue\,Time\,in\,the\,ASIA\,System}. \tag{6}$$

4 Properties of Simple Tandem Queues

In a simple tandem queue, the first queue time can be approximated by Kingman's equation if the arrival process is renewal. The challenge comes from the second queue time, since its arrival process may not be renewal. There two possible cases: (1) simple tandem queue with backend bottleneck (STQB), where the second server has higher utilization, (2) simple tandem queue with front-end bottleneck (STQF), where the first server utilization is at least as large as the second.

Accurately predicting the bottleneck queue time in STQB is important but difficult, since system queue time is dominated by the bottleneck queue time while the bottleneck facing a non-renewal departure process. Therefore, we will study the behavior of the second queue time in STQB in detail.

For simple tandem queues, the ASIA system queue time of the second server (QT_2^A) is

$$QT_2^A \cong \left(\frac{c_{a1}^2 + c_{s2}^2}{2}\right)\left(\frac{\rho_2}{1-\rho_2}\right)\frac{1}{\mu_2}, \tag{7}$$

where c_{a1}^2 is the inter-arrival time squared coefficient of variation (SCV) of the first server, c_{s2}^2 is the service time SCV of the second server, μ_2 is the mean service rate of the second server, and ρ_2 is the utilization of the second server.

While the fully coupled system queue time of the second server in STQF is zero, the fully coupled system queue time of the second server (QT_2^A) in STQB is given by

$$QT_2^C = \left(\frac{c_{a1}^2 + c_{s2}^2}{2}\right)\left(\frac{\rho_2}{1-\rho_2}\right)\frac{1}{\mu_2} - \left(\frac{c_{a1}^2 + c_{s1}^2}{2}\right)\left(\frac{\rho_1}{1-\rho_1}\right)\frac{1}{\mu_1}, \tag{8}$$

where c_{s1}^2 is the service time SCV of the first server, μ_1 is the mean service rate of the first server, and ρ_1 is the utilization of the first server, and other notation is the same as for Eq. (7).

The intrinsic gap of the second server in STQB is

$$IG = QT_2^A - QT_2^C = QT_1 = \left(\frac{c_{a1}^2 + c_{s1}^2}{2}\right)\left(\frac{\rho_1}{1-\rho_1}\right)\frac{1}{\mu_1}. \tag{9}$$

In STQB, the intrinsic gap of the second server is exactly the same as the queue time of the first server. Therefore, this intrinsic gap possesses the following nice property.

Property 1 (Heavy Traffic Property of the Intrinsic Gap Ratio in STQB) (Heavy Traffic Property of the Intrinsic Gap Ratio in STQB) *In simple tandem queues with backend bottlenecks, the intrinsic gap ratio of the second server goes to zero as the traffic intensity approaches 1.*

In STQB, when randomness exists, the second queue time as well as its ASIA system and FCS queue times approach infinity when the traffic intensity (ρ_2) approaches 1. However, as traffic intensity approaches 1, the intrinsic gap remains finite. Thus, the IGR of the second server goes to zero in heavy traffic.

To gain further insight into Property 1, we conducted a number of simulation experiments for STQB. In these experiments, we assumed Poisson arrivals (i.e. SCV = 1) and gamma-distributed service times. In a series of experiments for "small" SCV, values for the two servers are chosen from {0.1 (low), 0.5 (medium), 0.9 (high)}, resulting in nine experiment settings, i.e. (1, 0.1, 0.1), (1, 0.1, 0.5), (1, 0.1, 0.9), (1, 0.5, 0.1), (1, 0.5, 0.5), (1, 0.5, 0.9), (1, 0.9, 0.1), (1, 0.9, 0.5) and (1, 0.9, 0.9). In each experiment, the service time of the second server is 30, but the first service time is chosen from {10, 20, 25, 29}. Each observation in the tables is the average of 100–200 replications. Depending on the utilization and service times, each replication is the average of 200,000–50,000,000 data points after a warm up period of 50 years or longer. The intrinsic ratios of the second server in the STQB cases, when service time SCV is smaller than 1, are shown in Fig. 1. The results come from 36 experiments. All intrinsic ratios are between 0 and 1 and show regular patterns.

When the service time variability is greater than 1, we examine the cases of STQB. As before, we conduct 36 experiments with Poisson arrivals and gamma distributed service times. The service times are as in the first series of experiments. However, in this series, the service time SCV is chosen from 2, 5 or 8. Each observation is the average of 100 replications. Each replication is the average of 200,000–1,000,000 data points after a warm up period of 50 years or longer. Based on Fig.1, we have the following observation.

Observation 1 (Nearly-Linear Relationship) *The intrinsic ratio of the second server is approximately linear across most traffic intensities.*

Because the intrinsic ratio is developed based on the ASIA system and FCS, we can obtain the intrinsic ratio exactly when the arrival process is Poisson and the service times are exponential or constant. When the arrival process is Poisson, the intrinsic ratio is 1 when service times are exponential, and is 0 when the service times are constant at all utilizations. The intrinsic ratio slopes are 0 in these two cases. From the simulation results, the slope of the intrinsic ratios is also close to 0 when the service time SCV is between 0 and 1. The slopes become positive when the service time SCV is larger than 1. Therefore, we have the following conjecture:

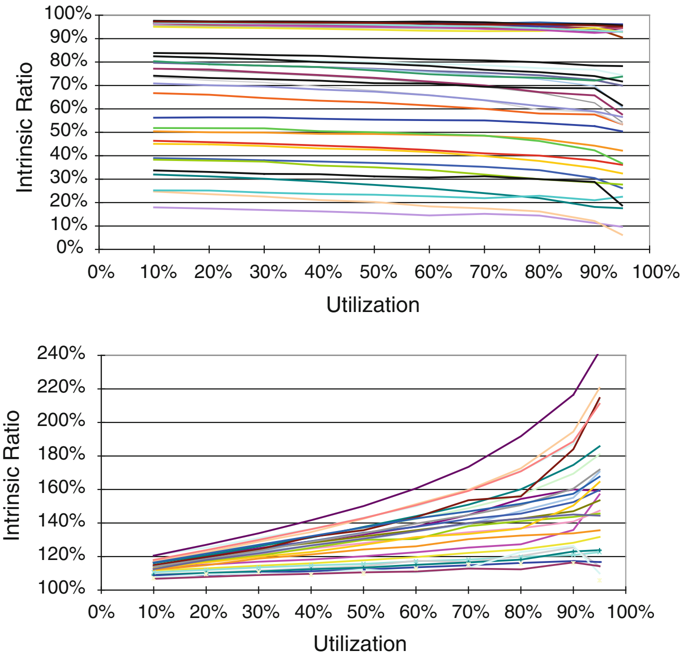


Fig. 1 Intrinsic ratio when service time SCV < 1 (*top*) and SCV > 1 (*below*)

Conjecture 1 (Upper and Lower Bounds for the Second Queue Time in Simple Tandem Queues) *In a simple tandem queue with Poisson arrivals, if the service time SCV of the first server is smaller than 1, the ASIA system queue time is an upper bound and the FCS queue time is a lower bound of the second queue time. If the service time SCV of the first server is greater than 1, the ASIA system queue time becomes a lower bound of the second server queue time.*

Because of Conjecture 1 and Property 1, the second queue time for STQB with Poisson arrivals is expected to be bounded within the intrinsic gap, and the IGR of the second server goes to zero in heavy traffic. These nice properties give us a reliable way to estimate the second queue time in STQB.

5 Simple Tandem Queues with Backend Bottlenecks

Based on the heavy traffic property and nearly-linear relationship of the intrinsic ratios, we propose to approximate the bottleneck queue time in STQB by

$$\begin{aligned} QT_2 &= QT_2^A - (1-y_2)\times IG \\ &\cong \left(\frac{c_{a1}^2+c_{s2}^2}{2}\right)\left(\frac{\rho_2}{1-\rho_2}\right)\frac{1}{\mu_2} - (1-y_2)\left(\frac{c_{a1}^2+c_{s1}^2}{2}\right)\left(\frac{\rho_1}{1-\rho_1}\right)\frac{1}{\mu_1}, \end{aligned} \tag{10}$$

where y_2 is the intrinsic ratio between the first and second server. When y_2 is 1, Eq. (10) is the second queue time in the ASIA system. When y_2 is 0, Eq. (10) is the second queue time in the fully coupled system. The heavy traffic property of the intrinsic gap (Property 1) plays an important role in approximating the second queue time of STQB. Since, based on Observation 1, the intrinsic ratio is finite, when the intrinsic gap in Eq. (5) becomes small, the approximate error of queue time, caused by the imprecise estimate of the intrinsic ratio, also becomes small.

The value of the intrinsic ratio is determined by four factors: initial arrival process, service time ratio (first service time/second service time), and service time SCVs of the first and second servers. If the intrinsic ratio can be approximated by the first and second moments of the inter-arrival and service times, it can be presented as a function of those parameters:

$$Intrinsic\,Ratio:\ y_2 \cong f(\lambda, c_{a1}^2, ST_1/ST_2, c_{s1}^2, c_{s2}^2), \tag{11}$$

where λ is the arrival rate, ST_i is service time of the i-th server. The challenge is to determine a good estimate of y_2. The following heuristics are proposed for estimating y_2: make it equal to the coefficient of variation of the first station service time. This heuristic is the direct result of the previous observation: When y_2 is either 0 or 1, Eq. (10) is either the second queue time in the fully coupled system or the ASIA system, respectively. Using cs1 to approximate y_2 seems to be a reasonable choice, since c_{s1} is 0 in the fully coupled system and is 1 in the ASIA system.

When the arrival process is Poisson and service time variability is smaller than 1, the average error of the heuristic is 3.3 % (cf. 11.0 % for QNA and 13.1 % for QNET). Since the first queue time can be computed exactly in this case, it is important to see the impact of the errors on system queue time. If we give a weight to the approximate errors by "Second QT/System QT", the weighted average error becomes 1.8 % for our heuristic, 6.3 % for QNA and 10.3 % for QNET. When the service time SCV is greater than 1, the heuristic does not perform well. In this situation, we may simply use QNA. We call the heuristic the intrinsic ratio (IR) methods, since they are based on the properties of the intrinsic ratio.

6 Conclusion

We have presented a new approximation approach for estimating queue time for simple tandem queues based on newly observed properties, namely the intrinsic gap and intrinsic ratio. Through those underlying properties, the computation is much simpler than the prior methods. Due to the heavy traffic property, the resulting model performs well for simple tandem queues with backend bottlenecks. This is very important, since the system queue time is dominated by the second server in STQB where the second server faces a non-renewal departure process.

In practical manufacturing system, the situation can be more complicated: parallel batching may exist and determination of service time may not be trivial (Wu et al. 2011). All the above will complicate the determination of the intrinsic ratio.

Our approach to approximating queue time does not depend on assumptions about the behavior of mathematical models. Instead, we have identified a fundamental property of tandem queues and exploited this property to deal directly with dependence among workstations. We have achieved notable improvement in the approximation errors, relatively to the prior approaches. The extension of the current approximate models to practical manufacturing systems has been studied by Wu and McGinnis (2012) with promising results.

References

Avi-Itzhak B (1965) A sequence of service stations with arbitrary input and regular service times. Manage Sci 11(5):565–571

Dai J (1992) Performance Analysis of queueing networks using reflecting brownian motions. http://www2.isye.gatech.edu/people/faculty/dai/Software.html

Dai JG, Harrison JM (1992) Reflected brownian motion in an orthant: numerical methods for steady-state analysis. Ann Appl Probab 2:65–86

Friedman HD (1965) Reduction methods for tandem queueing systems. Oper Res 13(1):121–131

Harrison JM, Nguyen A (1990) The QNET method for two-moment analysis of open queueing networks. Queueing Syst 6:1–32

Heyman DP (1975) A diffusion model approximation for the GI/G/1 queue in heavy traffic. Bell Syst Tech J 54(9):1637–1646

Jackson JR (1957) Networks of waiting Lines. Oper Res 5(4):518–521

Kleinrock L (1976) Queueing systems: computer applications. Wiley-Interscience, New York

Kuehn PJ (1979) Approximate analysis of general queuing networks by decomposition. IEEE Trans Commun 27(1):113–126

Marshall KT (1968) Some inequalities in queueing. Oper Res 16(3):651–665

Reiser M, Kobayashi H (1974) Accuracy of the diffusion approximation for some queueing Systems. IBM J Res Dev 18(2):110–124

Whitt W (1983) The queueing network analyzer. Bell Syst Tech J 62(9):2779–2815

Wu K, McGinnis L (2012) Performance evaluation for general queueing networks in manufacturing systems: characterizing the trade-off between queue time and utilization. Eur J Oper Res 221(2):328–339

Wu K, McGinnis L, Zwart B (2011) Queueing models for a single machine subject to multiple types of interruptions. IIE Trans 43(10):753–759

On Reliability Evaluation of Flow Networks with Time-Variant Quality Components

Shin-Guang Chen

Abstract In general, the reliability evaluation of a stochastic-flow network is with time-invariant quality components (including links or vertices). However, in practice, the quality of components for a stochastic-flow network may be variant due to deterioration or improvement by incomplete renewal. This paper presents a method to evaluate the two-terminal network reliability (2TNR) with time-variant quality components. A numerical example is presented to show the application of this method.

Keywords Time-variant quality component · Two-terminal network · Reliability · Minimal path

1 Introduction

The network reliability with time-invariant quality components has been deeply investigated for decades. For example, Aggarwal et al. (1975) first presented the reliability evaluation method for a binary-state network (no flow happens). Lee (1980) used lexicographic ordering and labeling scheme (Ford and Fulkerson 1962) to calculate the system reliability for a binary-state flow network (0 or a positive integer flow exists). Aggarwal et al. (1982) solved such a reliability problem in terms of minimal paths (MPs). Without MPs, Rueger (1986) extended to the case that nodes as well as arcs all have a positive-integer capacity and may fail. Considering that each arc has several states/capacities, such a network is called a stochastic-flow network (Xue 1985, for perfect node cases; Lin 2001, for imperfect node cases). Given the demand *d*, the system reliability is the probability

S.-G. Chen (✉)
Department of Industrial Engineering and Management, Tungnan University,
New Taipei City, Taiwan ROC
e-mail: Bobchen@mail.tnu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_6,

that the maximum flow of the network is not less than d. However, in practice, the quality of components for a stochastic-flow network may be variant due to deterioration or improvement by incomplete renewal.

This paper mainly aims at the reliability evaluation of a two-terminal and stochastic-flow network (2TNR) with time-variant quality component (nodes only) in terms of MPs. A path is a set of nodes and arcs whose existence results in the connection of source node and sink node. A MP is a path whose proper subset is not a path. When the network is live, there are several MP vectors respect to system demand d, called d-MP, can be found. Then, the network reliability is the union probability of all those d-MPs.

The remainder of the work is described as follows: The assumptions are addressed in Sect. 2. The network model is described in Sect. 3. Then, a numerical example is demonstrated in Sect. 4. Section 5 draws the conclusion for this paper.

2 Assumptions

Let $G = (A, B, M)$ be a stochastic-flow network where A is the set of arcs, $B = \{b_i | 1 \leq i \leq s\}$ is the set of nodes, and $M = (m_1, m_2, \ldots, m_s)$ is a vector with m_i (an integer) being the maximum capacity of b_i. Such a G is assumed to satisfy the following assumptions.

1. The capacity of b_i is an integer-valued random variable which takes values from the set $\{0, 1, 2, \ldots, m_i\}$ according to an empirical probability mass function (p.m.f.) μ_{it}, which can be obtained by a statistical observation in a moving time frame at time t. Note that the capacity 0 often means a failure or unavailability of this node at time t.
2. The arcs are perfect. That is, they are excluded from the reliability calculation.
3. Flow in G satisfies the flow-conservation law (Ford and Fulkerson 1962).
4. The states of each node are independent from each other.

3 The Network Model

Let $mp_1, mp_2, \ldots, mp_z$ be the MPs. Thus, the network model can be described in terms of two vectors: the capacity vector $X_t = (x_{1t}, x_{2t}, \ldots, x_{st})$, and the flow vector $F_t = (f_{1t}, f_{2t}, \ldots, f_{zt})$, where x_{it} denotes the current capacity of b_i at time t and f_{jt} denotes the current flow on mp_j at time t. Then, such a vector F_t is feasible iff

$$\sum_{j=1}^{z} \{f_{jt} | b_i \in mp_j\} \leq m_i \quad \text{for } i = 1, 2, \ldots, s. \tag{1}$$

Constraint (1) describes that the total flow through b_i can not exceed the maximum capacity of b_i at time t. We denote such set of F_t as $U_{Mt} = \{F_t | F_t$ is feasible under $M\}$. Similarly, F_t is feasible under $X_t = (x_{1t}, x_{2t}, \ldots, x_{st})$ iff

$$\sum_{j=1}^{z} \{f_{jt} | b_i \in mp_j\} \leq x_{it} \quad \text{for } i = 1, 2, \ldots, s \tag{2}$$

For clarity, let $U_{Xt} = \{F_t | F_t$ is feasible under $X_t\}$. The maximum flow under X_t is defined as $V(X_t) = \max\{\sum_{j=1}^{z} \{f_{jt} | F_t \in U_{Xt}\}$.

3.1 Reliability Evaluation

Given a demand d_t, the reliability R_{dt} is the probability that the maximum flow is not less than d_t, i.e., $R_{dt} = \Pr\{X_t | V(X_t) \geq d_t\}$ at time t. To calculate R_{dt}, it is advantageously to find the minimum capacity vector in $\{X_t | V(X_t) \geq d_t\}$. A minimum capacity vector X is said to be a d-MP iff (1) $V(X) \geq d$ and (2) $V(Y) < d$, for any other vector Y such that $Y < X$, in which $Y \leq X$ iff $y_j \leq x_j$, for $j = 1, 2, \ldots, s$ and $Y < X$ iff $Y \leq X$ and $y_j < x_j$, for at least one j. Suppose there are totally w_t d-MPs at time t: $X_{1t}, X_{2t}, \ldots, X_{wt}$, and $E_{it} = \{X_t | X_t \geq X_{it}\}$, the probability R_{dt} can be equivalently calculated via the well-known inclusion–exclusion principle or the RSDP algorithm (Zuo et al. 2007)

$$\begin{aligned} R_{dt} &= \Pr\{X_t | V(X_t) \geq d_t\} \\ &= \Pr(\bigcup_{i=1}^{w_t} E_{it}) \\ &= \sum_{k=1}^{w_t} (-1)^{k-1} \sum_{I \subset \{1,2,\ldots,w_t\}, |I|=k} \Pr\{\bigcap_{i \in I} E_{it}\}, \end{aligned} \tag{3}$$

where $\Pr\{\bigcap_{i \in I} E_{it}\} = \prod_{j=1}^{s} \sum_{l=\max\{x_{ij} | \forall i \in I\}}^{m_j} \mu_{jt}(l)$.

3.2 Generation of d-MPs

At first, we find the flow vector $F_t \in U_{Mt}$ such that the total flow of F_t equals d_t. It is defined as in the following equation

$$\sum_{j=1}^{z} f_{jt} = d_t. \tag{4}$$

Then, let $\mathbf{F}_t = \{F_t | F_t \in U_{Mt}$ and satisfies Eq. (4)$\}$. We show that a d-MP X_t exists if there is a $F_t \in \mathbf{F}_t$ by the following lemma.

Lemma 3.1 *Let X_t be a d-MP, then there is a $F_t \in \mathbf{F}_t$ such that*

$$x_{it} = \sum_{j=1}^{z} \{f_{jt} | a_i \in mp_j\} \quad \text{for } i = 1, 2, \ldots, s \tag{5}$$

Proof If X_t is a d-MP, then there is a F_t such that $F_t \in U_{Xt}$ and $F_t \in \mathbf{F}_t$. Suppose there is a k such that $x_{kt} > \sum_{j=1}^{z} \{f_{jt} | a_i \in mp_j\}$. Set $Y_t = (y_{1t}, y_{2t}, \ldots, y_{(k-1)t}, y_{kt}, y_{(k+1)t}, \ldots, y_{st}) = (x_{1t}, x_{2t}, \ldots, x_{(k-1)t}, x_{kt} - 1, x_{(k+1)t}, \ldots, x_{st})$. Hence $Y_t < X_t$ and $F_t \in U_{Yt}$ (since $\sum_{j=1}^{z} \{f_{jt} | a_i \in mp_j\} \le y_{it}, \quad \forall i$), which indicates that $V(Y_t) \ge d_t$ and contradicts to that X_t is a d-MP. □

Given any $F_t \in \mathbf{F}_t$, we generate a capacity vector $X_{Ft} = (x_{1t}, x_{2t}, \ldots, x_{st})$ via Eq. (5). Then, the set $\Omega = \{X_{Ft} \mid F_t \in \mathbf{F}_t\}$ is built. Let $\Omega_{min} = \{X_t | X_t$ is a minimal vector in $\Omega\}$. Lemma 3.1 indicates that the set Ω includes all d-MPs. The following lemma further proves that Ω_{min} is the set of d-MPs.

Lemma 3.2 $\Omega_{\min}$ *is the set of* d-MPs.

Proof Firstly, suppose $X_t \in \Omega_{min}$ (note that $V(X_t) \ge d_t$) but it is not a d-MP. Then there is a d-MP Y_t such that $Y_t < X_t$, which implies $Y_t \in \Omega$ and thus contradicts to that $X_t \in \Omega_{min}$. Hence, X_t is a d-MP. Conversely, suppose X_t is a d-MP (note that $X_t \in \Omega$) but $X_t \notin \Omega_{min}$ i.e., there is a $Y_t \in \Omega$ such that $Y_t < X_t$. Then, $V(Y_t) \ge d_t$ which contradicts to that X_t is a d-MP. Hence, $X_t \in \Omega_{min}$. □

4 A Numerical Example

Figure 1 shows a 5-nodes network. The demand is 4. Table 1 gives the results of sampling from the throughputs of all 5 nodes in a period $t = 1$–20. Table 2 shows the changes of b_1 quality from $t = 10$–20 by 10 units moving time frame.

There are 4 MPs found: $mp_1 = \{b_1, b_2, b_4, b_5\}$, $mp_2 = \{b_1, b_2, b_5\}$, $mp_3 = \{b_1, b_3, b_4, b_5\}$, $mp_4 = \{b_1, b_3, b_5\}$. All 4-MPs are generated step-by-step as follows:

Fig. 1 A 5-node network

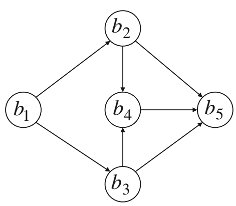


Table 1 The raw data

t	b_1	b_2	b_3	b_4	b_5	R_{dt}
1	2	1	1	1	2	–
2	4	0*	3	2	3	–
3	0	1	0	1	0	–
4	1	0	1	0	2	–
5	6	2	2	3	4	–
6	2	1	2	1	3	–
7	3	2	1	1	3	–
8	5	2	2	2	4	–
9	5	2	3	3	5	–
10	4	2	2	1	4	0.0720
11	6	0	3	2	5	0.1230
12	5	3	2	3	4	0.1728
13	5	3	3	3	5	0.3087
14	0	3	2	3	5	0.4368
15	6	3	0	3	3	0.3479
16	5	3	3	3	6	0.4928
17	5	3	3	3	6	0.6561
18	4	2	1	3	0	0.5616
19	5	3	2	0	6	0.5688
20	4	3	3	3	6	0.5760

*node failure

Table 2 The changes of b_1 quality from t = 10–20

t	The p.m.f of b_1						
	0	1	2	3	4	5	6
10	0.10	0.10	0.20	0.10	0.20	0.20	0.10
11	0.10	0.10	0.10	0.10	0.20	0.20	0.20
12	0.10	0.10	0.10	0.10	0.10	0.30	0.20
13	0.00	0.10	0.10	0.10	0.10	0.40	0.20
14	0.10	0.00	0.10	0.10	0.10	0.40	0.20
15	0.10	0.00	0.10	0.10	0.10	0.40	0.20
16	0.10	0.00	0.00	0.10	0.10	0.50	0.20
17	0.10	0.00	0.00	0.00	0.10	0.60	0.20
18	0.10	0.00	0.00	0.00	0.20	0.50	0.20
19	0.10	0.00	0.00	0.00	0.20	0.50	0.20
20	0.10	0.00	0.00	0.00	0.20	0.50	0.20

Step 1. Find the feasible vector $F_t = (f_{1t}, f_{2t}, \ldots, f_{4t})$ satisfying both capacity and demand constraints.

a. Enumerate f_{jt} for $0 \leq f_{jt} \leq 6$, $1 \leq j \leq 4$ do
b. If f_{jt} satisfies the following equations
$f_{1t} + f_{2t} + f_{3t} + f_{4t} \leq 6, f_{1t} + f_{2t} \leq 6, f_{3t} + f_{4t} \leq 6, f_{1t} + f_{3t} \leq 6,$
$f_{1t} + f_{2t} + f_{3t} + f_{4t} = 4,$
then $\mathbf{F}_t = \mathbf{F}_t \cup \{F_t\}$.
End enumeration.
The result is $\mathbf{F}_{t=10} = \{(0, 0, 0, 4)\ (0, 0, 1, 3), (0, 0, 2, 2), \ldots, (4, 0, 0, 0)\}$.

Step 2. Generate the set $\Omega = \{X_{Ft} \mid F_t \in \mathbf{F}_t\}$.

a. For F_t in $\mathbf{F}_t$ do
b. $x_{1t} = f_{1t} + f_{2t} + f_{3t} + f_{4t}$, $x_{2t} = f_{1t} + f_{2t}$, $x_{3t} = f_{3t} + f_{4t}$,
$x_{4t} = f_{1t} + f_{3t}$,
$x_{5t} = f_{1t} + f_{2t} + f_{3t} + f_{4t}$.
c. $U_{Xt} = U_{Xt} \cup \{X_{Ft}\}$.
End for-loop.
d. For X_t in U_{Xt} do
e. If $X_t \notin \Omega$, then $\Omega = \Omega \cup \{X_t\}$.
End for-loop.
At the end of the loop: $\Omega = \{X_{1t=10} = (4, 0, 4, 0, 4), X_{2t=10} = (4, 0, 4, 1, 4), \ldots, X_{25t=10} = (4, 4, 0, 4, 4)\}$.

Step 3. Find the set $\Omega_{min} = \{X_t \mid X_t$ is a minimum vector in $\Omega\}$ via pairwise comparison.

The result is $\Omega_{min} = \{X_{1t=10} = (4, 0, 4, 0, 4), X_{6t=10} = (4, 1, 3, 0, 4), X_{10t=10} = (4, 2, 2, 0, 4), X_{13t=10} = (4, 3, 1, 0, 4), X_{15t=10} = (4, 4, 0, 0, 4)\}$.

Finally, the probability $R_{4t=10}$ can be calculated in terms of 5 4-MPs. Let $E_{1t} = \{X_t \mid X_t \geq X_{1t}\}$, $E_{2t} = \{X_t \mid X_t \geq X_{6t}\}$, $E_{3t} = \{X_t \mid X_t \geq X_{10t}\}$, $E_{4t} = \{X_t \mid X_t \geq X_{13t}\}$ and $E_{5t} = \{X_t \mid X_t \geq X_{15t}\}$. From Eq. (3), we get $R_{4t=10} = \Pr\{\bigcup_{i=1}^{5} E_{it}\} = 0.0720$.

5 Conclusion

This paper proposed a reliability evaluation method for two-terminal and stochastic-flow networks (2TNR) with time-variant quality component (node only) in terms of MPs. The network reliability with time-invariant quality components has been deeply investigated for decades, such as the reliability evaluation of bi-state networks, bi-state flow networks, and stochastic-flow networks. However, in practice, the quality of components for a stochastic-flow network may be variant due to deterioration or improvement by incomplete renewal. A numerical example is demonstrated to explain the proposed method.

Future researches are suggested to investigate the reliability of imperfect double-resource networks with time-variant quality components.

Acknowledgments This work was supported in part by the National Science Council, Taiwan, Republic of China, under Grant No. NSC 101-2221-E-236-006.

References

Aggarwal KK, Gupta JS, Misra KB (1975) A simple method for reliability evaluation of a communication system. IEEE T Commun 23:563–565

Aggarwal KK, Chopra YC, Bajwa JS (1982) Capacity consideration in reliability analysis of communication systems. IEEE T Reliab 31:177–180

Ford LR, Fulkerson DR (1962) Flows in networks. Princeton University Press, NJ

Lee SH (1980) Reliability evaluation of a flow network. IEEE T Reliab 29:24–26

Lin YK (2001) A simple algorithm for reliability evaluation of a stochastic-flow network with node failure. Comput Oper Res 28:1277–1285

Rueger WJ (1986) Reliability analysis of networks with capacity-constraints and failures at branches and nodes. IEEE T Reliab 35:523–528

Xue J (1985) On multistate system analysis. IEEE T Reliab 34:329–337

Zuo MJ, Tian Z, Huang HZ (2007) An efficient method for reliability evaluation of multistate networks given all minimal path vectors. IIE Trans 39:811–817

Defect Detection of Solar Cells Using EL Imaging and Fourier Image Reconstruction

Ya-Hui Tsai, Du-Ming Tsai, Wei-Chen Li and Shih-Chieh Wu

Abstract Solar power is an attractive alternative source of electricity nowadays. Solar cells, which form the basis of a solar power system, are mainly based on crystalline silicon. Many defects cannot be visually observed with the conventional CCD imaging system. This paper presents defect inspection of multi-crystalline solar cells in electroluminescence (EL) images. A solar cell charged with electrical current emits infrared light. The intrinsic crystal grain boundaries and extrinsic defects of small cracks, breaks, and finger interruptions hardly reflect the infrared light. The EL image can thus distinctly highlight barely visible defects as dark objects. However, it also shows random dark regions in the background, which makes automatic inspection in EL images very difficult. A self-reference scheme based on the Fourier image reconstruction technique is proposed for defect detection of solar cells in EL images. The target defects appear as line- or bar-shaped objects in the EL image. The Fourier image reconstruction process is applied to remove the possible defects by setting the frequency components associated with the line- and bar-shaped defects to zero and then back-transforming the spectral image into a spatial image. The defect region can then be easily identified by evaluating the gray-level differences between the original image and its reconstructed image. The reference image is generated from the inspection image itself and, thus, can accommodate random inhomogeneous backgrounds. Experimental results on a set of various solar cells have shown that the proposed method performs effectively for detecting small cracks, breaks, and

Y.-H. Tsai · W.-C. Li
Mechanical Industry Research Laboratories, Industrial Technology Research Institute, 195, Sec. 4, Chung-Hsing Road, Chutung, Hsinchu, Taiwan, Republic of China
e-mail: yahuitsai@itri.org.tw

W.-C. Li
e-mail: jeecool@itri.org.tw

D.-M. Tsai (✉) · S.-C. Wu
Department of Industrial Engineering and Management, Yuan-Ze University, 135 Yuan-Tung Road, Nei-Li, Tao-Yuan, Taiwan, Republic of China
e-mail: iedmtsai@saturn.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_7,

finger interruptions. The computation time of the proposed method is also fast, making it suitable for practical implementation. It takes only 0.29 s to inspect a whole solar cell image with a size of 550 × 550 pixels.

Keywords Defect detection · Surface inspection · Solar cell · Fourier transform

1 Introduction

In recent years, the demand for solar cells has increased significantly due to growing environmental concerns and the global oil shortage. The demand could even be potentially boosted after the nuclear disaster in Fukushima, Japan. Solar cells, which convert the photons from the sun to electricity, are largely based on crystalline silicon in the currently installed solar power systems because of the competitive conversion efficiency and usable lifespan.

Since defects in solar cells critically reduce their conversion efficiency and usable lifetime, the inspection of solar cells is very important in the manufacturing process. Some fatal defects, such as small cracks lying within the wafer surface and subtle finger interruptions, may not be visually observed in the image captured by a typical CCD camera. In order to highlight the intrinsic and extrinsic deficiencies that degrade the conversion efficiency of a solar cell, the electroluminescence (EL) imaging technique (Fuyuki et al. 2005; Fuyuki and Kitiyanan 2009) has been proposed in recent years. In the EL imaging system, the solar cell is excited with voltage, and then a cooled Si-CCD camera or a more advanced InGaAs camera is used to capture the infrared light emitting from the excited solar cell. Areas of silicon with higher conversion efficiency present brighter luminescence in the sensed image. Figure 1 shows the configuration of the EL imaging system. Figure 2a shows the EL image of a defect-free solar cell. Figure 2b–d presents three EL images of defective solar cells that contain small cracks, breaks, and finger interruptions, respectively. The defect areas are inactive, resulting in dark regions that are visually observable in the sensed EL image. The EL imaging system not only shows the extrinsic defects as dark objects but also presents the dislocation and grain boundaries with dark gray levels in the sensed image. The background shows inhomogeneous patterns of dark blobs and clouds due to the random crystal grains in the multi-crystalline silicon wafer. This characteristic makes the automatic defect detection in EL images very difficult.

Recently, Li and Tsai (2011) presented a machine vision algorithm to detect saw-mark defects in multi-crystalline solar wafers in the wafer cutting process. The Fourier transform is used to smooth the crystal grain background as a non-textured surface. A line detection process is then carried out for each individual scan line of the filtered image to detect possible defect points that are distinctly apart from the line sought.

In this study, we further the development of an automatic detection method for critical surface defects of both exterior and interior small cracks, breaks, and finger

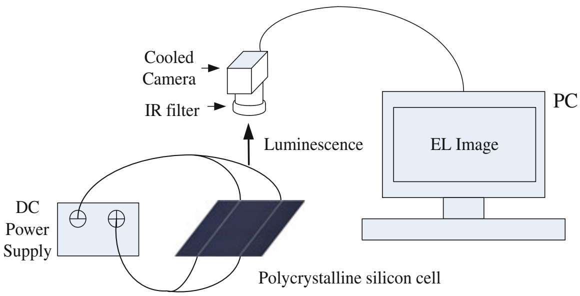


Fig. 1 Configuration of an EL imaging system

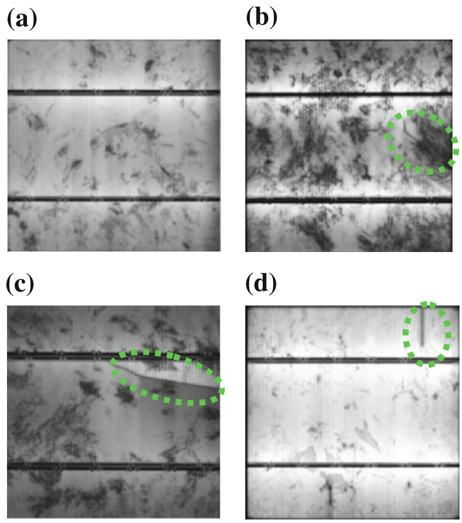


Fig. 2 EL images of solar cells **a** defect-free sample, **b** small crack, **c** break, and **d** finger-interruption

interruptions of a multi-crystalline solar cell in an EL image. The small crack appears as a thin line segment, and the break divides the infected area into a dark and a bright region in the EL image. The disconnected finger affects the area beneath the finger and its neighborhood and appears as a dark bar-shaped object along the finger direction in the EL image. In order to detect such defects against an inhomogeneous background, a self-reference scheme based on the Fourier image reconstruction is proposed for solar cell inspection in EL images.

2 Defect Detection in Inhomogeneous Surfaces

Self-reference approaches (Guan et al. 2003) that generate a golden template from the inspection image itself and image reconstruction approaches (Tsai and Huang 2003) that remove the background pattern have been used for defect detection in textured surfaces. The multi-crystalline solar cell in the EL image falls in the category of inhomogeneous textures. Conventional self-reference or image reconstruction methods cannot be directly extended for defect detection in randomly textured surfaces. The Fourier transform (FT) is a global representation of an image and, thus, gives no spatial information of the defect in the original EL image. In order to locate a defect in the EL image, we can eliminate the frequency components along a line with a specific slope angle in the spectrum image and then back-transform the image using the inverse FT. The reconstructed image can then be used as a defect-free reference image for comparison.

2.1 Fourier Image Reconstruction

Let $f(x, y)$ be the gray level at pixel coordinates (x, y) in an EL image of size $M \times N$. The two-dimensional discrete Fourier transform (DFT) of $f(x, y)$ is given by

$$F(u, v) = \sum_{y=0}^{N-1} \sum_{x=0}^{M-1} f(x, y) \cdot \exp\left[-j2\pi\left({}^{ux}/_{M} + {}^{vy}/_{N}\right)\right] \tag{1}$$

for spectral variables $u = 0, 1, 2, \ldots, M-1$ and $v = 0, 1, 2, \ldots, N-1$. The DFT is generally complex; that is $F(u, v) = R(u, v) + j.I(u, v)$, where $R(u, v)$ and $I(u, v)$ are the real and imaginary parts of $F(x, y)$, i.e.,

$$R(u, v) = \sum_{y=0}^{N-1} \sum_{x=0}^{M-1} f(x, y) \cdot \cos\left[2\pi\left({}^{ux}/_{M} + {}^{vy}/_{N}\right)\right] \tag{2a}$$

$$I(u, v) = \sum_{y=0}^{N-1} \sum_{x=0}^{M-1} f(x, y) \cdot \sin\left[2\pi\left({}^{ux}/_{M} + {}^{vy}/_{N}\right)\right] \tag{2b}$$

The power spectrum $P(x, y)$ of $F(x, y)$ is defined as

$$P(u, v) = |F(u, v)|^2 = R^2(u, v) + I^2(u, v) \tag{3}$$

Since the input image $f(x, y)$ is real, the FT exhibits conjugate symmetry. The magnitude of the transform is symmetric with respect to the DC center in the spectrum image. Figure 3a1 shows the EL image of a defective solar cell that contains a small line crack at an angle of 37°, and Fig. 3a2 is the corresponding Fourier spectrum image. It is expected to find a 127° high-energy straight line passing through the DC center in the spectrum image. However, the resulting spectrum image cannot sufficiently display a visible line due to the extremely short line segment of the small crack with respect to the whole EL image area.

In order to intensify the high-energy line for a defect with either a long or a short line segment in the Fourier spectrum image, the original solar cell image is equally divided into many non-overlapping subimages of smaller size. Figure 3b1

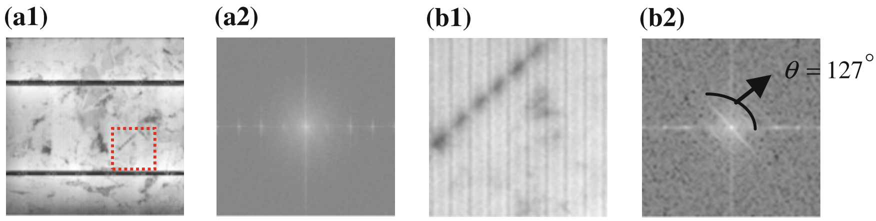


Fig. 3 Fourier spectrum images of solar cells: **a1** full-sized defective EL image of 550 × 550 pixels; **a2** spectrum image of (**a1**) where no lines can be visually observed; **b1** small crack in a 75 × 75 EL subimage; **b2** spectrum image of (**b1**), where a 127°-line can be distinctly observed

shows the crack defect in a 75 × 75 subimage. Figure 3b2 presents the corresponding Fourier spectrum, where the high-energy line associated with the 37° crack is now more distinctly present at 127° in the spectrum image.

2.2 Line Detection in Spectrum Images

To automatically detect high-energy lines associated with line-shaped defects in the Fourier spectrum image, we propose a line detection process for the task. The Hough transform (HT) is an effective technique for line detection under noisy and discontinuous conditions. It involves a voting process that transforms the set of points in the image space into a set of accumulated votes in the parameter space. A local peak larger than some threshold in the parameter space then indicates a line present in the image space. The line equation is then solely defined by the parameter of slope angle. The HT process scans every pixel (u, v) in the spectrum image, and calculates the slope angle

$$\theta = \tan^{-1}((v - v_0)/(u - u_0)) \tag{4}$$

where (u_0, v_0) is the central coordinates of the spectrum image, and is given by $(M/2, N/2)$ for an image of size $M \times N$. The voting weight for the 1-D accumulator $A(\theta)$ at slope angle θ is given by the Fourier spectrum $|F(u, v)|$; i.e.,

$$A(\theta) \leftarrow A(\theta) + |F(u, v)|$$

A local peak with significantly large accumulated magnitude indicates a possible line in the spectrum image. Due to the inherited structure of a solar cell in the EL image, the accumulator will show extremely high magnitudes in horizontal, vertical, and diagonal directions, i.e., angles at 0°, 45°, 90° and 135°. Figure 4a1, b1 show a defect-free and a defective EL subimage of solar cells, respectively. Figure 4a2, b2 are the corresponding accumulators $A(\theta)$ for the EL subimages in Fig. 4a1, b1, excluding the accumulated values at 0°, 45°, 90° and 135°. It can be seen that there are no significant peaks for the Fourier spectrum of the defect-free

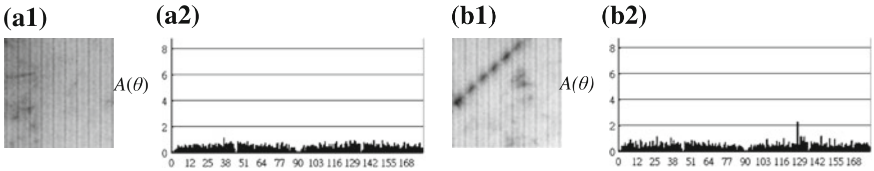


Fig. 4 The accumulator $A(\theta)$ of the Hough transform; **a1** defect-free EL subimage, **b1** defective EL image with a 37°-crack; **a2** accumulator $A(\theta)$ as a function of θ for defect-free sample (**a1**); **b2** accumulator $A(\theta)$ for defective sample (**b1**)

subimage. However, there is a distinct peak at $\theta = 127°$ corresponding to the 37° crack in the EL subimage.

In this study, the adaptive threshold T_θ for θ selection is given by the upper bound of a simple statistical control limit, which is defined as Eq. (5):

$$T_\theta = \mu_{A(\theta)} + K_\theta \cdot \sigma_{A(\theta)} \tag{5}$$

where K_θ is user specified control constant; it is given by 2.5 in this study. Note that we exclude 0°, 45°, 90° and 135° for the computation of the mean $\mu_{A(\theta)}$ and standard deviation $\sigma_{A(\theta)}$ of $A(\theta)$. All local maximum peaks with $A(\theta)$ greater than the angle threshold T_θ are recognized as suspected slope angles of defects, and are collected in a set:

$$\Theta = \left\{ \theta | A(\theta) > \mu_{A(\theta)} + K_\theta \cdot \sigma_{A(\theta)} \right\} \tag{6}$$

Since a true line crack generally results in distinctly high-energy frequency components in the spectrum image, setting $K_\theta = 2.5$ in this study is sufficiently small to ensure all true crack lines in the associated spectrum image can be selected.

2.3 *Defect Detection*

To tackle the problem of defect detection in an inhomogeneous surface, we remove all the possible defects and create a near defect-free reference image from each individual test image under inspection. This is done by assigning zero values to all frequency components in the vicinity of each detected line with slope angle θ^* in the collection Θ, and then back-transforming the revised Fourier spectrum using the inverse DFT.

Let Δw be the band-rejection width. For a given slope angle θ^*, $\theta^* \in \Theta$, the band-rejection region is bounded by two lines $L^+_{\theta^*}$ and $L^-_{\theta^*}$ that are parallel to $L_{\theta^*,0}$ with a width of Δw between these two lines, as shown in Fig. 5. The bounded lines $L^+_{\theta^*}$ and $L^-_{\theta^*}$ are given by

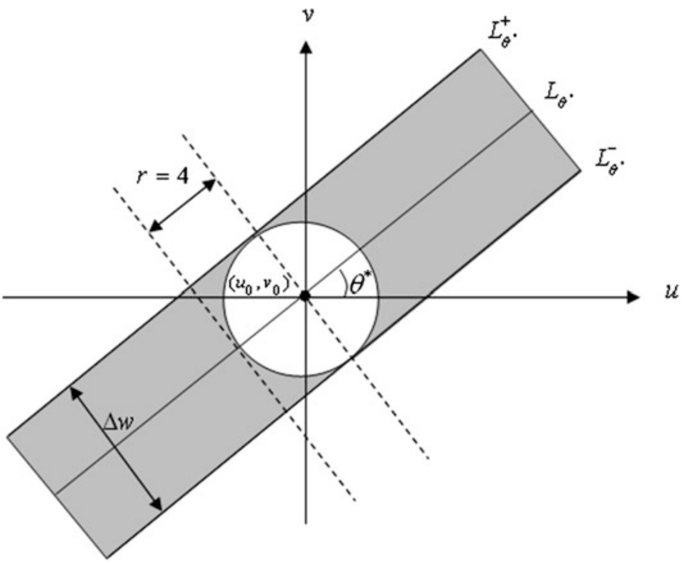


Fig. 5 Band-rejection region in the Fourier spectrum image for defect removal

$$L^+_{\theta^*} : (u - u_0)\tan\theta^* - (v - v_0) - b = 0 \tag{7a}$$

$$L^-_{\theta^*} : (u - u_0)\tan\theta^* - (v - v_0) - b = 0 \tag{7b}$$

where $b = (\Delta w/2)/\cos\theta^*$.

For any pixel (u, v) in the Fourier spectrum image that lies within the band-rejection region, i.e. $L^+_{\theta^*} \geq 0$ and $L^-_{\theta^*} \leq 0$, the associated $F(u, v)$ is set to zero. To preserve the background pattern in the reconstructed image, all frequency components lying within a small circle with the DC as the center must be retained without changing their spectrum values. Based on the removal process discussed above, the revised Fourier spectrum is given by

$$\hat{F}(u,v) = \begin{cases} 0, & if\,(L^+_{\theta^*} \geq 0 \;\; and \;\; L^-_{\theta^*} \leq 0) \;\; \& \;\; (u-u_0)^2 + (v-v_0)^2 > r^2 \\ F(u,\, v), & \text{otherwise} \end{cases}$$

In this study, the circular radius r is set to 4 for a 75 × 75 EL subimage. The self-reference image of an inspection image $f(u, v)$ of size $M \times N$ can now be reconstructed by the inverse discrete Fourier transform. Hence,

$$\hat{f}(x,\, y) = \frac{1}{M \cdot N} \sum_{v=0}^{N-1} \sum_{u=0}^{M-1} \hat{F}(u,\, v) \cdot \exp\left[j2\pi\left({}^{ux}\!/_{M} + {}^{vy}\!/_{N}\right)\right] \tag{8}$$

Defects in the EL subimage can be easily identified by subtracting the original image $f(u, v)$ from the reconstructed image $\hat{f}(x, y)$. The difference between $f(u, v)$ and $\hat{f}(x, y)$ is given by

$$\Delta f(x, y) = \left| f(x, y) - \hat{f}(x, y) \right| \tag{9}$$

The upper bound of a simple statistical control limit is thus used to set the threshold for segmenting defects from the background in the difference image $\Delta f(x, y)$. The threshold for $\Delta f(x, y)$ is given by

$$T_{\Delta f} = \mu_{\Delta f} + K_{\Delta f} \cdot \sigma_{\Delta f} \tag{10}$$

where $\mu_{\Delta f}$ and $\sigma_{\Delta f}$ are the mean and standard deviations of $\Delta f(x, y)$ in the whole image, and $K_{\Delta f}$ is a pre-determined control constant. The detection results can be represented by a binary image, wherein the pixel (u, v) with $\Delta f(x, y) > T_{\Delta f}$ is a defect point and is marked in black. It is otherwise a defect-free point and is marked in white in the binary image. Figure 6a1, b1 show, respectively, a defect-free and a small crack subimage. Their reconstructed images are presented in Fig. 6a2, b2. Figure 6a3, b3 are the corresponding difference images $\Delta f(x, y)$. The results show that the reconstructed image of the defect-free sample is similar to its original one, and no significant differences are found in the difference image.

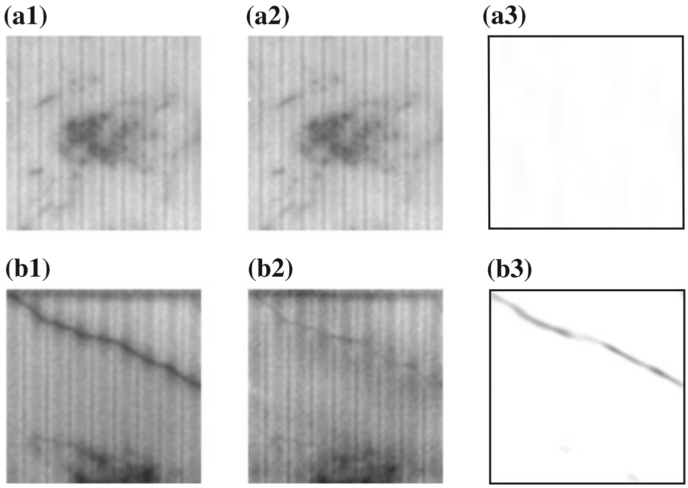


Fig. 6 Image reconstruction and image difference: **a1** defect-free EL subimage; **b1** defective EL subimage; **a2**, **b2** respective reconstructed images; **a3**, **b3** respective difference images

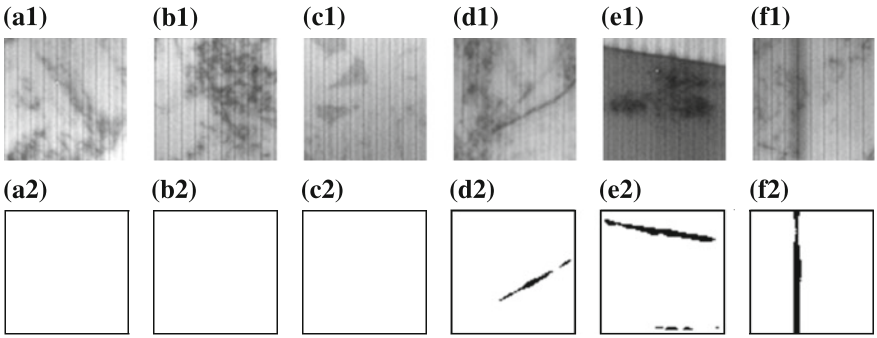


Fig. 7 Detection results on defect-free and defect solar cells: **a1–c1** EL subimages **d1** EL subimages with small cracks; **e1** EL subimages with breaks; **f1** EL subimage with finger interruption; **a2–f2** respective segmentation results

3 Experimental Results

This subsection demonstrates the detection results of various multi-crystalline solar cells in EL images. The parameter values are fixed with band-rejection width $\Delta w = 5$ and control constant $K_{\Delta f} = 1$ for all test samples in the experiment. Figure 7a1–c1 shows a set of three defect-free EL subimages of various solar cell surfaces, where random dark regions are present in the background. The detection results of Fig. 7a1–c1 with the same parameter setting are present in Fig. 7a2–c2. The results show uniformly white images and indicate no defects in the original EL images. Figure 7d1–f1 present, respectively, small cracks, breaks and finger interruption in the EL subimages. All three defects appear with cloud-shaped backgrounds in the EL images. The detection results are displayed as binary images, and are shown in Fig. 7d2–f2. The results indicate that the proposed self-reference method with the Fourier image reconstruction can well detect the small, local defects in EL images with inhomogeneous backgrounds.

In an additional experiment, we have also evaluated a total of 323 EL sub-images of solar cells, of which 308 are defect-free samples and 15 are defective samples containing various defects of small cracks, breaks, and finger interruptions. The proposed method, with the same parameter settings of $\Delta w = 5$ and $K_{\Delta f} = 1$, identifies correctly the defects in all 15 defective samples, and declares no false alarms for all 308 defect-free samples.

4 Conclusions

In this paper, we have proposed a self-reference scheme based on the Fourier image reconstruction to detect various defects in multicrystalline solar cells. Micro-cracks, breaks, and finger interruptions are severe defects found in solar cells. The EL imaging technique is thus used to highlight the defects in the sensed image. Experimental results show that the proposed method can effectively detect various defects and performs stably for defect-free images with random dark regions in the background. The proposed method is efficiently applied to a small subimage and achieves an average computation time of 0.29 s for a whole solar cell image of size 550 × 550 pixels.

References

Fuyuki T, Kondo H, Yamazaki T, Takahashi Y, Uraoka Y (2005) Photographic surveying of minority carrier diffusion length in polycrystalline silicon solar cells by electroluminescence. Appl Phys Lett 86:262108

Fuyuki T, Kitiyanan A (2009) Photographic diagnosis of crystalline silicon solar cells utilizing electroluminescence. Appl Phys A96:189–196

Guan SU, Xie P, Li H (2003) A golden-block-based self-refining scheme for repetitive patterned wafer inspections. Mach Vis Appl 13:314–321

Li WC, Tsai DM (2011) Automatic saw-mark detection in multicrystalline solar wafer images. Sol Energy Mater Sol Cells 95:2206–2220

Tsai DM, Huang TY (2003) Automated surface inspection for statistical textures. Image Vis Comput 21:307–323

Teaching Industrial Engineering: Developing a Conjoint Support System Catered for Non-Majors

Yoshiki Nakamura

Abstract Previously, business managers and college students seem to have not given enough thought to the study of Industrial Engineering (IE). Increasingly, however, they have become conscious of the importance of IE. In fact, many have started to consider the topic to be useful and critical for their future career. This being the case, it seems highly valuable to develop an educational program which deals specifically with both operation and concept of IE. The program so developed will help improve those who have already studied IE; at the same time, the system would likewise enhance and broaden the knowledge of those whose focus has been confined only to business management. This study tries to create an educational program which conjoins two different faces of business management. On one hand, the program targets on those who have an extensive experience in business management. On the other hand, the system likewise centers on those who know little about business management but have studied IE in the past. By using this cross cutting support method, two different will equally enhance their total knowledge of business administration.

Keywords Industrial and systems engineering education · The support system

1 Introduction

Both business administration students and company presidents should study industrial engineering (IE) because it is basic and essential to all business activity. "Cost management," "work study," and "KAIZEN," are among important IE

Y. Nakamura (✉)
Department of Business Administration, Aoyama Gakuin University, 4-4-25 Shibuya, Shibuya-ku, Tokyo 150-8366, Japan
e-mail: nakamura@busi.aoyama.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_8,

activities. Furthermore, effective IE study should include an understanding of the interrelationship between this course and student's or manager's prior knowledge.

In a typical Japanese college, three major methods are applied to teaching business management. First is the teacher–student lecture, wherein teacher's lectures are generally one-sided and the contents, even of the same subject, differ depending on the lecturer. Also, unfortunately, knowledge learned is applied only after graduation.

Second is the "case study," in which teachers present students with a theme based on a real business incident or situation (Alavi and Gallupe 2003; Gorman et al. 1997; Lambert et al. 1990; Mallick and Chaudhury 2000). Typically, students study the case in groups. The students discuss the given case, and present the answer and problem-solving by their own opinions in the case. The case study differs from lecture-style teaching in that students can simulate a company's real work situation. They conduct business meetings and also learn practical business management science in a simulated setting. The problem in this teaching method, however, is that the teachers' expectations and students' problem-solving outcomes do not always coincide.

The third approach is the educational business game (Graham and Gray 1969; Nonoyama et al. 2002; Riis 1995; Tseng 2009). This is a management game simulator that is based on actual business activities. It teaches such business aspects as management and the flow of funds through a game. As the teacher makes the computer program for the students, they learn what the teacher's wants them to. The downside of this teaching method is its strong "game" element. It also begs the question as to whether the game allows students to actually use their own information, knowledge, and reasoning in their decision-making.

Regarding the above-mentioned lecture method and under current educational conditions, we consider that there are two techniques in ideal lecturing: the first is students thinking and problem-solving using their own hands. The second is the student can feel and understand the relationship between the business and the contents the student learned through the support system. That system makes to similar to a real business situation wherein students learn business practical content and the study the student studied before.

This study proposes an educational program wherein students can study IE knowledge through the support system. The objective is to understand the interrelationship between new IE learning and prior knowledge and the influence both these factors have on each other. Concretely, students will form teams and use the mini-belt conveyor and miniature cars for their study. In preparing for the simulation, they must study the major IE fields of production management, cost management, work study, and KAIZEN activity. Because the students' learning process is hands on, I will build the support system wherein the relationship between students' prior knowledge and the knowledge they acquire during the program is observed. For example, how the students understand the influence of "hands-on work" on "business activities and the financial statement" will be observed.

2 The Outline of the Program

2.1 Set the Situation and the Contents of the Methodology

The subject in this educational program is an automobile industry. The company is the mid-sized car company and with a low profit margin. We chose the automobile industry because it is a manufacturing industry and its basic business operations include procurement, manufacturing, and sales (Fig. 1).

As a result, it is easy for the learner to devise a business plan and marketing analysis and understand the company's competitor. The methodology chosen involves making a team wherein students decide who plays the role of COE, CTO, etc.

In this instance, "the learner" is the student who studies the program and "the educator" is the teacher who manages and operates the educational program.

At the beginning of the program, the learner will be given the market and in-house information, a miniature automobile block, a belt conveyor and a support system file made by MS Office Excel. The activity flow will proceed as follows:

(1) Information analysis and forming a decision on the goal rate for the profit margin: learners determine how many cars are to be produced, i.e., the planned production amount. To arrive at this decision, the learners analyze the economic trends, competitor information, and in-house information about the company's finances from the financial statements.
(2) Simulate production experience.
(3) The proposal and the execution of KAIZEN.
(4) Examination of the miniature car's material and environmental elements.
(5) Discussion of the rate of the goal rate whether approaching the learner's set.

In the "marketing" class, for example, students study the importance of the market, competitor information, and the need for business analysis. It is, however,

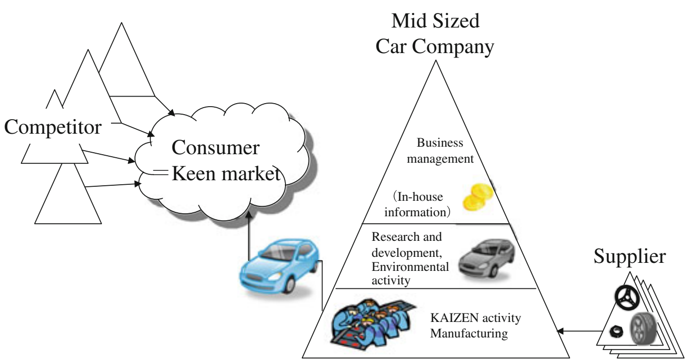


Fig. 1 Program situation

difficult to see the linkage between these studies and decision-making in the actual business activity. As a result, in Step 1, the learner will analyze this information and arrive at a decision on "the amount of planned production" and "the goal for the profit rate." (Details follow).

In Steps 2 and 3, the learners actually make the miniature car and measure the standard work and standard time. They also implement the KAIZEN process and address the environmental problem.

For the cost reduction at Step 4, they must decrease the automobile's materials cost. At the same time, they have to sell the new vehicle to attain the desired goal profit rate. Thus, the learners propose a sellable and popular automobile.

In Step 5, through activities 2, 3, and 4, the learners determine how close they are to the target. If they cannot achieve the set goal, they will determine what the problem is. By carrying out activities outlined in these steps and by having an access to the support system, students will visually understand the relationship among the goal profit rate, production, and the financial statements.

By following these steps in sequence, the learner can simulate business management, and especially the analysis, planning, and implementation phases as well as KAIZEN and the feedback. In this study, it is possible to conduct business management through the experiential and synthetic study, even in a university class.

2.2 The Program's Plan and Flow

The following table shows the flow of this educational program in a university class. The schedule was modeled on the typical Japanese university business class and is comprised of fifteen weekly 90-min sessions (Table 1).

Week 1:

The educator lectures on the educational program, its purpose, goals, and meaning. The learners form a team of three to four members. For the purposes of the team's function, its collegial decision-making nature is understood.

The team decides on the company name, the business philosophy, and each member's role. For unity among the team members in terms of awareness of the program's direction, these decision items will be set.

Weeks 2 and 3:

In the in-house analysis, the learner will examine the financial statements and propose the problem and plan for improvement. The financial analysis framework is used for the business analysis. To calculate the profit rate, this program uses business indicators and "the standard comparison method" with the industry average. If the rate is calculated to be lower than the industry average, it presents a problem for the learners' company. Each team calculates the indicator and determines and presents its own problems.

Table 1 Program schedule

Week	Contents	Notes
1	Lectures on the educational program	
2	In-house analysis 1	Financial analysis
3	In-house analysis 2	
4	Market and competitor analysis 1	Using information sheet
5	Market and competitor analysis 2	
6	Decides the amount of the production and the goal profit rate	Using support system
7	Midterm presentation	
8	Simulate production experience 1	Study standard time and cost
9	Simulate production experience 2	KAIZEN process
10	Simulate production experience 3	
11	Sell, cost and environmental acuities 1	
12	Sell, cost and environmental acuities 2	
13	Sell, cost and environmental acuities 3	
14	Sell, cost and environmental acuities 4	
15	Final presentation	

Weeks 4 and 5:

As for the market and competitor analysis, the learner is given Information sheet and examines it in relation to how it affects the company. This sheet is composed of macro information and the information on market conditions and the competitor environment. The macro environmental information includes the political environment, the economy, and social and technological factors. Market information consists of the purchase environment, the production situation, and sales factors. Competitor information relates to market share, profitability, and the trends in competitor company factors.

Week 6:

Using week 5 analysis, the team decides the amount of the production and the goal profit rate. After deciding on the production figures, they determine the sales data set and calculate the profit rate with the assistance from the support system.

Week 7:

To clarify what they have learned and accomplished, the team presents the results of the first six weeks' exercises. After the learner's presentation, the educator gives some answers example on the study that the learners might have. Every learner is in agreement with the direction of the study. For example, the educator might point out two things: lower sales and higher cost. Subsequently, this educator challenges them to achieve "more than 4 % of the rate of ordinary profit divided by capital" and "more than 2.8 % of the rate of ordinary profit divided by sales."

Weeks 8–10:

The learner actually produces the miniature automobile in the standard time and work set by the educator. After production, they discuss "unreasonable, unfruitful, and uneven production" and propose the KAIZEN plan. The support system provides information on the KAIZEN plan and reduction of labor cost. In week 10, the learner must make a presentation on the KAIZEN plan.

Weeks 11–14:

During this period, the learners consider two things: lowering the cost of materials and increasing sales. Lowering the material cost is studied according to the figures on the overall automobile. These costs are subject to an environmental index; however, recently in manufacturing, a product's environmental impact must be considered. This program, therefore, presents the indicators of the automobile's effect on the environment. The more environmentally friendly the car, the higher the environmental indicators. Keeping this in mind, the learner understands the relationship between the cost and the environment.

In this program, more than 80 indicators are required for an automobile to be certified as a low-fuel consumption and low-smog emission vehicle. The student needs these indicators to sell the car they develop. Moreover, they need to repeatedly meet the standard of workmanship, the production time, and the KAIZEN until the goal profit rate is accomplished.

Week 15:

The learners make their final presentation.

3 Details of the Support System

In this program, the learner can visually check the support system's influence when they propose the KAIZEN and accordingly change the automobile materials. Figure 2 shows the system flow.

The answers from the educator are "more than 4 % of the rate of the ordinary profit divided by the entire capital amount" and "more than 2.8 % of the rate of the ordinary profit divided by the sales." This problem has to be solved in two ways: "lower the cost" and "increase the sales."

In the "lower the cost" criteria, using the scroll bar of the material cost and the labor cost adjusts the "more than 2.8 % of the rate of the ordinary profit divided by the sales" through the support system (1). The former method does not achieve the "more than 4 % of the rate of the ordinary profit divided by the entire capital amount." Through the support system (2), the scroll bar, cash deposits, accounts receivable, the money due from accounts, products, semi-finished products, materials in process, and raw materials, all have to be reduced to meet the objectives (Fig. 3).

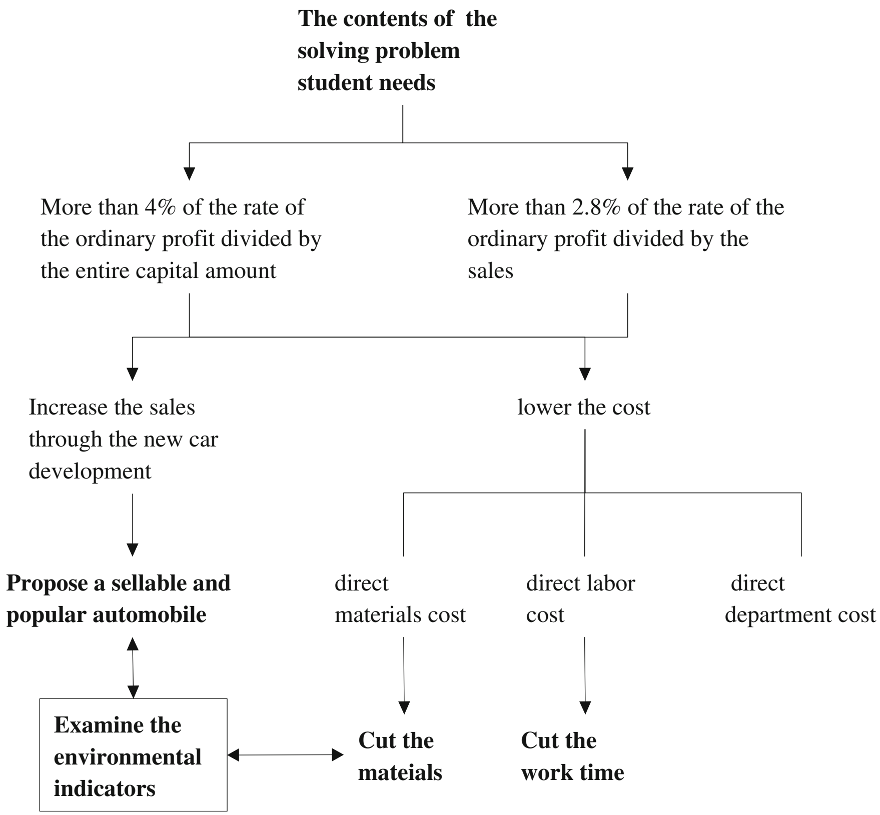


Fig. 2 System flow

In addition, the support system alone (2) does not improve the rate of the ordinary profit divided by the all capital. After scrolling the bar (2), the support system (3) has to be displayed. From screen (3), the learner recognizes that, above all else, they must make an effort to increase sales. In the "saving labor costs sheet," the support system shows the time and width required to cut this cost. On the basis of this sheet, the learners discuss work improvements and attempt to achieve labor cost savings. The "saving materials cost sheet" shows the structure and price of parts. It needs to reach the width reduction from the support system (1).

Learners also have environmental indicators. As a result, in developing the new automobile they need to achieve an environmental index above 80 in addition to material cost savings and higher sales at same time.

Through using the support system, the learner can understand their IE knowledge.

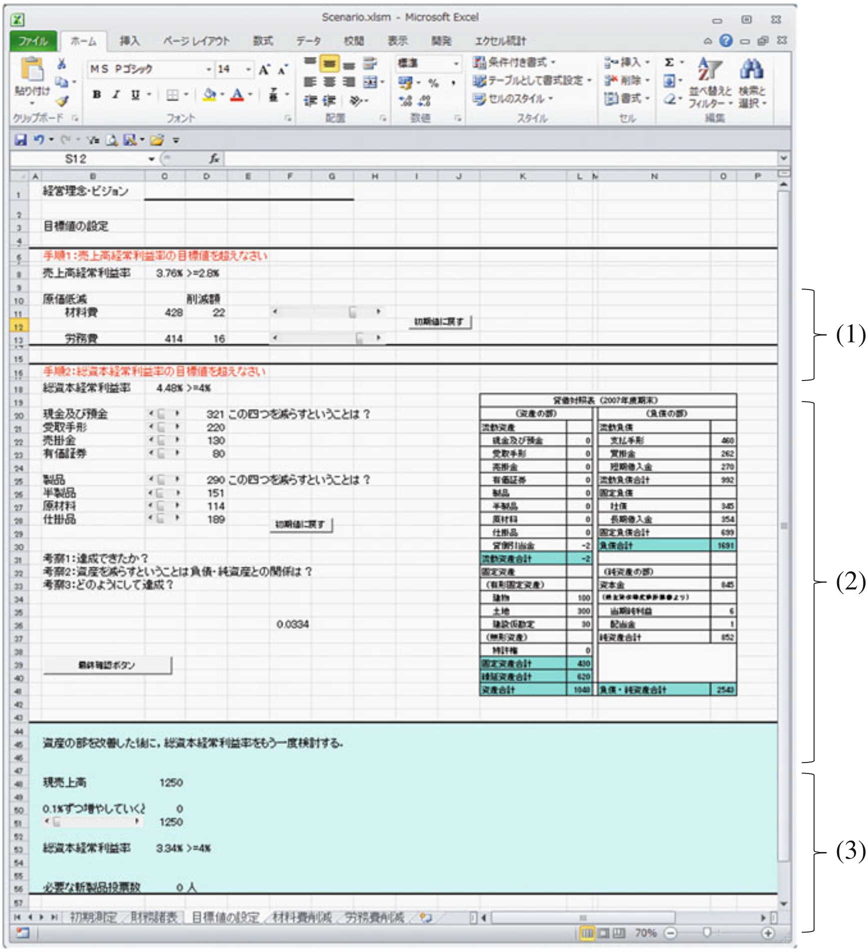


Fig. 3 Support system

4 Conclusion and Future Prospect

This paper presents a proposal for the educational program that addresses the IE study not only for the major's. Especially, IE's basic studies, KAIZEN, standard time and work, cost management, environmental activity and new product development, are able to exercise by their own hand. Through this program, the learners are is to understand not only IE concept, but also the relationship between new IE learning and prior knowledge which they have already.

We implemented this program with university students, a total of 23 students in 4 teams. A questionnaire survey was conducted after the program had ended to evaluate learning effectiveness. From the free comment, "I acquired the knowledge about IE and the relationship with the finance," "the importance of team work and discussion," etc. We believe that this program proposed in this paper is useful to study IE's elements and knowledge the learners studied before.

Future issues to be addressed include (1) implementation of the program for large numbers of learners, (2) the addition of the case, not only automobile industry but also the other manufacturing industries, and (3) enhancement of the support system.

Acknowledgments This research was supported by Grant-in-Aid for Young Scientists (B), (23710179) in Japan.

References

Alavi M, Gallupe R (2003) Using information technology in learning: case studies in business and management education programs. Acad Manage Learn Educ 2(2):139–153

Gorman G, Hanlon D, King W (1997) Some research perspectives on entrepreneurship education, enterprise education and education for small business management: a ten-year literature review. Int Small Bus J 15(3):56–77. doi:10.1177/0266242697153004

Graham R, Gray C (1969) Business games handbook. AMA, New York

Lambert D, Cooper M, Pagh J (1990) Supply chain management: implementation issues and research opportunities. Int J of Logs Manag 9(2):1–20

Mallick D, Chaudhury A (2000) Technology management education in MBA programs: a comparative study of knowledge and skill requirements. J Eng Technol Manage 17(2):153–173

Nonoyama T, Yanagida Y, Takahashi T, Narikawa T (2002) Business game practice (Japanese). Pearson Education Japan, Tokyo

Riis J (1995) Simulation games and learning in production management. Springer, Berlin

Tseng C (2009) Development of business game simulator for supporting collaborative problem-based learning. Paper presented at ICALT 2009, Riga Technical University, Latvia, 15–17 July 2009

An Automatic Image Enhancement Framework for Industrial Products Inspection

Chien-Cheng Chu, Chien-Chih Wang and Bernard C. Jiang

Abstract Image enhancement methods play a key role in image preprocessing. In practical, to obtain product characteristics, image enhancement methods are usually selected by trial-and-error or by experience. In this chapter, we proposed a novel procedure to automatically select image enhancement procedures by using singular value decomposition to extract features of an image. Forty-five industrial product images from literature and local companies were used in the experiment. The results showed that the contrast values had no significant differences with the literature. The study results implied that the system could automatically applied and effectively improve the image quality.

Keywords Visual inspection · Singular value decomposition · Feature database

1 Introduction

In practical applications, to increase the efficiency of the machine vision inspections, the inspection must use image enhancement to increase the contrast and decrease noise before detecting the objects. Most image enhancement methods are

C.-C. Chu
Department of Automation, Jabil Green Point, Taiwan, China
e-mail: chiencheng.chu@gmail.com

C.-C. Wang (✉)
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei city, Taiwan, Republic of China
e-mail: ieccwang@mail.mcut.edu.tw

B. C. Jiang
Department of Industrial Engineering and Management, Yuan Ze University, Jungli, Taiwan, Republic of China
e-mail: iebjiang@saturn.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_9,

independent and based on supervised techniques. For example, Wang et al. (2011) proposed multivariate analysis to automatically build an image enhancement model. However, the method must know the corresponding enhancement method of the training images. Therefore, a non-supervised image enhancement mechanism is needed in practice.

Image enhancement technology usually relies on differences in the grey levels and their structures to describe the image features. Yeh et al. (2003) proposed a histogram equalization scheme to enhance multi-layer ceramic chip capacitors (MLCC) surface defect features and a median filter was then used to denoise and maintain image sharpness. Ko (2002) used a fast Fourier transform and selected different kinds of masks to remove high-frequency data and thereby enhance fingerprint images. Kang and Hong (2000) utilized a wavelet transform to enhance medical ultrasound images and remove noise. Tsai and Lin (2002) used a Gaussian algorithm to smooth the images and make traditional coefficient correlation more effective. Szydłowski and Powałka (2012) used image normalization to overcome chatter images taken under different illumination conditions. Withayachumnankul et al. (2013) revealed the green channel of the original image. To assist the interpretation, the intensity of the image is inverted and then normalized to 0–255 in order to increase the contrast. The experiments show that the algorithm reveals cracks with high accuracy and high sensitivity.

From the above discussion, if fast image enhancement techniques can be proposed and put into practical application, these can shorten the time needed for detection and fill the demand of manufacturers for faster inspection. In this chapter, the extraction of image features through *singular value decomposition* (SVD) was proposed to use of these features as a basis for the construction of the database. The proposed procedure can quickly to automatically select the appropriate image enhancement methods.

2 Methodology

Assume that an image matrix size is $m \times n$. The matrix can find an SVD to make $A = U\Sigma V^T$, where U is an $m \times m$ unitary matrix, Σ is an $m \times n$ rectangular diagonal matrix with non-negative real numbers on the diagonal and V is an $n \times n$ unitary matrix. The diagonal entries $\Sigma_{n,n}$ of Σ are known as the singular values of A. Let $\Sigma_{n,n}$ return the value of location (n, n) in the matrix. The size of the matrix is $m \times m$ and $m > n$. In this study, $U\Sigma_{1,1}V^T$ was used to determine the basic structure for the image's features required for classification. Each image obtained by $U\Sigma_{1,1}V^T$ can obtain one feature matrix that most closely represents the original image.

After the SVD extraction, the inspected image may be divided according to two conditions. If the database already has a similar feature set, the classified image should be set to the feature's group. If the database system cannot find similar images using the SVD feature, the process sets the image as a new group. Finally, we obtain the highest matching process, and save it in the database for future use. The SSIM index calculation formula

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{\left(\mu_x^2 + \mu_y^2 + C_1\right)\left(\sigma_x^2 + \sigma_y^2 + C_2\right)} \tag{1}$$

where μ_x is the mean of x, μ_y is the mean of y, σ_x is the standard deviation of x, σ_y is the standard deviation of y. C_1 used in order to avoid obtaining $\mu_x^2 + \mu_y^2$ close to or equal to zero. Let $C_1 = (K_1L)^2$ and L be a dynamic range that is assumed by the image's pixel range. For example, for an 8-bit image, the dynamic range is from 0 to 255. At the same time, $K_1 \ll 1$ is a very small value, and this definition also applies to the contrast comparison function and structure function. Let $C_2 = (K_2L)^2, K_2 \ll 1$, this design is also used in order to prevent the denominator from approaching or becoming equal to zero.

The contrast value and entropy were used to estimate the results and determine the proposed method compared to the method in literature. The contrast value was a method that uses frequency to evaluate the quality of an image. The definition of the contrast value is as follows

$$\sum_{f=0}^{Max} \frac{(f - \mu_f)^2 n_f}{M \times N} \tag{2}$$

where, $M \times N$ is the image size, μ_f is the mean of grey levels equal to f, n_f is the sum of grey levels equal to f.

Next, the enhancement process stresses the foreground and makes the background inconspicuous. In other words, it aims to filter noise and cause the useless information to disappear, thus improving the thresholding. Entropy can measure the degree of data, and higher entropy means that more information in a group of data may exist in the foreground. Thus, for the enhancement process, higher entropy is better. The definition of entropy is as follows

$$\sum_{f=0}^{L} (p(f) \times \ln p(f)) \tag{3}$$

where, $p(f) = n_f/(M \times N)$

3 Experiment Analysis

The 45 test images (Fig. 1) obtained from literature (Chen 2003; Tsai et al. 2003; Yeh et al. 2003; Chen 2005; Lin and Ho 2005) were used to set up the database and to create an automatic enhancement method. These are images that are mainly

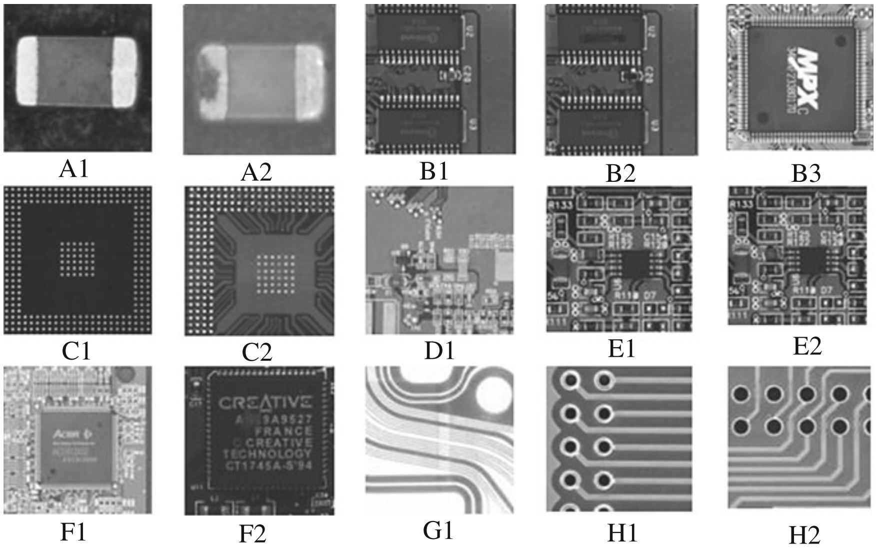


Fig. 1 The part of experiment images

obtained from electronic products, including capacitors, integrated circuit (IC), ball grid array (BGA), printed circuit board (PCB) and flexible printed circuit (FPC). Also, the research used common image enhancement methods to establish the automatic selection model for image enhancement. They included the uniform filter, histogram equalization, Gaussian filter, median filter and the sobel operator.

Tables 1 and 2 shows the analysis results of all images in the Fig. 1 and their calculated contrast values and entropy. From Tables 1 and 2, we can deduce that all of the entropy index results for the proposed methods are better than those in literature. The average entropy of the image relative to previous research increased

Table 1 Average contrast and entropy results using the proposed method

Image type	Proposed method					
	Contrast			Entropy		
	Before	After	Difference (%)	Before	After	Difference (%)
A	44.8453	45.0917	0.54	6.4288	6.4531	0.37
B	50.7090	45.1997	−10.86	6.7541	6.7390	−0.22
C	46.0046	42.5420	−7.53	5.9323	5.9951	1.06
D	36.6257	32.7884	−10.48	6.5143	6.3502	−2.52
E	58.3931	53.8714	−7.74	7.2699	7.3040	0.47
F	35.2855	30.8388	−12.60	6.4283	6.2788	−2.33
G	40.7573	37.9707	−0.683	5.4003	5.5108	2.05
H	52.9750	51.4671	−2.84	6.8421	6.9394	1.42

Table 2 Average contrast and entropy results using the literature method

Image type	Literature's method					
	Contrast			Entropy		
	Before	After	Difference (%)	Before	After	Difference (%)
A	44.8453	74.8553	66.92	6.4289	5.6038	−12.83
B	50.7090	45.1997	−10.86	6.7541	6.7390	−0.22
C	46.0046	42.5420	−7.53	5.9323	5.9951	1.06
D	36.4902	0.2274	−99.38	6.5143	0.3059	−95.30
E	58.3931	53.8714	−7.74	7.2699	7.3040	0.47
F	35.2855	0.2234	−99.37	6.4283	0.2979	−95.37
G	40.7573	71.5022	75.43	5.4003	4.4139	−18.27
H	52.9750	48.5487	−8.35	6.8421	6.8770	0.51

to 17.54 %. Using a paired *t* test, we compared the different significances for the proposed method and that in literature.

For contrast value, the 95 % CI for the mean difference was (−19.67, 20.37) and a p value $= 0.968$. This result shows that there are no significant differences in the contrast value between the proposed method and that in literature. For entropy index, the proposed method of increase is greater than the literature methods.

4 Conclusions

This research proposed an SVD-based framework to choose suitable enhancement methods that can quickly and effectively solve practical inspection problems. When compared with the methods in literature, this method provides a better unsupervised learning mechanism. As opposed to supervised methods, this method does not require pre-learning or specific characteristics. Therefore, this application is more flexible, but requires more technical knowledge to realize further improvements.

Acknowledgments The National Science Council of Taiwan, Project Number NSC 100-2628-E-131-001, supported this research.

References

Chen CC (2003) The application of wavelet theory to the defect detection in printed circuit board. Thesis (Master's degree). National Cheng Kung University, Tainan, Taiwan

Chen CS (2005) Applications of near infrared image process technique in the alignment of GaAs wafer. Thesis (Master's degree). Yuan Ze University, Taiwan

Kang SC, Hong SH (2000) Design and implementation of denoising filter for echocardiographic images based on wavelet method. The conference on microtechnologies in medicine and biology, Lyon, pp 80–83

Ko T (2002) Fingerprint enhancement by spectral analysis techniques. The proceedings of the 31st applied imagery pattern recognition workshop, pp 133–139

Lin HD, Ho DC (2005) A new detection method based on discrete cosine transform for pinhole defects applied to computer vision systems. The 5th international conference on intelligent processing and manufacturing of materials, Monterey, California, USA

Szydłowski M, Powałka B (2012) Chatter detection algorithm based on machine vision. Int J Adv Manuf Tech 62:517–528

Tsai DM, Lin BT (2002) Defect detection of gold-plated surfaces on PCBs using entropy measures. Int J Adv Manuf Tech 20:420–428

Tsai DM, Lin CT, Chen JF (2003) The evaluation of normalized cross correlations for defect detection. Pattern Recogn Lett 24:2525–2535

Wang CC, Jiang BC, Chou YS, Chu CC (2011) Multivariate analysis-based image enhancement model for machine vision inspection. Int J Prod Res 49:2999–3021

Withayachumnankul W, Kunakornvong P, Asavathongkul C, Sooraksa P (2013) Rapid detection of hairline cracks on the surface of piezoelectric ceramics. Int J Adv Manuf Tech 64:1275–1283

Yeh CH, Shen TC, Wu FC (2003) A case study: passive component inspection using a 1D wavelet transform. Int J Adv Manuf Tech 22:899–910

Ant Colony Optimization Algorithms for Unrelated Parallel Machine Scheduling with Controllable Processing Times and Eligibility Constraints

Chinyao Low, Rong-Kwei Li and Guan-He Wu

Abstract In this paper, we consider the problem of scheduling jobs on unrelated parallel machines with eligibility constraints, where job-processing times are controllable through the allocation of a nonrenewable common resource, and can be modeled by a linear resource consumption function. The objective is to assign the jobs to the machines and to allocate the resource so that the makespan is minimized. We provide an exact formulation of the addressed problem as an integer programming model. As the problem has been proven to be NP-hard even for the fixed job-processing times, two ant colony optimization (ACO) algorithms based on distinct procedures, respectively, are also presented and analyzed. Numerical results show that both the proposed algorithms are capable of solving large-sized problems within reasonable computational time and accuracy.

Keywords Scheduling · Unrelated parallel machines · Eligibility constraints · Resource allocation · Ant colony optimization

1 Introduction

We consider the problem of scheduling jobs on unrelated parallel machines with eligibility constraints to minimize the makespan (the maximum completion time). The processing time of a job is dependent on both the machine assigned and the

C. Low (✉)
Institute of Industrial Engineering and Management, National Yunlin University of Science and Technology, Yunlin, Taiwan, Republic of China
e-mail: lowcy@yuntech.edu.tw

R.-K. Li · G.-H. Wu
Department of Industrial Engineering and Management, National Chiao Tung University, Hsinchu, Taiwan, Republic of China
e-mail: ghwu.iem99g@nctu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_10,

amount of resource allocated. If job-processing times are fixed, the problem has been shown to be NP-Hard in the strong sense. Furthermore, Lenstra et al. (1990) showed that no approximation algorithm can achieve a worst-case ratio smaller than 3/2, unless P = NP.

In most classical machine scheduling models, job-processing times are generally treated as constant values and known in advance. However, in various realistic situations, jobs may also require, apart from machines, certain additional limited resources (e.g., manpower, electricity, catalyzer) for their performing, and the processing times can be considerably affected by consumption of such resources. In these situations, both the job scheduling and the distribution of limited resources to individual operations should be taken into account and coordinated carefully so as to optimize system performance.

The majority of works on scheduling models with controllable job-processing times have been presented for various single machine problems, such as those described in the review provided by Shabtay and Steiner (2007). Only a few studies have dealt with multi-processor systems. Jozefowska et al. (2002) presented a tabu search algorithm to deal with the identical parallel machine makespan problem under given resource constraints. Jansen and Mastrolilli (2004) proposed approximation algorithms for the problem of scheduling jobs on identical parallel machines, in which the processing times of the jobs were allowed to be compressed in return for compression cost. Shabtay and Kaspi (2006) examined the identical parallel machine scheduling problems with controllable processing times to minimize the makespan and total flow time. Mokhtari et al. (2010) suggested a hybrid discrete differential evolution algorithm combined with variable neighborhood search for a permutation flow shop scheduling problem, in which the processing times can be controlled by consumption of several types of resources. The objective was to minimize both makespan and total cost of resources.

As can be seen, most of the aforementioned studies assumed that each job can be processed on any machine. Nonetheless, this assumption usually deviates from the real-world situation. The presence of eligibility constraints is consistent with many manufacturing environments, for instance, a work center may be composed of different sets of machines with different capability for their performing, and so the jobs must be processed on the machines that can satisfy its process specification. Therefore, we concern on the general problem, where eligibility constraints may exist.

The remainder of this paper is organized as follows. The problem definition and formulation are presented in Sect. 2. In Sect. 3, we give the detailed steps of the proposed ACO algorithms. Computational results are shown in Sect. 4. We demonstrate that our applications of these ACO algorithms are efficient in obtaining near-optimal solutions for industrial sized problems. Finally, some concluding remarks are given in Sect. 5.

2 Problem Description and Formulation

There are n independent non-preemptive jobs have to be processed on m unrelated parallel machines. Each job j is considered available for processing at time zero, requires a single operation and can be processed only on a specific subset M_j of machines. The processing time of job j on machine i ($i \in M_j,\ j = 1, 2, \ldots, n$) is controllable, and can be modeled as a linear decreasing function of the amount of a nonrenewable resource, r_{ij}, used for its processing: $p_{ij}\left(r_{ij}\right) = b_{ij} - a_{ij} \cdot r_{ij}$, where b_{ij} and a_{ij} are the normal processing time and resource compression rate, respectively. It is assumed that $r_{ij} \in [\alpha_{ij},\ \beta_{ij}]$, where α_{ij} and β_{ij} are given bounds, and the total resource consumption cannot exceed the limited value R, $R \geq \sum_{j=1}^{n} min\left\{\alpha_{ij} | i \in M_j\right\}$. Without loss of generality, we assumed that all b_{ij}, a_{ij}, α_{ij}, β_{ij} and R are positive integers. The objective is to determine the optimal assignment of the jobs to the machines and resource allocation, such that the schedule makespan C_{max} is minimized.

Let x_{ij} denote binary variables equal to 1 if job j is processed on machine i and 0 otherwise. Let y_j be the amount of resource used for processing job j. With the above notation the problem under consideration can be formulated as follows:

$$\text{Min}\ \ C_{max} \tag{1}$$

subject to

$$\sum\nolimits_{i \in M_j} x_{ij} = 1 + m \cdot \sum\nolimits_{i \notin M_j} x_{ij}, \quad \forall j = 1, 2, \ldots, n, \tag{2}$$

$$\sum\nolimits_{i=1}^{m} \left(x_{ij} \cdot \alpha_{ij}\right) \leq y_j \leq \sum\nolimits_{i=1}^{m} \left(x_{ij} \cdot \beta_{ij}\right), \quad \forall j = 1, 2, \ldots, n, \tag{3}$$

$$\sum\nolimits_{j=1}^{n} y_j \leq R, \tag{4}$$

$$\sum\nolimits_{j=1}^{n} x_{ij} \cdot \left(b_{ij} - a_{ij} \cdot y_j\right) \leq C_{max}, \quad \forall i = 1, 2, \ldots, m, \tag{5}$$

$$x_{ij} \in \{0, 1\}, \quad \forall i = 1, 2, \ldots, m, \quad \forall j = 1, 2, \ldots, n, \tag{6}$$

$$y_j \in \{0, 1, \ldots, R\}, \quad \forall j = 1, 2, \ldots, n. \tag{7}$$

Constraint (2) ensures that each job is assigned to exactly one of its eligible machines. Constraints (3) and (4) guarantee that the amount of resource allocated to jobs are within the resource limits. Constraint (5) states that the total processing on each machine is a lower bound on the makespan. Constraints (6) and (7) define the value ranges of the variables. This model includes $m + 2n + 1$ constraints, $m \cdot n$ binary variables and n standard variables.

3 Solution Procedures

The ACO algorithm (Dorigo and Gambardella 1997) is essentially a population-based metaheuristic that imitates the cooperative behavior of real ants to tackle combinatorial optimization problems. The basic component of ACO is the stochastic solution construction mechanism. At each iteration, the artificial ants in ACO choose opportunely the next solution component to be appended in the partially constructed ones based on the favorability (pheromone values) and the cost (heuristic information) of adding the component, until a complete solution to the problem is reached. Once all ants have constructed their solutions, some of them are used for performing an update of the pheromone values. This will allow the succeeding ants to generate high quality solutions over time.

In this section, we propose two ACO algorithms based on distinct solution construction mechanisms for solving the addressed problem. The main idea in the first algorithm (ACO-I) is to simultaneously determine the assignment of the jobs to the machines and the amount of resource allotted for their performing during the solution construction process; while the solution procedure of the second algorithm (ACO-II) is composed of two phases, in which an initial schedule is generated with the constant job-processing times, and then the total processing on each machine is compressed in terms of the makespan using a resource allocation mechanism.

3.1 Development of the First Proposed ACO algorithm (ACO-I)

3.1.1 Solution Construction

In ACO-I, the pheromone information is represented by the matrix $[\tau(i, j_r)]$ which describes the favorability of allocating r units of resource to job j on machine i. Let $\mathcal{U}$ be the sets of unscheduled jobs, and $\widehat{M}_j$ be the set of the machines that are considered available for processing job j with respect to the eligibility and resource constraints. Given the amount R' of available resource, the upper bound on the consumed resource amount corresponding to machine-job pair (i, j) will be

$$\beta_{ij}^* = min\left\{ \left(R' - \sum_{j' \in \mathcal{U}, j' \neq j} min\{ \alpha_{ij'} | i \in \hat{M}_{j'} \} \right), \beta_{ij} \right\} \tag{8}$$

As a result, the probability of allocating r units of resource to job j on machine $i \in \hat{M}_j$ can be computed as follows:

$$j_r = \left\{ \begin{array}{cc} \arg\max_{j \in U, r \in [\alpha_{ij}, \beta^*_{ij}]} \left\{ [\tau(i,j_r)]^\alpha . [\eta(i,j_r)]^\beta . [\delta(i,j_r)]^\gamma \right\} & if\ q \le q_0 \\ \hat{J}_r & otherwise \end{array} \right\}. \quad (9)$$

where the random variable $\hat{J}_r$ is selected according to the probability distribution given by

$$p(i,j_r) = \left\{ \begin{array}{cc} \frac{[\tau(i,j_r)]^\alpha \cdot [\eta(i,j_r)]^\beta \cdot [\delta(i,j_r)]^\gamma}{\sum_{k \in U, s \in [\alpha_{ik}, \beta^*_{ik}]} [\tau(i,k_s)]^\alpha \cdot [\eta(i,k_s)]^\beta \cdot [\delta(i,k_s)]^\gamma} & if\ j \in U, r \in [\alpha_{ij}, \beta^*_{ij}] \\ 0 & otherwise \end{array} \right\}. \quad (10)$$

Of which, the heuristic information $\eta(i,j_r)$ and $\delta(i,j_r)$ are defined as

$$\eta(i,j_r) = \frac{1}{b_{ij} - a_{ij} \cdot r} \quad (11)$$

and

$$\delta(i,j_r) = \frac{R' - r}{\sum_{k \in U, k \neq j} min\left\{ \alpha_{ik} | i \in \hat{M}_k \right\}} \quad (12)$$

Besides, α, β, and γ are, respectively, the parameters representing the relative influence of pheromone and heuristic information, q is a random number uniformly distributed in $[0, 1]$ and q_0 is a parameter that determines the exploitation and exploration properties of the algorithm.

3.1.2 Local Pheromone Update

After an ant has constructed a complete solution, the local pheromone update procedure is implemented to evaporate the pheromone values in each link (i,j_r) selected by the ant in order to avoid premature convergence. The update rule is given by

$$\tau(i,j_r) \leftarrow (1 - \theta) \cdot \tau(i,j_r) + \theta \cdot \tau_0 \quad (13)$$

where $0 < \theta < 1$ is the evaporation rate and τ_0 is the initial pheromone value.

3.1.3 Global Pheromone Update

Once all of the k ants have constructed their solutions (i.e., an iteration), the iteration-best solution s^{ib} and the best-so-far solution s^{bs} will update the pheromone values to enforce the exploitation of search. This update rule is defined as

$$\tau(i,j_r) \leftarrow \tau(i,j_r) + \rho \cdot \left\{ w^{ib} \cdot C^{ib}(i,j_r) + w^{bs} \cdot C^{bs}(i,j_r) - \tau(i,j_r) \right\} \quad (14)$$

Of which, the parameter ρ is evaporation rate $(0 < \rho \leq 1)$, $C^*(i, j_r)$ is set to 1 if link $(i, j_r) \in s^*$, and 0 otherwise. w^{ib} $(0 \leq w^{ib} \leq 1)$ and w^{bs} are the parameters $(w^{ib} + w^{bs} = 1)$ representing the relative influence of the iteration-best solution and the best-so-far solution. Note that the update rule presented here is based on the Hypercube framework (Blum and Dorigo 2004), which automatically rescales the pheromone values and thereby bound them to the interval [0, 1].

3.2 Description of the Second Proposed ACO Algorithm (ACO-II)

In contrast to the ACO-I, the solution procedure of the ACO-II consists of two stages: *assignment* then *allocation.* In the assignment stage, the job-processing times are regarded as constant (i.e., $\hat{p}_{ij} = b_{ij} - a_{ij} \cdot \alpha_{ij}\ \forall i \in M_j, j = 1, 2, \ldots, n$), and the pheromone information is represented as an $m \times n$ matrix where each element $\tau(i, j)$ of the matrix describes the favorability of assigning job j to machine i. Accordingly, the probability of choosing job j to be appended on the machine $i \in \hat{M}_j$ can be computed as follows:

$$j = \begin{Bmatrix} argmax_{j \in \mathcal{U}}\left\{[\tau(i,j)]^{\alpha} \cdot [\eta(i,j)]^{\beta}\right\} & if\ q \leq q_0 \\ \hat{J} & otherwise \end{Bmatrix} \tag{15}$$

where $\hat{J}$ is a random variable selected according to the probability distribution given by

$$p(i,j) = \begin{Bmatrix} \frac{[\tau(i,j)]^{\alpha} \cdot [\eta(i,j)]^{\beta}}{\sum_{k \in \mathcal{U}}[\tau(i,k)]^{\alpha} \cdot [\eta(i,k)]^{\beta}} & if\ j \in U \\ 0 & otherwise \end{Bmatrix} \tag{16}$$

Of which, the heuristic information $\eta(i, j)$ is defined as

$$\eta(i,j) = \frac{1}{\hat{p}_{ij} = b_{ij} - a_{ij} \cdot \alpha_{ij}} \tag{17}$$

After the jobs on each machine have been specified, the update of the pheromone values is carried out according to

$$\tau(i,j) \leftarrow (1 - \theta) \cdot \tau(i,j) + \theta \cdot \tau_0 \tag{18}$$

Then, in the second stage we apply the following algorithm to determine the optimal resource allocation for the machine-job assignment generated. This resource allocation procedure was originally proposed by Su and Lien (2009) for identical parallel machine problem. Here, we generalize with slide modification the procedure to the case of unrelated machines. Define M_a as the set of machines with maximal completion time. Let $\{i, j\}$ be the machine-job pair determined in the assignment stage and $\hat{R}$ be the amount of remaining available resource. A detail description of the algorithm is presented below.

Step 0 Set $r_{\{i,j\}} = \alpha_{\{i,j\}}$, $i \in M_j$, $j = 1, 2, \ldots, n$

Step 1 If $\hat{R} \geq |M_a|$, then go to Step 2; Otherwise, go to Step 5

Step 2 Determine the job j such that $\beta_{\{i,j\}} = 0$, then set $a_{\{i,j\}} = 0$. Identify job t on machine $k \in M_a$ with the largest $a_{\{k,t\}}$. If $a_{\{k,t\}} \neq 0$, then go to Step 3; Otherwise, go to Step 5

Step 3 Update $r_{\{k,t\}} = r_{\{k,t\}} + 1$, $\beta_{\{k,t\}} = \beta_{\{k,t\}} - 1$, $\hat{R} = \hat{R} - 1$ and $M_a = \{M_a\} \backslash \{k\}$, then go to Step 4

Step 4 If $\hat{R} \neq 0$ then return to Step 1, else go to Step 5

Step 5 Calculate the resource allocation $r_{\{i,j\}}$ and terminate the procedure.

Finally, the resulted iteration-best solution and the best-so-far solution are used for performing an update of the pheromone values. This update rule is expressed by

$$\tau(i,j) \leftarrow \tau(i,j) + \rho \cdot \left\{ w^{ib} \cdot C^{ib}(i,j) + w^{bs} \cdot C^{bs}(i,j) - \tau(i,j) \right\} \quad (19)$$

4 Computational Results

The ACO algorithms shown in the previous section were coded in C++ and implemented on a 2.80 GHz AMD Athlon II CPU personal computer. The test problems we considered include the problems with 2, 3, 5, 10 machines and 3, 5, 10, 20, 30, 50 jobs. Normal processing times of jobs were generated from a discrete uniform distribution in the interval [1, 100]. The amount of available resource, the resource compression rate, and the bounds of consumed resource amount associated with each machine-job pair followed the discrete uniform distributions defined by the interval that satisfy the addressed resource constraints. For each problem size ($m \times n$), 3 test problems were generated and the algorithms were executed 10 times for each problem. Let $C_{max}(H)$ be the value of the objective function obtained by algorithm H, and thus the optimality gap can be defined as $G_{opt}(H) = C_{max}(H) - \text{optimum}/\text{optimum}$. Note that the optimal solution was obtained by solving the presented integer programming model with LINGO 11.0. For cases when an optimal solution cannot be obtained within a time limit 10,800 s (3 h), the optimality gap was calculated as $G_{opt}(H) = C_{max}(H) - C_{max}(ACO - \text{I})/C_{max}(ACO - \text{I})$. The computational results for all test problems are given in Table 1.

As the results show, both the algorithms performed well based on the averages of optimality gap and solution time for small sized problems. The algorithms attained optimal solutions in 9 problems out of 27 tested problems. Note that for all the small-sized problems evaluated, the solutions are the same in 10 runs of each

Table 1 Evaluation results of the proposed ACO algorithms

$m \times n$	Lingo		ACO-I		ACO-II	
	Avg. sol. time (s)	Avg. gap (%)	Avg. sol. time (s)	Avg. gap (%)	Avg. sol. time (s)	Avg. gap (%)
2 × 3	11.33	0.00	5.26	0.00	11.60	0.00
3 × 3	18.33	0.00	5.33	0.00	10.40	0.00
2 × 5	962.00	0.00	7.76	0.00	11.53	0.00
3 × 5	2,750.67	0.00	6.56	0.39	11.26	0.17
2 × 10	e. t. l.	–	18.23	–	26.70	2.89^{ψ}
5 × 20	e. t. l.	–	44.53	–	49.58	5.41^{ψ}
5 × 30	e. t. l.	–	117.20	–	93.13	4.36^{ψ}
5 × 50	e. t. l.	–	232.36	–	141.16	3.41^{ψ}
10 × 50	e. t. l.	–	228.40	–	121.13	5.15^{ψ}

e. t. l. = Exceed time limit; $^{\psi}$ gap calculated based on $C_{max}(ACO - \mathrm{I})$

test problem. This signified the robustness of the suggested algorithms. The results also evinced that the ACO-I generated similar, actually better on average, solutions in a short computation time as compared to the ACO-II. Additionally, the superiority of the ACO-I got more significant with the increase of the problem size. In summary, the suggested ACO algorithms can effectively solve the addressed problem to a certain scale in terms of the tradeoff between solution quality and computation time.

5 Conclusions

In this work, we introduce the problem of minimizing the makespan on a set of unrelated parallel machines with controllable processing times and eligibility constraints. This problem has been formulated as an integer programming model. Due to its computational complexity, two ACO-based heuristics are also presented and analyzed. Numerical results for problems with up to 50 jobs demonstrate that both the ACO algorithms can obtain the optimal or near optimal solutions for small and medium sized problems in a very short computation time, and the first proposed algorithm (ACO-I) outperforms the second proposed algorithm (ACO-II) in the case of relatively large-sized problems. Further research might extend our study to multi-stage scheduling problems, and consider other performance measures such as number of tardy jobs, maximum tardiness, and total weighted completion time.

Acknowledgments This work is partially supported by the National Science Council under Grant NSC-101-2221-E-224-070. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Blum C, Dorigo M (2004) The hyper-cube framework for ant colony optimization. IEEE Trans Syst Man Cybern 34(2):1161–1172

Dorigo M, Gambardella LM (1997) Ant colony system: a cooperative learning approach to the traveling salesman problem. IEEE Trans Evol Comput 1(1):53–66

Jansen K, Mastrolilli M (2004) Approximation schemes for parallel machine scheduling problems with controllable processing times. Comput Oper Res 31:1565–1581

Jozefowska J, Mika M, Rozycki R (2002) A heuristic approach to allocating the continuous resource in discrete continuous scheduling problems to minimize the makespan. J Sched 5:487–499

Lenstra JK, Shmoys DB, Tardos E (1990) Approximation algorithms for scheduling unrelated parallel machines. Math Program 46:259–271

Mokhtari H, Abadi INK, Cheraghalikhani A (2010) A multi-objective flow shop scheduling with resource-dependent processing times: trade-off between makespan and cost of resources. Int J Prod Res 49(19):5851–5875

Shabtay D, Kaspi (2006) Parallel machine scheduling with a convex resource consumption function. Eur J Oper Res 173:92–107

Shabtay D, Steiner G (2007) A survey of scheduling with controllable processing times. Discrete Appl Math 155:1643–1666

Su LH, Lien CY (2009) Scheduling parallel machines with resource-dependent processing times. Int J Prod Econ 117(2):256–266

General Model for Cross-Docking Distribution Planning Problem with Time Window Constraints

Parida Jewpanya and Voratas Kachitvichyanukul

Abstract The research studies a cross-docking distribution planning problem that consists of manufacturers, cross-docking centers and customers. It is focused on how to distribute and receive products within time interval restrictions of each node. This means that the manufacturer has specific time intervals for releasing products to be shipped to destinations, the cross-docking centers have time intervals to receive products from manufacturers and to release them to customers, and the customers also have their time intervals for receiving the products. A mixed integer programming model is formulated to deal with this time interval restrictions by including time window constraints at each level in the network. Also, the multiple types of products and consolidation of customer orders are considered. The objective function is to minimize the total cost which combines the transportation cost and inventory cost. A LINGO program was improved from Jewpanya and Kachitvichyanukul (General model of Cross-docking distribution planning problem. In: Proceedings of the 7th international congress on logistics and SCM systems, Seoul, 2012) to efficiently handle the problem with time window constraints. Some example problems are solved to demonstrate the optimal distribution plan of the cross-docking distribution planning problem under the limitation of each time window.

Keywords Cross-docking distribution planning problem · Cross-docking · Cross-docking center · Time window

P. Jewpanya (✉)
Department of Industrial Engineering, Rajamangala university of Technology Lanna, Tak 63000, Thailand
e-mail: parida.jewpanya@gmail.com

V. Kachitvichyanukul
Industrial and Manufacturing Engineering, Asian Institute of Technology (AIT), Pathumtani 12120, Thailand
e-mail: voratas@ait.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_11,

1 Introduction

Cross-docking is one of the more important distribution techniques in the supply chain network. It is used to eliminate the storage cost by reducing the amount of products stored in the cross-docking station or cross-docking center by delivering to destinations as soon as possible (Santos et al. 2013). The cross-docking concept may also be used to improve the customer satisfaction level (Dondo and Cerdá 2013). Some example indicators for customer satisfaction level are on-time delivery and percentage of demand served. These mean that the quantity of goods must meet requirements within the customer expected time. Therefore, in a cross-docking distribution system, products are transported by manufacturers or suppliers to the cross-docking center where multiple products will be consolidated by customers order. After that, the delivery process will begin by sending those products to each customer. Therefore, typical operations at the cross-docking center include: (1) products arrived at the cross-docking center are unloaded at the receiving dock; (2) products are split into smaller lots and consolidated with other products according to customer orders and destinations; and (3) Products are moved to suitable location on the shipping dock and are loaded into truck for transporting to customer (Arabani et al. 2009).

As the function of cross-docking network is to reduce the inventory and to satisfy the customer need, not only that the quantities of products must meet the requirements but they must also be delivered within the time constraints of the network. This is because in real operations, suppliers, distribution center and customers may have specific time periods to ship and receive products. This is normally referred to as time window constraint. When time windows are fixed, the uncertainty of daily operations can be reduced and the service level can be improved. Ma et al. (2011) and Jai-oon (2011) studied the cross-docking distribution problem with time window constraint in the network. The model is for single product and has discrete time window constraint of manufacturers for shipping products to the destinations. Jewpanya and Kachitvichyanukul (2012) extended the model to handle multiple products and continuous time window constraints.

A good cross-docking distribution plan can help the network to reduce the transportation delay, to minimize the freight transfer time from supplier to customer, and to lower relevant costs such as transportation cost and inventory cost. This paper focuses on the problem of how to deliver products from manufacturers to customers to reduce such costs as transportation cost and inventory cost that also takes time constraints into consideration. It extends the cross-docking distribution planning model in Jewpanya and Kachitvichyanukul (2012) to include time windows for all parties: manufacturer time windows, cross-docking time windows and customer time windows as shown schematically in Fig. 1. Moreover, multiple products and consolidation of customer orders are included. A general mathematical model for cross-dock distribution planning is given in the next section.

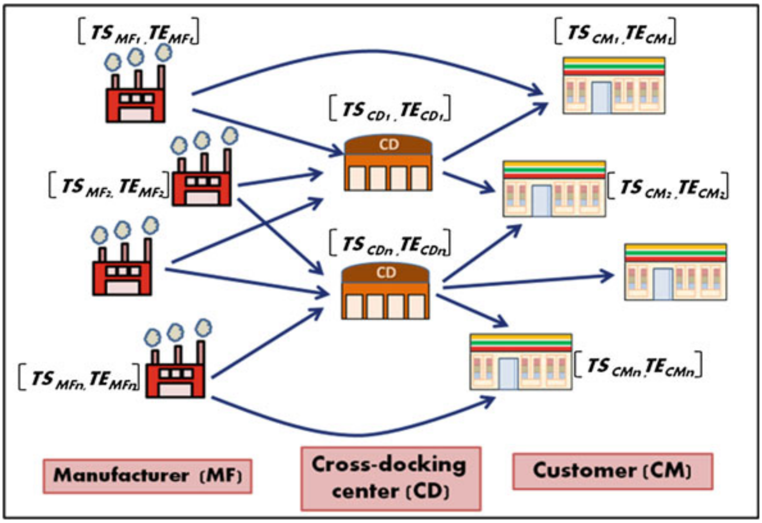


Fig. 1 Cross-docking distribution network with time windows

2 The Mathematical Model

The mathematical model for the cross-docking distribution planning problem with time window is based on the model from Jewpanya and Kachitvichyanukul (2012). This study extends the model to consider the restricted time interval of Manufacturers (i), Cross-docking center (k) and Customers (j) in the cross-docking network and the consolidation of products by customer orders. The constraints are added to the model to cover the general situations often occurred in the distribution network planning.

Indices:

i	Origin node	$i = 1, 2,\ldots, I$
j	Destination node	$j = 1, 2,\ldots, J$
k	Cross-docking center	$k = 1, 2,\ldots, K$
r	Product type	$r = 1, 2,\ldots, R$
t	Time	$T_{min} \le t \le T_{max}$

Parameters:

Q	The truck capacity
C'_{ij}	The set up cost of truck from location i to j
C''_{ik}	The set up cost of truck from location i to k
C'''_{kj}	The set up cost of truck from location k to j

(continued)

(continued)

D'_{ij}	The distance from manufacturer i to customer j
D''_{ik}	The distance from manufacturer i to cross-docking center k
D'''_{kj}	The distance from cross-docking center k to customer j
I	The cost of a unit distance
H	The cost of handling a unit product r for a unit time at cross-docking center
G'_{ij}	Total shipping time on route (i, j)
G''_{ik}	Total shipping time on route (i, k)
G'''_{kj}	Total shipping time on route (k, j)
τ_i^M	The starting time points of manufacturer i
φ_i^M	The ending time points of manufacturer i
τ_k^{CD}	The starting time to receive and release products at cross-docking center k
φ_k^{CD}	The ending time to receive and release products at cross-docking center k
τ_j^C	The starting time to receive products for customer j
φ_j^C	The ending time to receive products for customer j
T_{min}	The minimum times
T_{max}	The maximum times
$M_{j,r}$	The demand of product type r for customer j
$S_{i,r}$	The supply capacity of manufacturer i of product type r

Decision variables:

V'_{ijt}	The number of truck used on (i, j) at time t
V''_{ijt}	The number of truck used on (i, k) at time t
V'''_{kjt}	The number of truck used on (k, j) at time t
Z_{rkt}	The number of product r in cross-docking center k at time t
P'_{ijrt}	The quantity of product r delivery from manufacturer i to customer j at time t
P''_{ikrt}	The quantity of product r delivery from manufacturer i to cross-docking center k at time t
P'''_{kjrt}	The quantity of product r delivery from cross-docking center k to customer j at time t
τ'_{ij}	The feasible starting time points of manufacturer i that can deliver the product to customer j
φ'_{ij}	The feasible ending time points of manufacturer i that can deliver the product to customer j
τ''_{ik}	The feasible starting time points of manufacturer i that can send products to cross-docking center k
φ''_{ik}	The feasible ending time points of manufacturer i that can send products to cross-docking center k
τ'''_{kj}	The feasible starting time points of cross-docking center k that can deliver the product to customer j
φ'''_{kj}	The feasible ending time points of cross-docking center k that can deliver the product to customer j

Objective function:

$$\text{Minimize}\, f = (COST_{\text{transportation}} + COST_{\text{inventory}})$$

$$COST_{\text{Transportation}} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{t=T_{min}}^{T_{max}}[V'_{ijt}\cdot(C'_{ij} + I\cdot D'_{ij})] + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{t=T_{min}}^{T_{max}}[V''_{ikt}\cdot(C''_{ik} + I\cdot D''_{ik})]$$
$$+ \sum_{k=1}^{K}\sum_{j=1}^{J}\sum_{t=T_{min}}^{T_{max}}[V'''_{kjt}\cdot(C'''_{kj} + I\cdot D'''_{kj})]$$

$$COST_{\text{inventory}} = \sum_{k=1}^{K} H \sum_{r=1}^{R}\sum_{t=T_{min}}^{T_{max}} Z_{r,k,t}$$

The two main costs included in the decision are transportation cost and inventory cost. The transportation cost consists of three types of links in the network. The first type of links are the links from manufacturers to cross-docking centers (*i, k*). The second type of links are from manufacturers directly to customers (*i, j*). And finally, links from cross-docking centers to customers. In each link, the costs that concern about the number of truck are considered; the setup cost of truck and the unit distance cost. The inventory cost is calculated from the change of inventory level in the cross-docking centers at time *t*, and the cost of handling a unit product for a unit time at cross-docking center.

The objective function is to be minimized subjected to the constraints as described in the next section.

2.1 Time Window Constraint

In real operations, suppliers, distribution centers and customers may have specific time periods to ship and receive products. This is the time window constraint. If it can be managed in proper way, it may lead to high distribution efficiency in the cross-docking network. Therefore, the model considers the time windows for all links between parties in the cross-docking network, customer $[\tau'_{ij}, \varphi'_{ij}]$, manufacturer to cross-docking center $[\tau''_{ik}, \varphi''_{ik}]$, and cross-docking center to customer $[\tau'''_{kj}, \varphi'''_{kj}]$. The important time window constraints are formulated below:

$$\tau'_{ij} = Min\,\{x|x = [(\tau^{C}_{j} - G'_{ij}),\,(\varphi^{C}_{j} - G'_{ij})]\,and\,x \in [\tau^{M}_{i},\,\varphi^{M}_{i}]\}\quad \text{for all } i \text{ and } j \tag{1}$$

$$\varphi'_{ij} = Max\,\{x|x = [(\tau^{C}_{j} - G'_{ij}),\,(\varphi^{C}_{j} - G'_{ij})]\,and\,x \in [\tau^{M}_{i},\,\varphi^{M}_{i}]\}\quad \text{for all } i \text{ and } j \tag{2}$$

$$\tau''_{ik} = Min\,\{x|x = [(\tau^{CD}_{k} - G''_{ik}),\,(\varphi^{CD}_{k} - G''_{ik})]\,and\,x \in [\tau^{M}_{i},\,\varphi^{M}_{i}]\}\quad \text{for all } i \text{ and } k \tag{3}$$

$$\varphi''_{ik} = Max\{x|x = [(\tau_k^{CD} - G''_{ik}),\ (\varphi_k^{CD} - G''_{ik})]\ and\ x \in [\tau_i^M,\ \varphi_i^M]\} \quad \text{for all} \quad i \text{ and } k \tag{4}$$

$$\tau'''_{kj} = Min\{x|x = [(\tau_j^C - G'''_{kj}),\ (\varphi_j^C - G'''_{kj})]\ and\ x \in [\tau_k^{CD},\ \varphi_k^{CD}]\} \quad \text{for all} \quad k \text{ and } j \tag{5}$$

$$\varphi'''_{kj} = Max\{x|x = [(\tau_j^C - G'''_{kj}),\ (\varphi_j^C - G'''_{kj})]\ and\ x \in [\tau_k^{CD},\ \varphi_k^{CD}]\} \quad \text{for all} \quad k \text{ and } j \tag{6}$$

Time window constraints are separated into three groups. The first group include Constraints (1) and (2) describe the feasible starting time and ending time for manufacturers i to deliver the products directly to customers j within the receiving feasible starting time and ending time of customers $j[\tau_j^C,\ \varphi_j^C]$. The second group, constraints (3) and (4) are the feasible starting time and ending time for manufacturer to release products to cross-docking center. Another group includes Constraints (5) and (6) describe the feasible starting time and ending time for cross-docking center k to deliver the products to customer j within the receiving feasible starting time and ending time point of customers.

The first group of time window constraint, manufacturers can directly send products to customer within the customer expected time. For example, if the release time windows of manufacturers are: $[\tau_i^M,\ \varphi_i^M] = [\tau_1^M,\ \varphi_1^M] = [8.00,\ 8.50]$, $[\tau_2^M,\ \varphi_2^M] = [8.50,\ 10.50]$ and the customers has accepted time: $[\tau_j^C,\ \varphi_j^C] = [\tau_1^C,\ \varphi_1^C] = [14.00,\ 17.00]$ and suppose the shipping time from manufacturer to this customer is 7.50. Therefore, the release times of manufacturers that can deliver products to customers within expected time of customers $[\tau'_{ij}, \varphi'_{ij}]$ are from constraints (1) and (2) and the results are:

$$\tau'_{11} = Min\{x|x = [(14.00 - 7.50),\ (17.00 - 7.50)] = [6.50, 9.50]\ and\ [6.50, 9.50] \in [8.00, 8.50]\} = 8.00$$

$$\varphi'_{11} = Max\{x|x = [(14.00 - 7.50),\ (17.00 - 7.50)] = [6.50, 9.50]\ and\ [6.50, 9.50] \in [8.00, 8.50]\} = 8.50$$

Therefore, the release time of manufacturer1 that can send products to customer1 is [8.00, 8.50].

In the same way with the first group, the time window that manufacturer can release products to customer via the cross-docking center in constraints (3) and (4). For instance, the same manufacturer above send products to the cross-docking center that opens at 10.30 and closes at 11.45. The shipping time from manufacturer to this cross-docking center is 1.40. Therefore, the release time for manufacturer to send product to cross-docking center is [8.90, 10.50].

The last group, the time windows for the cross-docking centers, they are the time window that cross-docking center can send products to customer so that it can reach the customers within expected receiving time window ($[\tau'''_{kj}\varphi'''_{kj}]$). For example, the expected time of customer $[\tau^c_1, \varphi^c_1] = [14.00, 17.00]$. And the time the cross-docking can operate is from 10.30 to 11.45. The transportation takes time for 2.90. The release time window of cross-docking center to customer can be calculated following Eqs. (5) and (6).

$$\tau'''_{11} = Min\{x|x = [(14.00 - 2.90), (17.00 - 2.90)] = [11.10, 14.10]\ and\ [11.10, 14.10] \in [10.30, 11.45]\} = 11.10$$

$$\varphi'''_{11} = Max\{x|x = [(14.00 - 2.90), (17.00 - 2.90)] = [11.10, 14.10]\ and\ [11.10, 14.10] \in [10.30, 11.45]\} = 11.45$$

Thus, the release time window at cross-docking center that can send products to customer is [11.10, 11.45]. This time window model is more general when compare with Jewpanya and Kachitvichyanukul (2012). It can solve the realistic time window problem. This is because the model can deal with every party within the distribution network, i.e., manufacturers, cross-docking centers and customers.

2.2 Supply and Demand Constraint

To satisfy the customer needs, all of requirements must be carefully considered. The quantities of products that are sent to customers must meet the customer demand and they must not exceed the supply of manufacturer.

$$\sum_{i=1}^{I}\sum_{t=\tau'_{ij}}^{\varphi'_{ij}} P'_{ijrt} + \sum_{k=1}^{K}\sum_{t=\tau'''_{kj}}^{\varphi'''_{kj}} P'''_{kjrt} = M_{j,r} \quad \text{for all } j \text{ and } r \tag{7}$$

$$\sum_{j=1}^{J}\sum_{t=\tau'_{ij}}^{\varphi'_{ij}} P'_{ijrt} + \sum_{k=1}^{K}\sum_{t=\tau''_{ik}}^{\varphi''_{ik}} P''_{ikrt} \le S_{i,r} \quad \text{for all } i \text{ and } r \tag{8}$$

Constraint (7) ensures that the number of products delivered to customer must meet the customer demand while constraint (8) confirms the total quantity of products shipped from manufacturers do not exceed the available supply.

2.3 Constraints of Inventory in Cross-Docking Center and Volume Constraints with Customer Order Consolidation

The cross-docking center can be seen as a warehouse where a reduced quantity of products is stored in a short term stock. Constraint (9) ensures that the flow of product at each cross-docking center at each time is non-negative. Constraint (10) indicates that there are no products in each cross-docking center at the starting time point. Constraint (11) states the number of product in each cross-docking center at time t.

$$Z_{r,k,t} \geq 0 \quad \text{for all } r \text{ and } k,\ \tau_k^{CD} \leq t \leq \varphi_k^{CD} \tag{9}$$

$$Z_{r,k,T_{min-1}} = 0 \quad \text{for all } r \text{ and } k \tag{10}$$

$$Z_{r,k,t} = Z_{r,k,t-1} + \sum_{i=1}^{I} P''_{ikrt} - \sum_{j=1}^{J} P'''_{kjrt} \quad \text{for all } k \text{ and } r,\ \tau_k^{CD} \leq t \leq \varphi_k^{CD} \tag{11}$$

$$\sum_{t=\tau'_{ij}}^{\varphi'_{ij}} \sum_{r=1}^{R} P'_{ijrt} \leq V'_{ijt} \cdot Q \quad \text{for all } i \text{ and } j \tag{12}$$

$$\sum_{t=\tau''_{ik}}^{\varphi''_{ik}} \sum_{r=1}^{R} P''_{ikrt} \leq V''_{ikt} \cdot Q \quad \text{for all } i \text{ and } k \tag{13}$$

$$\sum_{t=\tau'''_{kj}}^{\varphi'''_{kj}} \sum_{r=1}^{R} P'''_{kjrt} \leq V'''_{kjt} \cdot Q \quad \text{for all } k \text{ and } j \tag{14}$$

It is common to consolidate products from different manufacturers by customer order to improve transportation efficiency. Constraints (12), (13) and (14) combine products into a larger volume for each customer before it is allocated to truck which has a fixed capacity and this is done on a product basis with order consolidation.

3 Time Window Constraint for LINGO Model

Time window in cross-docking distribution planning model should consider the specific releasing time of manufacturers, the expected receiving time of customers, also the receiving and shipping time windows of cross-docking center. Time window constraint should be carefully handled because it can help to reduce the inventories and waiting time of products in the storage site. Furthermore, this may lead to customer satisfaction.

In this study, the time window model in LINGO is extended from Jewpanya and Kachitvichyanukul (2012). The previous time window model deals only with manufacturer and customer time windows. That is not proper for the realistic operation. Therefore, this paper, the time window model of LINGO was designed to cover time windows for all parties follow the constraint in Sect. 2.1. Moreover, it is modified to reduce the running time by improving a part of time window constraint in the LINGO model.

For LINGO model, the time window was considered as an index in the program that was run from a beginning time (T_{min}) to an ending time (T_{max}) in very routes of network consist of, route from i to j and route i to k to j (for all i, j, k). Jewpanya and Kachitvichyanukul (2012) specified the beginning time is the time that first manufacturer can send products to the destinations. And, the ending is the time that the last customer can receive the products. For example, in Table 2, T_{min} is 8.00 and T_{max} is 17.00. From 8.00 to 17.00, there are 900 index combination that must be run in every route (i to j and i to k to j) in order to find the best answer. This make the running time quite long.

Therefore, the development in this study is to reduce the combination of time index in the LINGO model. The beginning time (T_{min}) and ending time (T_{max}) are separated into two groups. The first group is T_{min} and T_{max} of route manufacturers to customers (i to j). The second is for route manufacturers to cross-docking center to customers (i to k to j). In the first group, T_{min} is considered from the beginning that the first manufacturer can send products to the customers. For example, the same problem above (Table 2), the starting time considered (T_{min}) is 8.00. But for T_{max} will consider the time that last manufacturer can release the product to customers within the customer expected time. This can be calculated follows this:

$$T_{max} = \max(\varphi_j^C - G'_{ij}), \quad \text{for all } i, j$$

If the shipping time from manufacturer to customer (G'_{ij}) is showed at Fig. 2, T_{max} is 11.4. By considering this, the LINGO model needs to generate index

		CM1	CM2	CM3
Distance_(i,j)	MF1	450	408	390
	MF2	408	336	360
ShippingT_(i,j)	MF1	7.50	6.80	6.50
	MF2	6.80	5.60	6.00
		CD1		
Distance_(i,k)	MF1	120		
	MF2	108		
ShippingT_(i,k)	MF1	2.00		
	MF2	1.80		
		CM1	CM2	CM3
Distance_(k,j)	CD1	114	180	150
Shipping_(k,j)	CD1	1.90	3.00	2.50

Fig. 2 Shipping time for example in Sect. 3

combination from 8.00 to 11.40 that is only 300 combinations in every possible route for link manufacturer to customer. It can be seen that the combination is reduced from 900 to 300 in each i to j.

The second group is for the link manufacturer to cross-docking center to customer (i to k to j). T_{min} is still same with the first group. For the ending time, T_{max} is indicated that last cross-docking center can release the product to customers within the customer expected time are investigated. And the calculation is this:

$$T_{max} = \max(\varphi_j^C - G'_{kj}), \quad \text{for all } k, j$$

Therefore, in the second group, T_{max} is 15.1. The index generated will be 710 combinations. It means that the time in every route in the second group (i to k to j) will run only 710 combinations. That also reduced from 900.

With the improvement, the solution can be seen in the next section, the illustrative examples to explain the operation of cross-docking distribution with time window constraint in Sect. 4.1 and Comparison of the computational time in Sect. 4.2.

4 Computation Results

4.1 The Distribution Planning Results

The cross-docking distribution planning problems are solved using the model in this paper in order to find the optimal distribution plan under the limitation of time window. There are three problems instances used as illustrative examples are

Table 1 Test problem instance

Instance	Test set name	Manufacturers	Cross-docking centers	Customers	No. of products type
1	2MF 1CD 3CM 2P	2	1	3	2
2	2MF 2CD 3CM 3P	2	2	3	3
3	3MF 2CD 4CM 3P	3	2	4	3

Table 2 Specific data for problem instance 1

2MF_1CD_3CM_2P		Manufacturer		Cross-docking center	Customer		
		MF1	MF2	CD1	CM1	CM2	CM3
Time	Starting time	8.00	8.50	10.00	14.00	14.45	12.00
	Ending time	8.50	10.50	13.00	17.00	17.00	16.50
Supply/demand	P1	2,000	200		250	300	500
	P2	600	2,500		300	600	200

Table 3 Specific data for problem instance 2

2MF_2CD_3CM_3P		Manufacturer		Cross-docking center		Customer		
		MF1	MF2	CD1	CD2	CM1	CM2	CM3
Time	Starting time	7.30	8.50	10.00	10.00	13.50	14.45	13.50
	Ending time	12.00	12.00	13.00	13.50	17.00	17.00	16.50
Supply/demand	P1	2,000	200			250	300	500
	P2	0	2,500			300	600	200
	P3	2,200	0			100	0	250

Table 4 Specific data for problem instance 3

3MF_2CD_4CM_3P		Manufacturer			Cross-docking center		Customer			
		MF1	MF2	MF3	CD1	CD2	CM1	CM2	CM3	CM4
Time	Starting time	7.30	8.50	8.50	7.00	8.00	13.50	14.45	13.50	15.00
	Ending time	8.50	10.50	10.00	15.50	14.20	17.00	17.00	17.00	17.00
Supply/demand	P1	2,000	200	0			250	300	500	0
	P2	0	2,500	600			300	600	200	0
	P3	2,200	1,000	400			100	0	250	650

Table 5 Distribution plan for problem instance 1

From	Depart time	To	Arrival time	Inventory	Inventory time	Amount of	
						P1	P2
MF1	8.30	CD1	10.30	–	–	500	–
MF1	8.50	CD1	10.50	–	–	350	–
MF1	9.39	CD1	11.19	–	–	–	200
MF2	9.65	CD1	11.45	–	–	–	600
MF2	10.30	CD1	12.10	–	–	200	300
CD1	10.30	CM3	12.80	–	–	500	–
–	–	–	–	CD1	10.50–11.44	350	–
CD1	11.19	CM3	13.69	–	–	–	200
CD1	11.45	CM2	14.45	–	–	300	600
–	–	–	–	CD1	11.45–12.09	50	–
CD1	12.11	CM1	14.01	–	–	250	300
Total costs			107,251.30				
Inventory cost			255.50				
Transportation cost			106,995.80				

given in Table 1. The key elements in the examples include number of manufacturers, cross-docking centers, customers and products.

Detailed information of each problem is showed in Tables 2, 3 and 4. Those problems are the cross-docking distribution planning problem that has the limitation of time in each node, manufacturer node, cross-docking center node and customer node. Moreover, it has the different supply and demand as indicated in the Table.

After solving the model using LINGO software, the distribution plan of the problem instance 1 is shown in the Table 5. The plan of distribution start at time 8.30 manufacturer 1 sends 500 units of product P1 to cross-docking center 1 and it arrives at time 10.30. Then, time 8.50, manufacturer 1 release products P1 350 units to the same cross-docking center arrive at 10.50. After that at time 9.39 and 9.65, manufacturer 2 ships 200 and 600 units of product P2 to the cross-docking center 1. They arrive at 11.19 and 11.45 respectively. The other details are shown in Table 5.

From the planning result in Table 5, the arrival time of every destination must be within their expected time window. For example, MF1 release P1 to CD1, the depart time from MF1 is 8.30 and it arrived CD1 at 10.30. In this case, the time window of CD1 is [10.00, 13.00]. It means that CD1 can receive the products because it arrives within expected time of CD1.

For instances 2 and 3, the distribution plan of products are indicated in Tables 6 and 7.

These results can provide the distribution plan of the cross-docking distribution planning problem that has the minimum total cost. Moreover, this plan satisfied the time window constraints of manufacturers, cross-docking centers and customers in the cross-docking network.

Table 6 Distribution plan for problem instance 2

From	Depart time	To	Arrival time	Inventory	Inventory time	Amount of		
						P1	P2	P3
MF1	8.50	CD1	10.50	–	–	850	–	350
MF2	10.01	CD2	11.59	–	–	200	–	–
MF2	10.50	CD1	12.30	–	–	–	300	–
MF2	10.50	CD2	12.08	–	–	–	800	–
–	–	–	–	CD1	10.50–10.98	850	–	–
–	–	–	–	CD1	10.50–10.99	–	–	350
–	–	–	–	CD1	10.99–11.44	550	–	–
–	–	–	–	CD1	11.00–11.59	–	–	100
CD1	11.00	CM3	13.50	–		300	–	250
–	–	–	–	CD1	11.45–11.59	250	–	–
CD1	11.45	CM2	14.45	–	–	300	–	–
CD2	11.59	CM3	13.51	–	–	200	–	–
CD1	11.60	CM1	13.50	–	–	250	–	100
CD2	12.08	CM2	14.58	–	–	–	600	–
CD2	12.08	CM3	14.00	–	–	–	200	–
CD1	12.30	CM1	14.20	–	–	–	300	–
Total costs			117,203.20					
Inventory cost			661.50					
Transportation cost			116,541.70					

Table 7 Distribution plan for problem instance 3

From	Depart time	To	Arrival time	Inventory	Inventory time	Amount of		
						P1	P2	P3
MF1	8.50	CD1	10.50	–	–	850	–	–
MF2	9.20	CD1	11.00	–	–	–	–	250
MF2	9.74	CD1	11.54	–	–	–	200	–
MF2	10.05	CD2	11.65	–	–	200	900	–
MF2	10.09	CD2	11.69	–	–	–	–	750
–	–	–	–	CD1	10.50–10.99	600	–	–
CD1	10.50	CM1	13.50	–	–	250	–	–
–	–	–	–	CD1	11.00–11.44	100	–	–
CD1	11.00	CM3	13.50	–	–	500	–	250
CD1	11.45	CM2	14.45	–	–	100	–	–
CD1	11.54	CM3	14.04	–	–	–	200	–
CD2	11.65	CM1	14.75	–	–	–	300	–
CD2	11.65	CM2	14.45	–	–	200	–	–
CD2	11.69	CM1	14.79	–	–	–	–	100
CD2	11.69	CM2	14.49	–	–	–	600	–
CD2	11.69	CM4	15.01	–	–	–	–	650
Total costs			162,612.30					
Inventory cost			241.50					
Transportation cost			162,853.80					

Table 8 Computational time

Instance	Test set name	Computational time (s)		Improve time (%)
		Previous solution	Current solution	
1	2MF 1CD 2CM 2P	60.50	0.70	98.84
2	2MF 1CD 2CM 3P	103.55	1.26	98.78
3	2MF 1CD 3CM 2P	143.32	23.85	83.35
4	2MF 2CD 3CM 3P	154.34	45.09	70.78
5	2MF 2CD 4CM 4P	204.40	55.46	72.86
6	3MF 1CD 2CM 2P	561.11	102.20	81.78
7	3MF 1CD 4CM 2P	879.70	239.98	72.72
8	3MF 2CD 4CM 3P	1249.94	522.78	58.17
9	3MF 2CD 5CM 4P	2390.03	908.57	61.98
10	4MF 2CD 5CM 5P	3398.22	1269.90	62.63

4.2 Comparison of the Computational Time

The LINGO model from Jewpanya and Kachitvichyanukul (2012) is improved to deal with all time window constraints and to reduce the running time of program that have explained in Sect. 3. Ten problem instances were run with the original model and with the revised model in this paper. The result shows in Table 8. It demonstrates that the computational time is improved from the previous work average 76.19 %.

5 Conclusion

This research presented a formulation of the cross-docking distribution planning model with multiple products, order consolidation and time windows that was extended from the previous work to consider all of time window in the cross-docking network, manufacturers, cross-docking center and customers. This model is linear and can be solved by LINGO for small problem sizes. Three small distribution planning problems are used to illustrate the model. The results indicate that this model can obtain the distribution plan with minimum cost and under the limitation of time windows. Moreover, ten instances were run with two models those are current model and previous model obtained from Jewpanya and Kachitvichyanukul (2012) by using LINGO to compare the computational time. The results show that the improved LINGO model can find solutions in much shorter time with average improvement of about 76.19 %.

References

Arabani ARB, Ghomi SMTF, Zandieh M (2009) A multi-criteria cross-docking scheduling with just-in-time approach. Int J Adv Manuf Technol

Dondo R, Cerdá J (2013) A sweep-heuristic based formulation for the vehicle routing problem with cross-docking. Comput Chem Eng 48:293–311

Jai-oon A (2011) A particle swarm optimization algorithm for cross-docking distribution networks. Master Thesis, Asian Institute of Technology, Thailand

Jewpanya P, Kachitvichyanukul V (2012) General model of Cross-docking distribution planning problem. In: Proceedings of the 7th international congress on logistics and SCM systems, Seoul, 7–9 June 2012

Ma H, Miao Z, Lim A, Rodrigues B (2011) Crossdocking distribution networks with setup cost and time window constraint. Omega 39:64–72

Santos FA, Mateus GR, Cunha ASD (2013) The pickup and delivery problem with cross-docking. Comput Oper Res 40:1085–1093

A New Solution Representation for Solving Location Routing Problem via Particle Swarm Optimization

Jie Liu and Voratas Kachitvichyanukul

Abstract This paper presents an algorithm based on the particle swarm optimization algorithm with multiple social learning terms (GLNPSO) to solve the capacitated location routing problem (CLRP). The decoding method determines customers clustering followed by depot location and ends with route construction. The performance of the decoding method is compared with previous work using a set of benchmark instances. The experimental results reveal that proposed decoding method found more stable solutions that are clustered around the best solutions with less variation.

Keywords Location routing problem · Particle swarm optimization · Solution representation · Decoding

1 Introduction

Location routing problem (LRP) is basically an integration of two sub-problems: a strategic location-allocation problem (LAP) and an operational vehicle routing problem (VRP) (Bruns 1998). LRP shares the common properties of LAP and VRP both of which are strong NP-hard problems. The comprehensive review on Location routing problem can be found in (Nagy and Salhi 2007). The synthesis of LRP study with a hierarchical taxonomy and classification scheme as well as reviews of different solution methodologies are given in (Min et al. 1998).

J. Liu (✉) · V. Kachitvichyanukul
Industrial System Engineering, School of Engineering and Technology, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumtani 12120, Thailand
e-mail: st111504@ait.ac.th

V. Kachitvichyanukul
e-mail: voratas@ait.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_12,

Liu and Kachitvichyanukul (2012) proposed a decoding method for solving general LRP based on GLNPSO framework (Pongchairerks and Kachitvichyanukul 2009). This paper improved the decoding method in Liu and Kachitvichyanukul (2012) and tested the method using the benchmark instances from the website of http://prodhonc.free.fr/Instances/instances_us.htm.

The remainder of this paper is organized as follows. Section 2 describes the problem and introduces the literature reviews. Section 3 describes the solution representation and the decoding method. The results of the computational experiments are provided in Sect. 4. Conclusions are given in Sect. 5.

2 Problem Definition and Related Works

This paper considers the discrete location-routing problem (CLRP) with the capacity constraints on both depot and route and with the homogeneous fleet type and unlimited number of vehicles. Early exact algorithms for the problem included: Laporte and Nobert (1981), Averbakh and Berman (1994), Laporte et al. (1986), and Ghosh et al. (1981).

Some of the more recent heuristic algorithms for LRP are cited here. Wu et al. (2002) decomposed LRP into two sub-problems of LAP and VRP and solved the two sub-problems in an iterative manner by simulated annealing based with a tabu list to avoid cycling. Prins et al. (2006a) combined greedy randomized adaptive search procedure (GRASP) with a path relinking mechanism to solve the LRP with capacitated depots and routes with homogeneous fleet and unlimited vehicle. Prins et al. (2006b) and Duhamel et al. (2008) proposed different memetic algorithms by hybridizing genetic algorithm with a local search procedure (GAHLS) and different chromosomes. Liu and Kachitvichyanukul (2012) proposed an algorithm based on GLNPSO for solving CLRP.

This paper proposed a new solution representation that extends the work by Liu and Kachitvichyanukul (2012). The solution representation and decoding method is given in the next section.

3 Solution Representation and Decoding Method

An indirect representation is used in this paper. A particle position $[\theta l_1, \theta l_2, \ldots, \theta l_H]$, is transformed into selected locations, customer assignment and service routes via the decoding process. For LRP problem with n depots and m customers, the dimension of the particle is $n + m$. Each dimension of the particle is initialized with random number between 0 and 1. Figure 1 illustrates a sample particle for an LRP problem with 3 depots and 10 customers.

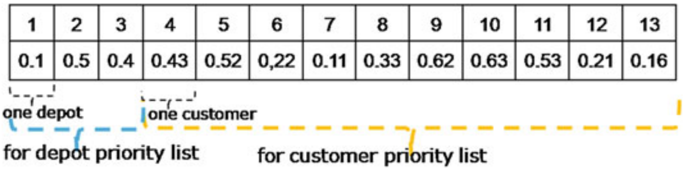


Fig. 1 Example of one particle for LRP with 3 depots and 10 customers

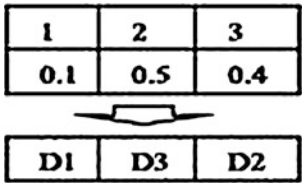


Fig. 2 Depots priority

The decoding of depot priority and customer priority are shown in Figs. 2, and 3. Priority sequence is sorted in ascending order of the value of each dimension.

Given that the coordinate of a location *i* is denoted as (x_i, y_i), the Euclidian distance between any two locations *i*,*j* is given in Eq. (1).

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (1)$$

Two proximity matrices are created for clustering of customers and depots. The customers proximity to the depots shown in Table 1 for the sample particle given in Fig. 1. Similarly, the customers proximity to other customers can be formed as shown in Table 2.

The clustering for the proposed decoding method is based on the customers selected from the priority list given in Fig. 3 so customer 4 is used as the center of the first group. From Table 2, the customers that are closed to customer 4 are customers 5, 3, and so on. The clustering of the customers based on Fig. 3 and Table 2 are shown in Fig. 4. The next unassigned customer on the priority list is customer 10, and it is used to form the second group, etc. The geometrical center of each group is calculated and the distance between the depots and the

Fig. 3 Decoding customers priority

Table 1 Proximity matrix of relative position between customers to depot

	Customers
D1	c3, c1, c5, c2, c4, c6, c8, c9, c10, c7
D2	c2, c9, c1, c5, c4, c7, c3, c8, c6, c10
D3	c6, c10, c7, c1, c9, c2, c5, c3, c8, c4

Table 2 Proximity matrix of relative position between pair customers

	Sequence of distance in ascending order
c1	9, 2, 3, 5, 7, 4, 8, 6, 10
c2	1, 9, 5, 3, 4, 7, 8, 6, 10
c3	5, 8, 4, 1, 2, 9, 6, 7, 10
c4	5, 3, 8, 2, 1, 9, 6, 7, 10
c5	4, 3, 2, 1, 8, 9, 7, 6, 10
c6	10, 1, 7, 8, 3, 9, 5, 2, 4
c7	9, 1, 2, 6, 5, 3, 10, 4, 8
c8	3, 4, 5, 1, 2, 6, 10, 9, 7
c9	7, 1, 2, 5, 3, 4, 6, 8, 10
c10	6, 8, 1, 3, 7, 9, 5, 2, 4

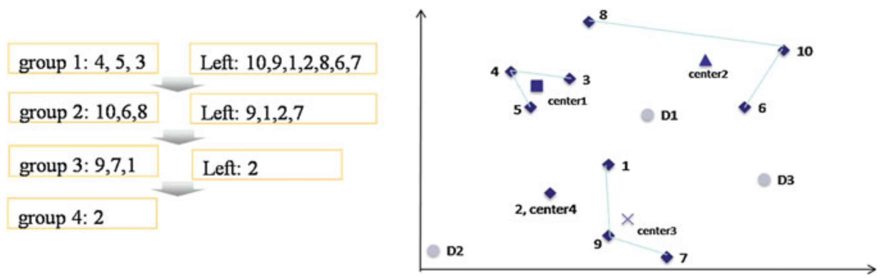


Fig. 4 Grouping process for all customers

geometrical centers are then used to assign customer group preference to depot as shown in Table 3. Finally, the routes are constructed by lowest cost insertion heuristic and the routes are given in Fig. 5.

4 Computational Experiments

Benchmark test datasets for general capacitated LRP are obtained from the website with URL, (http://prodhonc.free.fr/Instances/instances_us.htm). The objective is the total cost which is defined as the sum of the opening cost for depots, the fixed cost of routes, and the total distance times 100.

The decoding methods are implemented in C# programming language under Microsoft Visual studio. NET4.0. The GLNPSO algorithm from the ET-Lib object

Table 3 Proximity matrix of relative position between groups and each depot

	Group 1–4			
D1	**g2**	**g3**	g1	g4
D3	g2	g3	**g4**	**g1**
D2	g4	g3	g1	g2

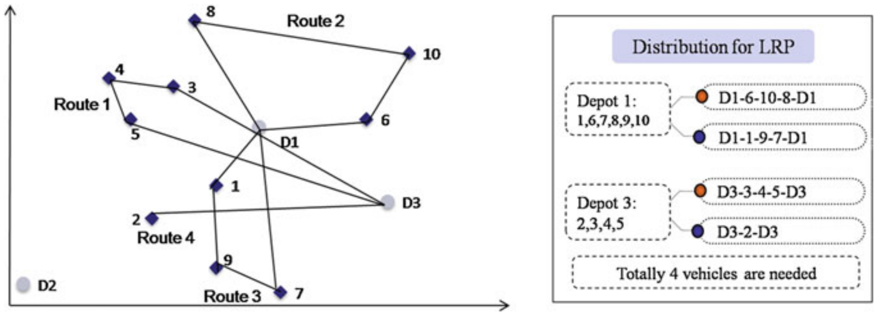


Fig. 5 The distribution for LRP example using the proposed decoding

Table 4 Parameters setting of GLNPSO for CLRP

Parameters	Value
Number of particle	20, 40, 50
Number of iteration	100 ~ 1,500
Number of neighborhood (NB)	5
Inertial weight (w)	Linearly decreasing from 0.9 to 0.4
Acceleration constant, *cp*, *cg*, *cl*, *cn*	1, 1, 1, 1

library is used (Nguyen et al. 2010). The experiments are carried out on a desktop computer with Intel (R) Core(TM)2 Quad CPU, Q9550 @ 2.83 GHz, 2.83 GHz, 3.00 GB of RAM.

The parameters used in the experiments are based on previous study by (Ai and Kachitvichyanukul 2008), as shown in Table 4, the number of particles and number of iteration are fixed with respective to different size of instance.

The two decoding methods are tested with 30 problem instances. The solutions and the comparisons with best known solution (BKS) and solutions by other heuristics are listed. The two main measurements are the percent deviation from the best known solution (DEV) and the computational time (CPU). The results are shown in Table 5.

As shown in Table 5, the proposed decoding yields 1 new BKS out of 30 problem instances. However, the variation of solution is much smaller with only 4 instances have DEV over 5 %, and only 2 instances DEV over 10 % while most of the instances are below 5 %. For type “a” instances, computer times by these two decoding methods are closed, but for type “b” instance, time required by the proposed decoding is much shorter.

Table 5 The solution quality and solution times

Instance	BKS	Liu and Kachitvichyanukul (2012)			Proposed decoding		
		Cost	DEV %	CPU	Cost	DEV %	CPU
20-5-1a	54,793	54,149	−1.18	1	55,034	0.44	1
20-5-1b	39,104	44,297	13.28	5	41,929	7.22	2
20-5-2a	48,908	50,369	2.99	1	48,895	−0.02	1
20-5-2b	37,542	41,511	10.57	5	38,966	3.79	2
50-5-1a	90,111	92,685	2.86	20	93,290	3.53	18
50-5-1b	63,242	63,485	0.38	58	64,418	1.86	28
50-5-2a	88,298	97,419	10.33	17	91,797	3.96	17
50-5-2b	67,340	70,819	5.17	50	68,949	1.94	26
50-5-2BIS	84,055	87,085	3.13	18	85,367	1.56	18
50-5-2bBIS	51,822	58,674	13.22	57	54,973	6.08	25
50-5-3a	86,203	90,761	5.29	20	87,962	2.04	18
50-5-3b	61,830	66,361	7.33	55	63,998	3.51	27
100-5-1a	275,993	295,690	7.14	152	288,328	4.47	120
100-5-1b	214,392	229,490	7.00	372	220,752	2.97	231
100-5-2a	194,598	193,946	−0.34	145	198,223	1.86	183
100-5-2b	157,173	156,246	−0.59	361	159,446	1.45	251
100-5-3a	200,246	206,087	2.91	148	206,710	3.23	184
100-5-3b	152,586	154,587	1.31	433	154,741	1.41	248
100-10-1a	290,429	285,164	−1.81	153	322,954	11.20	186
100-10-1b	234641	231,802	−1.21	370	272,556	16.12	247
100-10-2a	244,265	242,890	−0.56	163	248,806	1.86	184
100-10-2b	203,988	203,790	−0.10	426	207,502	1.72	249
100-10-3a	253,344	247,379	−2.35	160	262,405	3.58	185
100-10-3b	204,597	200,579	−1.96	530	209,540	2.42	249
200-10-1a	479,425	496,553	3.57	1,358	48,989	2.18	1,962
200-10-1b	378,773	384,811	1.59	3,160	385,785	1.85	2,383
200-10-2a	450,468	472,770	4.91	1,346	457,168	1.48	1,963
200-10-2b	374,435	386,670	3.28	3,682	381,297	1.83	2,366
200-10-3a	472,898	478,828	1.25	1,324	480,348	1.58	1,935
200-10-3b	364,178	368,360	1.15	2,993	370,746	1.80	2320

As seen in Table 5, decoding method from Liu and Kachitvichyanukul (2012) can reach more best known solutions than the proposed decoding method. However, the proposed decoding method is more consistent in that the average gap between the solutions and the BKS are much smaller. For decoding method from Liu and Kachitvichyanukul (2012), the preclustering of customers around the depot restricted the route construction that frequently leads to suboptimal routes. For medium and larger problem instances, more grouping combinations can be formed and the drawbacks had less effect on the search results. It can be seen from Table 5 that the proposed decoding method is more consistent and the average gap is less than 5 %. This is expected since the design of the decoding method is aimed at increasing the diversity of routes formed in the route construction step. For problem instances 2, 19, and 20, further investigation should be carried out to see if there is any problem specific situations that prevent the route construction to reach better routes.

5 Conclusion

This paper proposed a solution representation and decoding method for solving CLRP problem using GLNPSO. The proposed solution representation is evaluated on a set of benchmark problem instances. Based on the experimental results, the following conclusions are drawn:

- The proposed decoding method is more consistent than that by Liu and Kachitvichyanukul (2012), the average gap is below 5 % with only a few problem instances with gap higher than 5 %.
- Liu and Kachitvichyanukul (2012) can reach better solutions more often but the average performance is poorer.
- The comparison of computational time is inconclusive. More experiments with larger samples are required to make a definite conclusion.

References

Ai TJ, Kachitvichyanukul V (2008) A study on adaptive particle swarm optimization for solving vehicle routing problems. Paper in the APIEMS 2008 conference. Bali, Dec 2008

Averbakh I, Berman O (1994) Routing and location-routing p-delivery men problems on a path. Transp Sci 28:184–197

Bruns AD (1998) Zweistufige Standortplanung unter Berü cksichtigung von Tourenplanungsaspekten—Primale Heuristiken und Lokale Suchverfahren. Ph.D dissertation, Sankt Gallen University

Duhamel C, Lacomme P, Prins C, Prodhon C (2008) A memetic approach for the capacitated location routing problem. Paper presented in the EU/meeting 2008 workshop on metaheuristics for logistics and vehicle routing. France, 23–24 Oct 2008

Ghosh JK, Sinha SB, Acharya D (1981) A generalized reduced gradient based approach to round-trip location problem. Sci Manage Transp Systems 209–213

Laporte G, Nobert Y (1981) An exact algorithm for minimizing routing and operating costs in depot location. Eur J Oper Res 6:224–226

Laporte G, Nobert Y, Arpin D (1986) An exact algorithm for solving a capacitated location-routing problem. Ann Oper Res 6:291–310

Liu J, Kachitvichyanukul V (2012) Particle swarm optimization for solving location routing problem. In: Proceedings of the 13th Asia pacific industrial engineering and management systems conference. Phuket, Thailand, pp 1891–1899, Dec 2012

Min H, Jayaraman V, Srivastava R (1998) Combined location-routing problems: a synthesis and future research directions. Eur J Oper Res 108:1–15

Nagy G, Salhi S (2007) Location-routing: issues, models and methods. Eur J Oper Res 177:649–672

Nguyen S, Ai TJ, Kachitvichyanukul V (2010) Object library for evolutionary techniques ETLib: user's guide. High Performance Computing Group, Asian Institute of Technology, Thailand
Pongchairerks P, Kachitvichyanukul V (2009) Particle swarm optimization algorithm with multiple social learning structures. Int J Oper Res 6(2):176–194
Prins C, Prodhon C, Calvo RW (2006a) Solving the capacitated location-routing problem by a GRASP complemented by a learning process and a path relinking. Q J Oper Res 4(3):221–238
Prins C, Prodhon C, Calvo RW (2006b) A memetic algorithm with population management (MA|PM) for the capacitated location-routing problem. EvoCOP 2006:183–194
Wu TH, Low C, Bai JW (2002) Heuristic solutions to multi-depot location-routing problems. Comput Oper Res 29:1393–1415

An Efficient Multiple Object Tracking Method with Mobile RFID Readers

Chieh-Yuan Tsai and Chen-Yi Huang

Abstract RFID (Radio Frequency Identification) technology originally is designed for object identification. Due to its relatively low cost and easy deployment, RFID technology becomes a popular approach for tracking the positions of objects. Many researchers proposed variant object tracking algorithms to quickly locate objects. Although these algorithms are efficient for certain applications, their tracking methods are limited on multiple objects with fixed RFID readers or single object with mobile RFID readers. None of them focus on tracking multiple objects with mobile RFID readers. To bridge this gap, this study develops an efficient multiple object tracking method with mobile RFID readers. First, the omni-directional antenna in a mobile RFID reader is used to judge the annular regions at which objects locate by adjusting the reader's reading range. Second, the directional antenna in the mobile RFID reader is used to judge the circular sectors of objects according to the received signal strengths in each direction. Third, four picking strategies are proposed to decide whether an object is picked in current step or later step. Finally, the simulated annealing algorithm is performed for all objects in the list of current step to generate the picking sequence with shortest distance. The experiments show that the proposed tracking method can help users find multiple objects in shortest distance.

Keywords RFID · Multiple object tracking · Picking sequence · Simulated annealing (SA) algorithm

C.-Y. Tsai (✉)
Department of Industrial Engineering and Management, Yuan-Ze University, No. 135, Yungtung Road, Chungli City, Taoyuan, Taiwan, Republic of China
e-mail: cytsai@saturn.yzu.edu.tw

C.-Y. Huang
Department of Production, Powertech Technology Inc., No. 26, Datong Rd, Hsinchu Industrial Park, Hukou, Hsinchu, Taiwan, Republic of China
e-mail: mattcyhuang@pti.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_13,

1 Introduction

In recent years, many object tracking technologies has been developed such as GPS, infrared technology, radar, ultrasonic, and Radio Frequency Identification (RFID). Each technology has its own advantage and limitation. For example, GPS localization technology is popular in navigation field but not suitable for indoor environment. The equipment cost for infrared technology is low but line-of-sight and short-range signal transmission is its major limitations. RFID is a communication technology which receives many attentions in the fields of entrance management, logistics and warehouse management, medical care, and others.

In recent years, RFID technology has been successfully applied to object localization. However, a lot of RFID readers might be required to precisely estimate the accurate object position. Lionel et al. (2004) proposed a LANDMARC method that uses reference tags to reduce the cost and to improve the localization accuracy. Shih et al. (2006) and Zhao et al. (2007) proposed different approaches to improve LANDMARC method. Another important research area is to search objects using mobile RFID reader. That is, a user holds a mobile RFID reader and moves in the searching area to find objects. When the user receives the signal from an object, he/she will know the object is within the range. However, a user needs to move constantly with try and error approach to determine object position. Song et al. (2007) aimed at the mobile localization and proposed a prototype system. Bekkali et al. (2007) used two mobile readers to locate objects and used a filter to reduce the localization variation.

To improve the performance of object searching using mobile RFID readers, this study develops an efficient multiple object tracking method with mobile RFID readers. First, the omni-directional antenna in a mobile RFID reader is used to judge the annular regions at which objects locate by adjusting the reader's reading range. Second, the directional antenna in the mobile RFID reader is used to judge the circular sectors of objects according to the received signal strengths in each direction. Third, four picking strategies are proposed to decide whether an object is picked in current step or later step. Finally, the simulated annealing algorithm is performed for all objects in the list of current step to generate the picking sequence with shortest distance.

2 Methodology

2.1 Objects Tracking in Two Stages

In the first stage, a user takes a mobile RFID reader to scan objects when he/she moves to a desired position (called detecting point). The received signal strength (RSS) in the reader is used to determine the distance between the mobile reader and the object. That is, the annual region at which an object locates can be

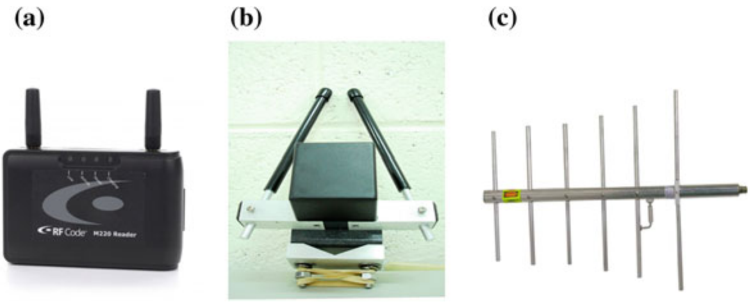


Fig. 1 **a** The mobile RFID reader. **b** Omni antenna. **c** Yagi antenna

determined. In the second stage, the direction (circular sector) of the object can be determined if the signal is received from the direction. By matching both annual region and circular sector, object position can be estimated. To achieve the above goal, this research adopts the mobile reader having two channels. Each channel connects to different antennas having different reading ranges and functions. Omni antenna is used in the first stage to scan objects, while Yagi Antenna is used to point out object direction in the second stage. Figure 1 visually shows the mobile RFID reader, Omni antenna, and Yagi antenna used in this study.

2.2 Object Picking

After finishing the first and second stage, a user will know which sub-area that an object is in. However, the precise position of the target object in the sub-area is not clear unless the user moves to the sub-area and takes a look. Therefore, this research suggests the user move to the center of the sub-area first, then moves along the arc of the sub-area to see where the target object is. If the object is found, then he/she will pick the object. Figure 2 shows a user moves toward left first (route 1). If the user could find the target object, he/she will pick the object and go to the next target object sub-region; otherwise, the user moves back the central point and search objects in the reversed direction (route 2).

2.3 Searching Route

As mentioned in Sect. 2.1, a user moves a fixed distance to detecting point then scan whether there is object in the current reading range. Since the exact location of an object is unknown, this research adopts the creeping line search style with S route to find objects as shown in Fig. 3. Starting from the initial position, a user

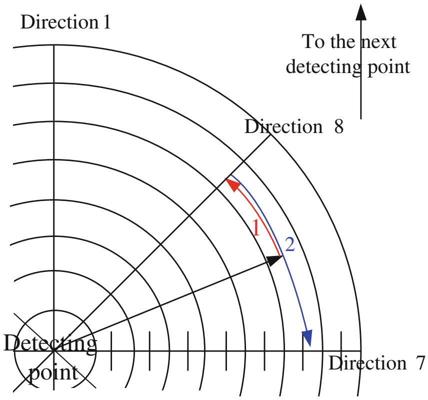


Fig. 2 Object picking in the sub-area

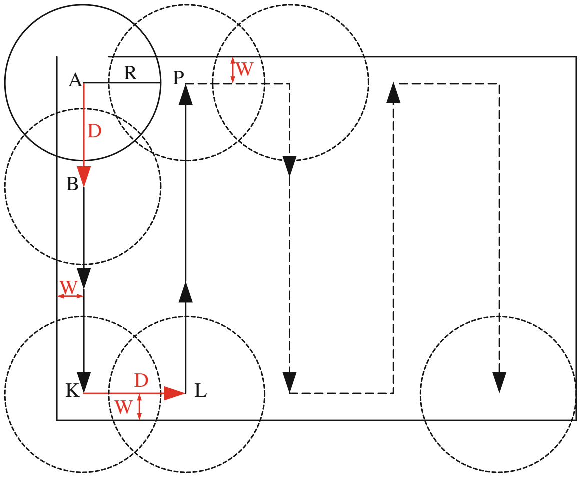


Fig. 3 Searching objects with S route

moves a fixed distance D each time and operates the mobile reader for object detection in the detecting position. It is clear that there is overlapped scanning area in two neighboring search points so that no area will be missed.

2.4 Path Planning

After generating the pick list, the system will arrange the picking order. Starting from detecting point A, a user picks all objects in the list, and then move to detecting point B. However, in each detecting point, the system will generate a shortest-path. Some assumptions are made to have the shortest path planning: (1) Moving path between target objects is without directionality, in other words, is a symmetric TSP problem. (2) All objects could be picked directly (Complete Graph). (3) The sub-area center is known in advance. (4) Each object can be picked only once. (5) N objects been picked from A to B is known. To solve the above problem, this research uses the simulated annealing (SA) algorithm to obtain the shortest path.

3 Case Study

The multiple objects searching method is programed using Microsoft Visual Studio 2005. The simulation program will derive the quantity and coordination of detecting points if the size of searching area is provided. In each detecting point, the program will determine how many objects should be picked by four strategies. Under the same strategy, simulated annealing algorithm will calculate the optimal picking path. Figure 4 shows the interface of the developed multiple objects searching program.

For example, the largest read range for a reader is 80 m in which each power level of the reader is 10 m. The searching area is 540*540 m^2. A user starts to search objects at (50, 0). Figure 5 shows the user moving path. The red block expresses the detecting point, and the black route means the path the user will follow. The start point of this route is from (50, 50), pass through (50, 160), and to (50, 270).

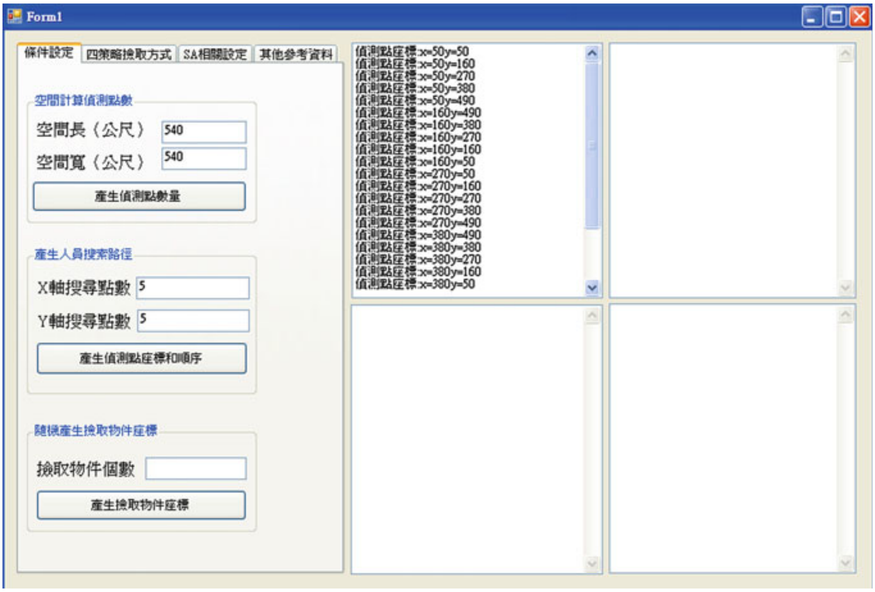


Fig. 4 User interface of the system

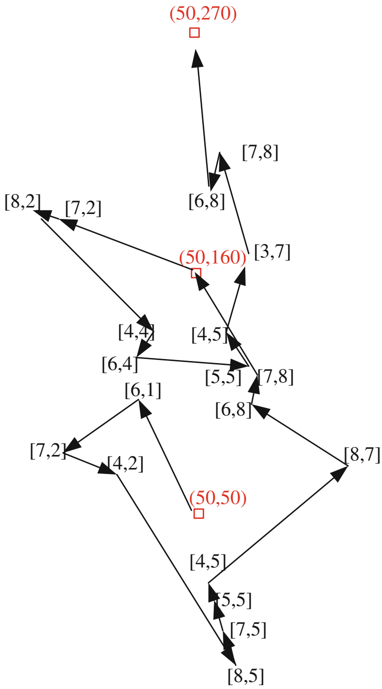


Fig. 5 The picking path example

4 Conclusions

To reduce the searching space and time for finding objects, this research proposes a multiple objects search method. Each object is embedded with an active RFID tag. A user holds the mobile RFID reader installed with Omni antenna and Yagi antenna to detect objects. According to two-stage approach, a user can know which sub-area an object is. The final pick route will be determined by the simulated annealing method. Currently, only squared area is considered. It will be worthwhile to develop a searching method for any kind of shape. In addition, no obstacle is considered in current method. However, obstacles might prevent user's movement. It is suggested that future works can include obstacle consideration.

Acknowledgments This work was partially supported by the National Science Council of Taiwan No. NSC98-2221-E-155-16.

References

Bekkali A, Sanson H, Matsumoto M (2007) RFID indoor positioning based on probabilistic RFID map and Kalman filtering. Paper presented at the 3rd IEEE international conference on wireless and mobile computing, networking and communications, pp 21–21

Lionel MN, Liu Y, Lau YC, Patil AP (2004) LANDMARC: indoor location sensing using active RFID. Wirel Netw 10:701–710

Shih ST, Hsieh K, Chen PY (2006) An improvement approach of indoor location sensing using active RFID. Paper presented at the first international conference on innovative computing, information and control, pp 453–456

Song J, Haas CT, Caldas CH (2007) A proximity-based method for locating RFID tagged objects. Adv Eng Inform 21:367–376

Zhao Y, Liu Y, Ni LM (2007) VIRE: Active RFID-based localization using virtual reference elimination. Paper presented at the international conference on parallel processing, p 56

A New Bounded Intensity Function for Repairable Systems

Fu-Kwun Wang and Yi-Chen Lu

Abstract Lifetime failure data might have a bathtub-shaped failure rate. In this study, we propose a new model based on a mixture of bounded Burr XII distribution and bounded intensity process, to describe a failure process including a decreasing intensity phase, an increasing phase, and an accommodation phase for repairable systems. The estimates of the model parameters are easily obtained using the maximum likelihood estimation method. Through numerical example, the results show that our proposed model outperforms other existing models, such as superposed power law process, Log-linear process-power law process, and bounded bathtub intensity process with regard to mean square errors.

Keywords Bathtub-shaped failure rate · Bounded intensity function · Maximum likelihood estimation · Repairable system

1 Introduction

In some situations, lifetime failure data might have a bathtub-shaped failure rate. These models can be categorized into three types to describe the bathtub-shaped intensity function: a single model (Crevecoeur 1993; Xie et al. 2002; Lai et al. 2003; Liu and Wang 2013), mixture models (Lee 1980; Pulcini 2001a, b; Guida and Pulcini 2009), and a mixture of two distributions (Jiang and Murthy 1998; Block et al. 2008, 2010).

F.-K. Wang (✉) · Y.-C. Lu
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei 106, Taiwan, Republic of China
e-mail: fukwun@mail.ntust.edu.tw

Y.-C. Lu
e-mail: D10101009@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_14,

In our literature review, some mixture models propose to describe the bathtub-shaped intensity such as the superposed-power law process (S-PLP) model by Pulcini (2001a, b) and the bounded bathtub intensity process (BBIP) model by Guida and Pulcini (2009). The failure intensity functions of S-PLP model and BBIP model are defined as

$$\lambda(t)_{S-PLP} = \lambda_1(t) + \lambda_2(t) = \frac{\beta_1}{\alpha_1}\left(\frac{t}{\alpha_1}\right)^{\beta_1-1} + \frac{\beta_2}{\alpha_2}\left(\frac{t}{\alpha_2}\right)^{\beta_2-1}, \quad t \geq 0;\ \alpha_1, \beta_1, \alpha_2, \beta_2 > 0, \tag{1}$$

and

$$\lambda(t)_{BBIP} = \lambda_1(t) + \lambda_2(t) = ae^{(\frac{-t}{b})} + \alpha[1 - e^{(\frac{-t}{\beta})}], \quad a, b, \alpha, \beta > 0,\ t \geq 0. \tag{2}$$

However, for the increasing intensity phase when the system age grows, the failure intensity should tend to become constant in wear-out conditions for large system ages, if the repairs were exactly minimal. This result is often known as Drenick's theorem. It can be noted that failure intensity should be bounded and tend to become constant in the failure pattern of deteriorating systems. The S-PLP model cannot be applied to Drenick's theorem and has two drawbacks: $\lambda(t)_{S-PLP} \xrightarrow{t\to 0} \infty$ and $\lambda(t)_{S-PLP} \xrightarrow{t\to\infty} \infty$. Therefore, Guida and Pulcini (2009) proposed the BBIP model to satisfy Drenick's theorem and overcome these two drawbacks. This BBIP model has overcome the drawbacks of $\lambda(t)_{BBIP} \xrightarrow{t\to 0} a$ and $\lambda(t)_{BBIP} \xrightarrow{t\to\infty} \alpha$.

However, Krivtsov (2007) showed that the NHPP's rate of occurrence of failures formally coincides with the intensity function of the underlying lifetime distribution. Therefore, other lifetime distributions (lognormal, normal, Gumbel, a mixture of underlying distributions, etc.) could be chosen for the ROCOF of the respective NHPPs. This finding motivates us to formulate a new mixture model based on the Burr XII distribution in order to describe the bathtub-shaped failure rate.

2 New Model

The proposed bounded model is obtained by combining two independent NHPPs, the first being a bounded intensity process with decreasing intensity function

$$\lambda_1(t) = a + \frac{kct^{c-1}}{1+t^c}, \quad a, c, k > 0,\ t \geq 0, \tag{3}$$

where a is a positive constant and k and c are the shape parameters; the second being a bounded intensity process (Pulcini 2001a, b) with increasing bounded intensity function

$$\lambda_2(t) = \alpha[1 - e^{(\frac{-t}{\beta})}], \quad \alpha,\ \beta > 0,\ t \geq 0. \tag{4}$$

Thus, the intensity function of the proposed model is established as

$$\lambda(t) = \lambda_1(t) + \lambda_2(t) = a + \frac{kct^{c-1}}{1+t^c} + \alpha[1 - e^{(\frac{-t}{\beta})}], \quad a,\ c,\ k,\ \alpha,\ \beta > 0,\ t \geq 0, \tag{5}$$

where the parameters a and $a + \alpha$ are the values of the failure intensity at t = 0 and $t \to \infty$, respectively. The first derivative is equal to α/β at t = 0. The mean cumulative number of failures for the proposed model is given by

$$m(t) = \int_0^t \left(a + \frac{kcu^{c-1}}{1+u^c} + \alpha[1 - e^{(\frac{-u}{\beta})}]\right)\mathrm{d}u = at + k\ln(1+t^c) + \alpha\beta\left(\frac{t}{\beta} - 1 + e^{\frac{-t}{\beta}}\right). \tag{6}$$

3 Parameters Estimation

If the data are time-truncated (say T), then the likelihood function is given as

$$L(a, c, k, \alpha, \beta | t_1, t_2, \ldots, t_n) = \prod_{i=1}^{n} \lambda(t_i) \times e^{-m(T)}. \tag{7}$$

Then, the log-likelihood function is given by

$$\ln L = \sum_{i=1}^{n} \ln\left[a + \frac{kct_i^{c-1}}{1+t_i^c} + \alpha(1 - e^{\frac{-t_i}{\beta}})\right] - [aT + k\ln(1+T^c)] - \alpha\beta\left[\frac{T}{\beta} - 1 + e^{\frac{-T}{\beta}}\right]. \tag{8}$$

The parameter estimates in (8) can be determined by general-purpose optimization function from R Development Core Team (2013).

In testing for a trend with operating time for time-truncated data, the Laplace statistic and the MIL-HDBK-189 statistic are defined as

$$LA = \frac{\sum_{i=1}^{n} t_i - \frac{nT}{2}}{T\sqrt{\frac{n}{12}}} \sim N(0,\ 1), \tag{9}$$

and

$$Z = 2\sum_{i=1}^{n} \ln\left(\frac{T}{t_i}\right) \sim \chi^2(2n). \tag{10}$$

Firstly, we assess the presence or absence of a trend in these data. In this study, we evaluate the Laplace statistic and MIL-HDBK-189 statistic, which are able to provide evidence of a monotonic trend when the null hypothesis is an HPP (Vaurio 1999). From these studies, we can conclude that LA and Z are effective in detecting monotonic trends with efficiency better or roughly equal to many other tests that are mathematically more complex (Kvaloy and Lindqvist 1998).

Glaser (1980) has obtained sufficient conditions to ensure whether a lifetime model has a bathtub failure rate or not. In this study, we use a graphical method based on the total time on test (TTT) transform (Barlow and Campo 1975; Bergman and Klefsjo 1982). It has been shown that the failure rate is increasing (decreasing) if the scaled TTT-transform is concave (convex). In addition, for a distribution with bathtub (unimodal) failure rate, the TTT-transform is initially convex (concave) and then concave (convex) (Aarset 1987).

We evaluate the performance of the model using the mean of squared errors (MSE). The MSE is defined as

$$MSE = \frac{1}{n}\sum_{i=1}^{n}[\hat{m}(t_i) - y_i]^2, \tag{11}$$

where $\hat{m}(t_i)$ is the estimated cumulative number of failures at time t_i obtained from the model and y_i is the total number of failures observed at time t_i according to the actual data. For MSE, the smaller the metric value, the better the model fits.

4 Illustrative Examples

The data concerned the powertrain system of a bus (Guida and Pulcini 2009). We take the travel distance as the time (unit = 1,000 km) to compare the proposed model with the S-PLP, LLP-PLP, and BBIP models; the parameter estimates were

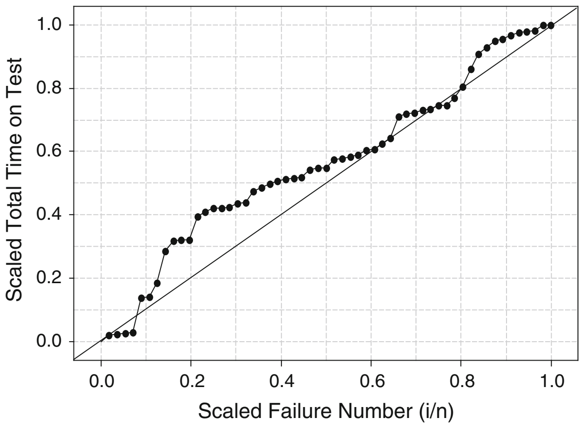


Fig. 1 TTT plot on the 55 observations in Bus 510

Table 1 Comparison of different models for example 1

Model	Estimated parameters	log-likelihood	MSE
S-PLP	$\alpha_1 = 7.32$	−161.639	10.81
	$\beta_1 = 0.6919$		
	$\alpha_2 = 48.62$		
	$\beta_2 = 1.754$		
LLP-PLP	$a = 0.3443$	−160.268	12.93
	$b = 10.0602$		
	$\alpha = 33.3399$		
	$\beta = 1.5962$		
BBIP	$a = 0.3693$	−159.6792	9.10
	$b = 10.1103$		
	$\alpha = 0.2016$		
	$\beta = 150.82$		
Proposed model	$a = 1.54 \times 10^{-17}$	−160.9126	9.01
	$c = 53.57$		
	$k = 0.0174$		
	$\alpha = 0.2045$		
	$\beta = 168.71$		

Note $a = 1.54 \times 10^{-17} \approx 0$

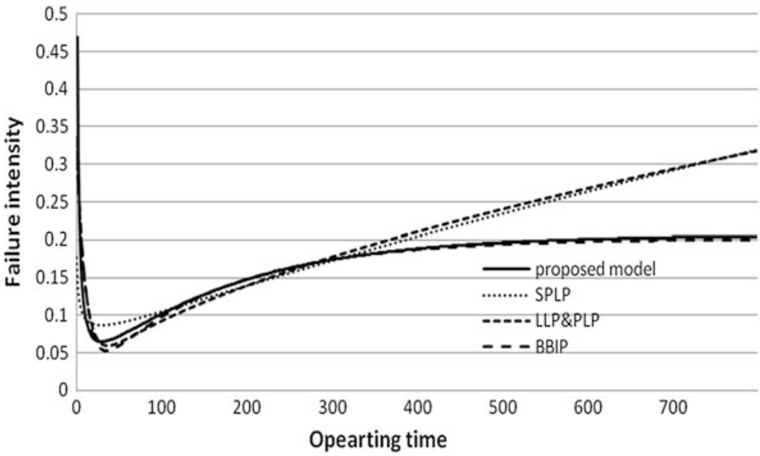


Fig. 2 Plots of $\lambda(t)$ against time t for example 1

obtained using general-purpose optimization function from R Development Core Team (2013).

Example 1: We considered the data that is time-truncated at T = 394.064. The Laplace statistic and the MIL-HDBK-189 statistic for the above data are LA = 1.61 and Z = 90.31, respectively, which provide a result in the trend test. The p-values of Laplace statistic and MIL-HDBK-189 statistic are 0.054 and 0.086, respectively; therefore, we can know the data should be non-monotone. The

TTT plot is shown in Fig. 1. The scaled TTT-transform is initially convex and then concave, which indicates that the data have a bathtub-shaped failure rate characteristic.

The comparative results of our proposed model and the other models (S-PLP, LLP-PLP and BBIP) are shown in Table 1. It appears that our proposed model fits these data better than the other models in MSE. Figure 2 depicts the plots of $\lambda(t)$ against time t for the different models and shows a bathtub-shaped curve during test time. The use of the S-PLP and LLP-PLP models could lead to wrong conclusions in such situations because their failure intensity tends to infinity as t tends to infinity. Thus, it appears that the bounded type model provides a better representation than the no bounded model or partially bounded model for situations of the large system ages.

5 Conclusions

The S-PLP model is one of the mixture models used for the bathtub-shaped failure intensity during the development test phase for a system. However, the intensity function of the S-PLP model does not satisfy Drenick's theorem and has two unrealistic situations for the bathtub-shaped failure intensity case. Recently, Guida and Pulcini (2009) proposed the BBIP model to overcome these two drawbacks. In this study, we have proposed a new mixture model for bathtub-shaped failure intensity. Results obtained from numerical examples show that our proposed model outperforms the other models in terms of MSE for Bus510. We conclude that our proposed model can compete with BBIP in some bathtub-shaped failure intensities for a repairable system.

Acknowledgments The authors are grateful for financial support from the National Science Council in Taiwan under the Grant NSC-101-2221-E011-050-MY3.

References

Aarset MV (1987) How to identity a bathtub hazard rate. IEEE Trans Reliab 36:106–108

Barlow RE, Campo R (1975) Total time on test processes and applications to failure data analysis. Siam, Philadelphia

Bergman B, Klefsjo B (1982) A graphical method applicable to age replacement problems. IEEE Trans Reliab 31:478–481

Block HW, Li Y, Savits TH, Wang J (2008) Continuous mixtures with bathtub-shaped failure rates. J Appl Probab 45:260–270

Block HW, Langberg NA, Savits TH (2010) Continuous mixtures of exponentials and IFR gammas having bathtub-shaped failure rates. J Appl Probab 47:899–907

Crevecoeur GU (1993) A model for the integrity assessment of ageing repairable systems. IEEE Trans Reliab 42:148–155

Glaser RE (1980) Bathtub and related failure rate characterizations. J Am Stat Assoc 75:667–672

Guida M, Pulcini G (2009) Reliability analysis of mechanical systems with bounded and bathtub shaped intensity function. IEEE Trans Reliab 58:432–443
Jiang R, Murthy DNP (1998) Mixture of Weibull distribution—parametric characterization of failure rate function. Appl Stoch Models Data Anal 14:47–65
Krivtsov VV (2007) Practical extensions to NHPP application in repairable system reliability. Reliab Eng Syst Saf 92:560–562
Kvaloy JT, Lindqvist B (1998) TTT-based tests for trend in repairable system data. Reliab Eng Syst Saf 60:13–28
Lai CD, Xie M, Murthy DNP (2003) A modified Weibull distribution. IEEE Trans Reliab 52:33–37
Lee L (1980) Testing adequacy of the Weibull and log linear rate models for a poisson process. Technometrics 22:195–199
Liu J, Wang Y (2013) On Crevecoeur's bathtub-shaped failure rate model. Comput Stat Data Anal 57:645–660
Pulcini G (2001a) Modeling the failure data of repairable equipment with bathtub failure intensity. Reliab Eng Syst Saf 71:209–218
Pulcini G (2001b) A bounded intensity process for the reliability of repairable equipment. J Qual Technol 33:480–492
R Development Core Team (2013) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna
Vaurio JK (1999) Identification of process and distribution characteristics by testing monotonic and non-monotonic trends in failure intensities and hazard rates. Reliab Eng Syst Saf 64:345–357
Xie M, Tang Y, Goh TN (2002) A modified Weibull extension with bathtub-shaped failure rate function. Reliab Eng Syst Saf 76:279–285

Value Creation Through 3PL for Automotive Logistical Excellence

Chin Lin Wen, Schnell Jeng, Danang Kisworo, Paul K. P. Wee and H. M. Wee

Abstract Change is the only constant in today's business environment. Flexibility and adaptability have become key factors of organizational success. In today's global business environment, organizations not only faced with issues of where to source their parts but also how to ship and store these parts effectively and efficiently. This issue is magnified as the complication of the products produced increases. Automotive industry has highly complicated parts which are sourced from around the globe. Through 3PL strategies, an automotive manufacturer can minimize downtime risk, reduce delivery lead time and ultimately improve its ability to adjust to the changing market demand. In this paper, we investigate the logistic factors affecting the automotive industry and discuss the challenges. An actual case study from DB Schenker, a German 3PL company, is used to illustrate the benefits of an effective VMI, information technology and inventory tracking in the supply chain. It can synchronize information and physical flow of goods across the supply chain. DB Schenker uses state-of-the-art storage and order-picking technologies in order to meet the very precise production time schedule, while keeping warehouse costs to a minimum.

Keywords VMI · Logistics · Excellence · Supply chain · Inventory · 3PL

C. L. Wen (✉) · S. Jeng · D. Kisworo · P. K. P. Wee · H. M. Wee
Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chung Li, Taiwan, Republic of China
e-mail: chinlin@cycu.edu.tw

H. M. Wee
e-mail: weehm@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_15,

1 Introduction

At the start of the second automotive century, the global car industry finds itself in a major phase of transition and arguably, in one of its most interesting times. Beyond the days of Henry Ford, high-variety mass production, and the early adoption of lean production concepts, the global car industry currently faces significant uncertainty of how to regain profit-ability, which averages at less than 4 % EBIT (Earning Before Interest and Taxes) at present. The industry is threatened by global production over-capacity and rising stock levels of unsold vehicles. Vehicle manufacturers have attempted to meet future challenges through a series of (often doubtful) global mergers and acquisition, hoping for better economies of scale through platform and component sharing. At the same time, previous core competencies, such as component or module assembly, are being outsourced to large first tier suppliers some of which have already over-taken their vehicle manufacturer customers in terms of turnover and size. Further uncertainty stems from the European End-of-Life-of-Vehicle legislation, requiring manufacturers to recycle 95 % of the total vehicle by 2015. If implemented in its current form, this will make this reverse flow of parts and materials an integral part of the supply chain.

2 Related Literature

2.1 Third Party Logistic

A third-party logistics provider (abbreviated 3PL, or sometimes TPL) is a firm that provides service to its customers of outsourced (or "third party") logistics services for part, or all of their supply chain management functions. Third party logistics providers typically specialize in integrated operation, warehousing and transportation services that can be scaled and customized to customers' needs based on market conditions and the demands and delivery service requirements for their products and materials. Often, these services go beyond logistics and included value-added services related to the production or procurement of goods, i.e., services that integrate parts of the supply chain. Then the provider is called third-party supply chain management provider (3PSCM) or supply chain management service provider (SCMSP). Third Party Logistics System is a process which targets a particular Function in the management. It may be like warehousing, transportation, raw material provider, etc.

3PL logistics service advantages e.g., provide quality delivery on services for the local retail market. Has multiple routes, parcels cover districts. All employees must receive on-the-job training to ensure the quality of logistics services. Has a customer hotline, with the delivery of purchase to meet customers needs for logistics.

LSPs provide for their customers traditional logistics services such as transportation and warehousing, and supplementary services such as order administration and track-and-trace services suppliers and customers in supply chains (Hertz and Alfredsson 2003). They handle larger shares of their customers' activities and are therefore significant actors in supply chains.

The pursuit of improved efficiency performance in logistics operations is a constant business challenge (Tezuka 2011). One initiative that is proving productive and allows businesses to concentrate on their core competencies is the outsourcing of the logistics function to partners, known as third-party logistics (3PL) providers. 3PL providers provide an opportunity for businesses to improve customer service, respond to competition and eliminate assets (Handfield and Nichols 1999). Many 3PL providers have broadened their activities to provide a range of services that include warehousing, distribution, freight forwarding and manufacturing.

2.2 Automotive Industry

In the recent years, the automotive industry has shown an increased interest in lead time reduction. Shorter lead times (Erdem et al. 2005) Increase responsiveness to market changes and Reduce pipeline inventory, and Improve customer satisfaction.

The total lead time depends on: the time between receiving an order from the customers or dealers and launching the production of this order, the manufacturing lead time, and the time to ship the final product to customers. With the JIT systems' emphasis on balancing the mixed model assembly lines, especially on reducing the variation of the consumption rate of the parts (Kubiak 1993).

3 Case Study

The case study is developed base on the following questions.

1. How company makes sure that the several tier on suppliers have capable information system to automated messaging when they have shortages of material?
2. How to make all the dealers confidence with 3PL to work together in outbound logistic?

4 Discussion

4.1 Vendor Managed Inventory

The supplier decides on the appropriate inventory levels of each of the products and the appropriate inventory policies to maintain these levels. In most cases, the customers tend to avail themselves of a Third Party Logistics provider to manage their vendor-managed-inventory hub.

Vendor managed inventory (VMI) is a business models in which the buyer of a product (business) provides certain information to a vendor (supply chain) supplier of that product and the supplier takes full responsibility for maintaining an agreed inventory of the material, usually at the buyer's consumption location. A third-party logistics provider can also be involved to make sure that the buyer has the required level of inventory by adjusting the demand and supply gaps (Southard and Swenseth 2008).

As a symbiotic relationship, VMI makes it less likely that a business will unintentionally become out of stock of a good (Cetinkaya 2000) and reduces inventory in the supply chain (Yao et al. 2007). Furthermore, vendor (supplier) representatives in a store benefit the vendor by ensuring the product is properly displayed and store staffs are familiar with the features of the product line, all the while helping to clean and organize their product lines for the store.

One of the keys to making VMI work is shared risk. In some cases, if the inventory does not sell, the vendor (supplier) will repurchase the product from the buyer (retailer). In other cases, the product may be in the possession of the retailer but is not owned by the retailer until the sale takes place, meaning that the retailer simply houses (and assists with the sale of) the product in exchange for a predetermined commission or profit (sometimes referred to as consignment stock). A special form of this commission business is scan-based trading whereas VMI is usually applied but not mandatory to be used.

DB Schenker was one of the first 3PLs to develop VMI and supplier park solutions for the Electronics and Automotive industries. DB Schenker apply the latest techniques and systems to provide services ranging from material consolidation at origin, order management, inbound transportation, line-side feeding, order sequencing, quality assurance, kitting and pre-production preparation or un-packaging/packaging services in addition to a range of tailored solutions to support your production.

4.2 Information Technology

Strong information technology systems are increasingly a core competence to ensure competitiveness. Bar Code and Pick by Voice are valuable technologies for tracking inventory in the supply chain. It can synchronize information and physical flow of goods across the supply chain.

A barcode is an optical machine-readable representation of data relating to the object that contains information (as identification) about the object it labels. Originally, barcodes systematically represented data by varying the widths and spacing of parallel lines and sometimes numerals that is designed to be scanned and read into computer memory. Voice-directed warehousing (VDW) refers to the use of the speech recognition and speech synthesis software to allow workers to communicate with the Warehouse Management System in warehouses and distribution centers.

One of the great productivity benefits of voice-based systems is that they allow operators to do two things at once whereas other media used in warehouses such as paper or radio frequency terminals tend to require that you surrender the use of at least one hand or you have to stop and read something before proceeding. This productivity benefit tends to be inversely related to the fraction of an operator's day spent walking. Information technology is a vital element for providing professional and reliable forwarding and logistics services around the world. DB Schenker is capable of efficient electronic interchange of all relevant shipping information, lead times, performance indicators, etc. Unified worldwide information and communication systems are the backbone to handle shipments not only physically, but also informational to the satisfaction of the clientele. Sophisticated methods such as SWORD, EDI, tracking incl. electronic proofs of delivery (ePOD), barcoding /scanning and mobile communications ensure efficient processes and smooth flow of information between DB Schenker, the local subsidiaries and branches and not least the customers.

5 Conclusion

The thrust of any 3PL-generated VMI program is the reduction of inventory while maintaining customer service and production leveled. The economy continues to put pressure on many industries and the automotive industry is no exception. One of the key supply chain issues facing automakers today involves long order-to-delivery lead times and unreliable production schedules that lead to excess inventory throughout the value chain. Providing a sophisticated production supply to the plant, 3PL has had a significant role to play in the automotive manufacturer's new record. Main recipes for success are the Just-in-Time and Just-in-Sequence strategies, KANBAN, VMI hub, warehouse management system and Value Added Services. JIT has served as a very effective method in the automotive industry for managing functions such as production, purchasing, inventory control, warehousing and transportation. It's potential benefits are limitless. Sustainability is becoming an increasingly important criterion for automotive logistics. 3PLs have to be adaptable and be able to offer solutions at early stages. JIT II is an extension of the vendor managed inventory concept. This could be further discussed in the future on how a 3PL could contribute its solution to this concept.

References

Cetinkaya S, Lee C-Y (2000) Stock replenishment and shipment scheduling for vendor-managed inventory systems. Manage Sci 46:217–232

Erdem E, Reha U, Paul VP, George B, Subramanian K, Jeffrey DT (2005) Outbound supply chain network design with mode selection, lead times and capacitated vehicle distribution centers. Eur J Oper Res 165:182–206

Handfield RB, Nichols EL Jr (1999) Introduction to supply chain management. Prentice Hall, Upper Saddle River

Hertz S, Alfredsson M (2003) Strategic development of third party logistics providers. Ind Mark Manage 32:139–149

Kubiak W (1993) Minimizing variation of production rates in just-in-time system: a survey. Eur J Oper Res 66:259–271

Southard PB, Swenseth SR (2008) Evaluating vendor-managed inventory (VMI) in non-traditional environments using simulations. Int J Prod Econ 116:275–287

Tezuka K (2011) Rationale for utilizing 3PL in supply chain management: a shippers' economic perspective. IATSS Res 35(1):24–29

Yao Y, Evers PT, Dresner ME (2007) Supply chain integration in vendor-managed inventory. Decis Support Syst 43:663–674

Dynamics of Food and Beverage Subsector Industry in East Java Province: The Effect of Investment on Total Labor Absorption

Putri Amelia, Budisantoso Wirjodirdjo and Niniet Indah Arvitrida

Abstract Gross Regional Domestic Product (GRDP) gives an overview of economic development performance in over time. The GRDP value in East Java province is increasing in every year, but this value cannot reduce unemployment rate. The existing of economic development condition is not able to absorb the large number of unemployment where the number of work force is also increasing in the period of time. These phenomena will influence social and economic problems in a region. Investment is one of ways that could be used in order to increase the field of business and reduce the unemployment rate. In this paper, describes the industrial development in food and beverage industries subsector in East Java. By using system dynamic approach, it will construct the change of business investment related to labor absorption in East Java which is affected by economic and climate change of industrial business factors. This research will consider several policy scenarios that have been taken by government such as changes in the proportion of infrastructure funds, the proportion of aid investment by government and licensing index. This scenario could reach the main objective of the system.

Keywords Food and beverage subsector industry · Investment · Labor force · System dynamic

P. Amelia (✉) · B. Wirjodirdjo · N. I. Arvitrida
Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember Surabaya, Surabaya, Indonesia
e-mail: putri.amelia.ie@gmail.com

B. Wirjodirdjo
e-mail: wirjodirdjo@gmail.com

N. I. Arvitrida
e-mail: arvietrida@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_16,

1 Introduction

Economic growth is one of indicators to see development results that has been done. It defines as the increasing value of goods and services that produced by every sector of the economy in a region. Many ways have been done by the local government in order to develop economy in a region. One of the ways that taken by government is making local government law number 22 of 1999 about regional autonomy and law number 32 and 33 of 2004 about fiscal balancing between central and local government. Then, economic growth in each region especially in each province in Indonesia will be more optimal.

The GRDP value in each region will give an overview of economic development performance in every year. Base on Central Bureau of Statistics in Indonesia shows five major islands in Indonesia which has the highest GRDP value is Java Island. On this island, the highest GRDP value is DKI Jakarta province which has Rp 862,158,910,750,000, and then the next highest province is an East Java province Rp 778,455,772,460,000.

The GRDP value in each region will give the overview of economic development performance in every year which consist agriculture, mining and quarrying, manufacture industry, electricity gas and water supply, construction, trade hotel and restaurant transportation and communication, banking and other financial intermediaries, and services sector. From nine economic sectors, manufacturing industry sector is an important sector from other sector development. The increase output of manufacturing industry will affect the increase number of products in other sectors. Therefore, the manufacturing sector is often regarded as the leading sector from another sector in economic sector (Arsyad 2000).

In the GRDP comparison at current price between DKI Jakarta and East Java province, it is known that manufacturing industry sector is the third-largest contributing sector in economic sector. Moreover, the amount of manufacturing industry GRDP sector in DKI Jakarta province is least than in East Java province. East Java province has a larger industrial area than DKI Jakarta province which is 7.40380 ha. Therefore, East java province has a bigger opportunity to open the industrial business than in the DKI Jakarta province.

The amount of GRDP contribution in current market still cannot absorb the large number of unemployment in East Java province. In fact, economic development has not been able to create the increase of job opportunities faster than the labor force. Based on Table 1 it showed that unemployed people in East Java have not absorbed fully in every sector in the economy sector.

Table 1 East java province labor force in 2005–2009

Period	Labor force	Employed	Unemployed
2009	20338568	19305056	1033512
2008	20178590	18882277	1296313
2007	20177924	18811421	1366503
2006	19244959	17669660	1575299

Food and beverage industry subsector is part of the manufacturing industry sector which gives the significant contribution in the economic development. In addition, this sector also contributed a great contribution in employment. The manufacturing industry contribution to the economic development in four consecutive years from 2005 to 2008 is 12.4, 14, 14.5, and 15.4 %. The amount of the contribution sector was offset by the labor contribution in East Java province which is 20, 21, 21, and 21 % (BPS 2010a, b). This value gives a larger contribution than economic development contribution. Moreover, food and beverage industry is a kind of labor-intensive industries. Labor-intensive industries are one of the type industries which oriented to the largest labor rather than in the capital industry for purchasing a new technology. If this subsector is continued to be developed, it will get the large labor absorption.

Investment is an attempt that can be done to support the increase of industries tin a region. The increase of investment will influence production capacity in industrial sector. Then, it will also impact the increase of output value in the regional development sectors, economic growth, and the personal real income (Samuelson 1995). Due to the increase of personal real income, it will affect the purchasing of goods and services produced in a region. Moreover, it will influence the living standard and community prosperity in a region (Yasin et al. 2002). Eventually, the huge number of demand can encourage the number of investment projects in an area.

Investment activities, investors always have many considerations in investment decisions. One of the factors is investment climate. The Circumstances of investment climate depends on the potential and the economic crisis (Sarwedi 2005). Based on the existing data on the Regional Autonomy Committee (2008), East Java province has a rating of 6 from 33 provinces in Indonesia in case of investment climate index. Based on these data it can be seen that the province of East Java province is still not capable of being a top choice in making investments. Although, there are various regulations and policies that are made by central and local governments in order to increase investment attractiveness such as infrastructure policies, regulations regarding business licensing, tax and others.

In short, in order to increase the investment, it is needed the favorable investment climate. The right of investment climate will trigger the increment of investment industry. Then it will also affect the number of labor absorption and reduce the unemployed. In fact the investment climate in the region is always changing according to the state economy, and other factors that influence it. As a result, it will impact the uncertainty and dynamics of the industrial investment and also change the unemployed people in a region. Therefore, in this research will be discussed about the influence food and beverage industry sub-sectors investment to the labor absorption in East Java by using systems dynamic approach. This method could describe climate change investment due to changes in business and economic factors in East Java. Simulation model will also be considered the regulations and current policies that have been made by central government or local government. Then, in order to know the hole of the system, it can be known the main variable main variables that can affect the amount of the food and beverage industry investment. Finally, it can be known the right policy that can be conduct to the system through the alternative policy scenario.

2 Conceptual Model of System Dynamic

Conceptualization model begins with identifying variables that interact and influence in the system. Identification variables are given by knowing the characteristics and behavior of the investment system in food and beverage industry. Variables that exist in the study were obtained from the literature, brainstorming, and government ministry such as the Department of Trade and Industry, Investment Coordinating Board and Central Bureau of Statistics.

Moreover, the indentified variable has been done in order to analyze the cause and effect relationship between variable in system. In Fig. 1, it will provide a general overview of the system. There are 2 kind of loop which is negative and positive loop. Positive loop was illustrated by the red line flow, and the negative loop was illustrated by the blue line flow. One example of a positive causal loop consists "investment-production-infrastructure availability-energy cost-input-value added" variable (Fig. 1). Then, One example of a negative causal loop consists "investment-other cost-input-value added" variable (Fig. 1).

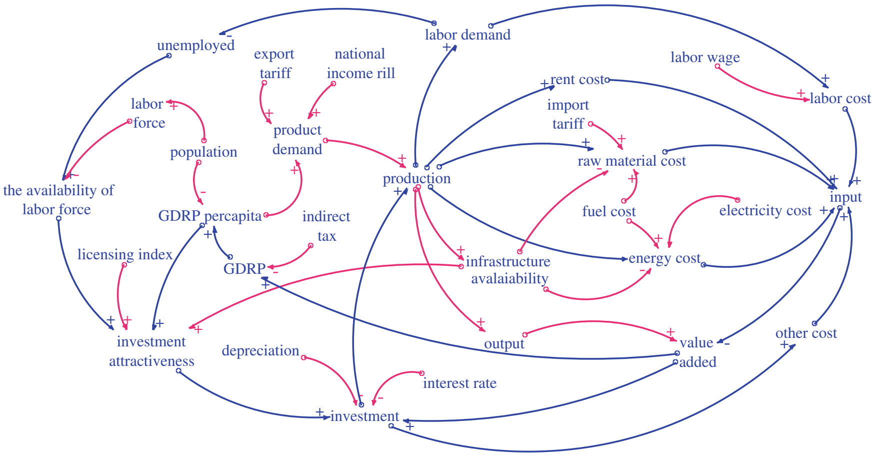


Fig. 1 Causal loop diagram

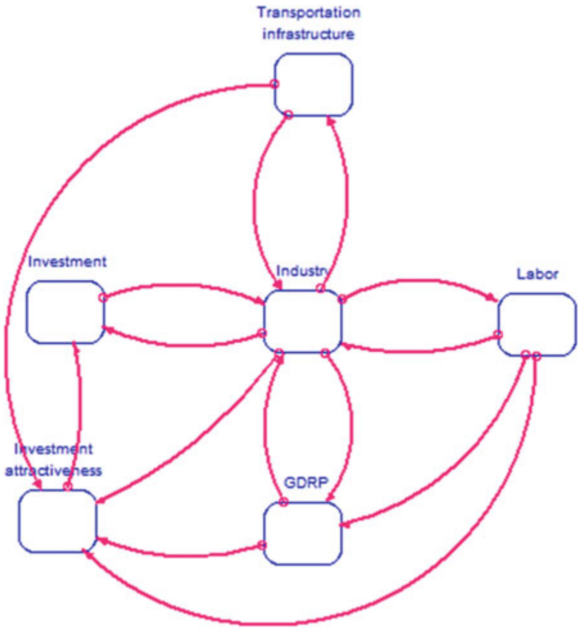
3 System Dynamic Simulation

In the food and beverage industry system, there are 6 main modules which consists investment module, industry module, labor module, GRDP module, transportation infrastructure module, and investment attractiveness module (Fig. 2). Moreover, 6 main modules will interact with each other. In each main module contains many variables which are interacting with other variables. In this system, the period of simulation will run from 2006 to 2025. The long period of the system is based on the long term development plan targets by East Java government (Fig. 3).

4 Verification and Validation

Verification model aims to examine the error and ensure the model that is built according to logic research problem. Verification is done by checking formulations (equations) and checking unit variables. Otherwise, validation model aims to examine that the model could represent the real system. The validation test consists of structure model test, model parameters test, extreme conditions test, and behavior model test using Barlas method (1996).

Fig. 2 Main module



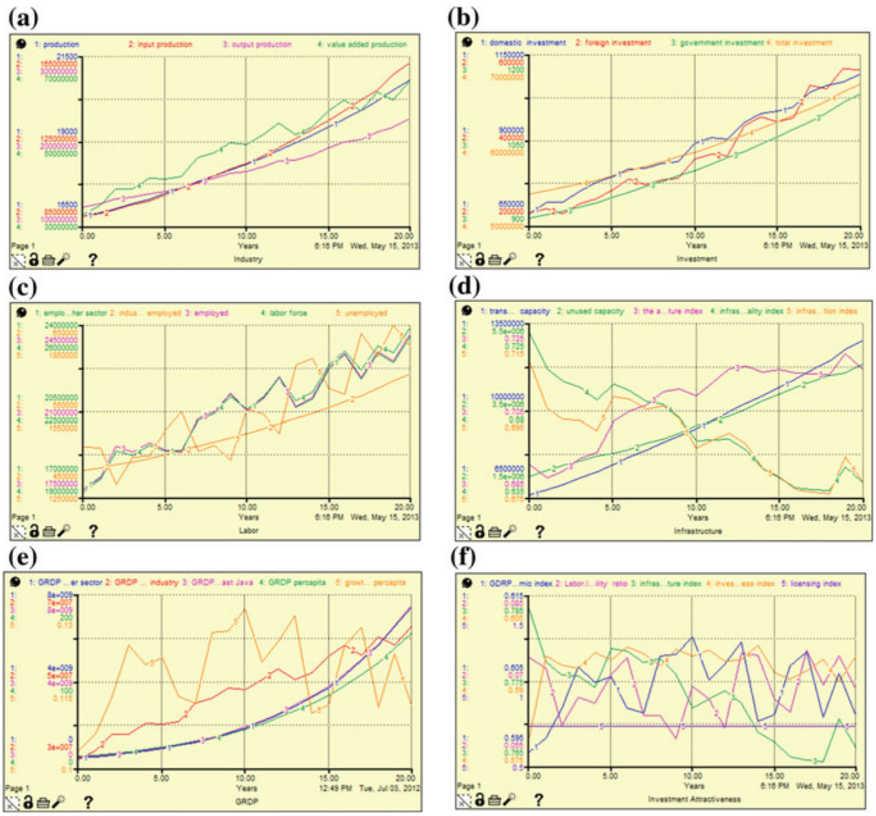


Fig. 3 Simulation model. **a** Industry sub module, **b** Investment sub module, **c** Labor sub module, **d** Transportation infrastructure sub module, **e** GRDP sub module, **f** Investment attractiveness sub module

5 Policies Scenario

Improvements scenario are done to increase food and beverage industrial investment and reduce the unemployment. In each scenario, it considers 2 scenarios which increases and decreases the value of decision variables.

5.1 Scenario 1: Changes in Infrastructure Funds

The value of infrastructure fund variable will give a major impact on the infrastructure availability and value added that has been produced by all sector. In this scenario will conduct two scenarios which increase the value to be 0.15 in the first scenario, and decrease the value to be 0.05 in the second scenario (Table 2).

Table 2 Scenario 1: changes in infrastructure funds

Control variable	Lower limit	Upper limit	Existing	Scenario 1	Scenario 2
Infrastructure	0	1	0.1	0.15	0.05

Table 3 Scenario 2: changes in investment assistance fund

Control variable	Lower limit	Upper limit	Existing	Scenario 1	Scenario 2
Infrastructure proportion	0	1	0.000017	0.000034	0.000005

Table 4 Scenario 3: changes in regional licensing index

Control variable	Lower limit	Upper limit	Existing	Scenario 1	Scenario 2
Licensing index	0	1	0.73	0.83	0.5

Based on the simulation results is known that the growth rate of food and beverage industrial investment scenario 1 is increasing 0.08 %. Otherwise, the growth rate of food and beverage industrial investment scenario 1 is decreasing 0.02 %. In the terms of workforce, it is known that the unemployment rate on average each year in the first scenario has decreased 0.01 % and it will increase 0.01 in the second scenario.

5.2 Scenario 2: Changes in Investment Assistance Fund

In every year, the government has provided investment funds especially on small business loans. On this scenario will be changes in the proportion of investment funds that provided by the local government. Based on the simulation results, it is known that the growth rate of food and beverage industrial investment in scenario 1 is increasing 0.001 %. Then the growth rate of food and beverage industrial investment in scenario 2 is decreasing 0.0009 %. In the terms of workforce, it is known that the unemployment rate in the first scenario decreased 0.0004 %, and then the value in the second scenario increased 0.0002 % (Table 3).

5.3 Scenario 3: Changes in Regional Licensing Index

In this system, licensing has a role to increase the investment attractiveness in a region. Based on the simulation results, it known that growth rate investment in scenario 1 increased 0.02 %, and in scenario 2 decreased 1.4 %. In the terms of workforce, it is known that the unemployment rate in the first scenario decreased 0.004 %, then an increase in the second scenario of 0.01 % (Table 4).

6 Conclusions and Research Recommendations

The development food and beverage industry depends on the amount of investment in this subsector. The amount of investment depends on opportunities for foreign and domestic investment. In order to know the right policy that related to investment. In this research, there are three scenarios which consists changes in the proportion of infrastructure funds, changes in investment assistance fund and changes in the investment index. Based on a scenario, it showed that the most influential to increase investment and labor absorption is first scenario which is increasing proportion of infrastructure funds.

Recommendation for future research can focus in the special industrial scale such as large and medium industries or micro and small industries. In addition, the future research can conduct about other sectors that can give the most effect to food and beverage industry sectors such as trade and transport sectors.

Acknowledgments This research is supported by the Department of Trade and Industry in East Java province and East Java Investment Coordinating Board to Mr. Arya as Department Industry in East Java province and Mrs. Desi as staff East java Investment Coordinating Board for their supports of domain knowledge and data collection.

References

Arsyad L (2000) Ekonomi Pembangunan. Sekolah Tinggi Ilmu Ekonomi Yayasan keluarga Pahlawan Negara. S. YKPN. Yogyakarta

Barlas Y (1996) Formal aspects of model validity and validation in system dynamics. System Dynamics Review 12:3. Wiley

BPS (2010) Keadaan Angkatan Kerja di Provinsi Jawa Timur 2010. Surabaya, Badan Pusat Statistik Jawa Timur

BPS (2010) Pertumbuhan Ekonomi Jawa Timur Tahun 2010. Surabaya, Badan Pusat Statistik Jawa Timur

Samuelson (1995) Intellectual property rights and the global information economy. J Commun ACM 39:7

Sarwedi (2005) Investasi Asing Langsung di Indonesia dan Faktor yang mempengaruhinya. Jurnal Akuntasi dan Keuaangan 4:17–35

Yasin, Baihagi et al (2002) Pemograman visual 2002. Surabaya

Solving Two-Sided Assembly Line Balancing Problems Using an Integrated Evolution and Swarm Intelligence

Hindriyanto Dwi Purnomo, Hui-Ming Wee and Yugowati Praharsi

Abstract Assembly line balancing problem (ALBP) is an important problem in manufacturing due to its high investment cost. The objective of the assembly line balancing problem is to assign tasks to workstations in order to minimize the assembly cost, fulfill the demand and satisfy the constraints of the assembly process. In this study, a novel optimization method which integrates the evolution and swarm intelligence algorithms is proposed to solve the two-sided assembly line balancing problems. The proposed method mimics the basic soccer player movement where there are two main movements, the *move off* and the *move forward*. In this paper, the *move off* and the *move forward* are designed based on the specific features of two-sided assembly line balancing problems. Prioritize tasks and critical tasks are implemented in the *move off* and *move forward* respectively. The performance of the proposed method is compared to the heuristic and ant colony based method mentioned in the literature.

Keywords Move off · Move forward · Two-sided assembly lines

H. D. Purnomo (✉) · Y. Praharsi
Department of Information Technology, Satya Wacana Christian University,
Salatiga 50711, Indonesia
e-mail: hindriyanto.purnomo@staff.uksw.edu

Y. Praharsi
e-mail: yugowati.praharsi@staff.uksw.edu

H.-M. Wee
Department of Industrial and System Engineering, Chung Yuan Christian University,
32023 Chungli, Taiwan, Republic of China
e-mail: weehm@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_17,

1 Introduction

Assembly line balancing problem (ALBP) is an important problem in manufacturing due to the higher investment cost; it comprises all the decisions and tasks including the system capacity (Boysen et al. 2007). An assembly line is a sequential workstation that is connected by material handling system (Askin and Standridge 1993). Based on the task orientation, ALBP is commonly classified into one-sided assembly line and two-sided assembly line. One-sided assembly line balancing problems (OALBP) is the most widely studied assembly line balancing problem (Lee et al. 2001) while little attention has been given for the two-sided assembly line balancing problems (TALBP). However, TALBPs are very important for large-sized products such as buses and truck (Kim et al. 2000, 2009).

The objective of the assembly line balancing problems is to assign tasks to workstations in order to minimize the assembly cost, fulfill the demand and satisfy the constraints of the assembly process. The ALBP is an NP-hard combinatorial problem (Gutjahr and Nemhauser 1964). Therefore, heuristic and meta-heuristic methods are commonly used to solve these problems; they are: genetic algorithm (Kim et al. 2000, 2009), ant colony optimization (Simaria and Vilarinho 2009), simulated annealing (Özcan 2010), particle swarm optimization (Nearchou 2011), and bee colony optimization (Özbakır and Tapkan 2011).

In this paper, we proposed a new method that combines the basic concept of evolution algorithm and swarm intelligence algorithm to solve two-sided assembly line balancing problem. The method mimics the soccer player movements in deciding their position based on the ball and other player's position. The rest of the paper is organized as follows. Section 2 describes the TALBP model. Section 3 explains the proposed method. Section 4 explains the implementation of the proposed method in TALBP. Section 5 presents the experiment and discusses the results. Conclusion and future directions are presented in Sect. 6.

2 Two-sided Assembly Line Balancing Problem

The two-sided assembly lines consist of workstations that are located in each side of the line, the left side and the right side. A mated workstation performs different task simultaneously on the same individual product. The tasks directions are classified into: left (L), right (R) and either (E). The consideration of the assembly direction may result in idle time (Özcan 2010) or interference (Simaria and Vilarinho 2009).

The primary objective of the TALBP is minimizing the number of workstations for a given cycle time C which is equivalent to reducing the idle time d as much as possible. Assembly lines with a small amount of idle time offer high efficiency. The assembly line efficiency is defined as:

$$WE = \frac{\sum_{i=1}^{n} t_i}{wC}; \quad i \in I \tag{1}$$

Besides decreasing the idle time, the tasks should be distributed as equally as possible to balance the workload of the workstations. The average idle time in a workstation is given by:

$$\bar{\mathrm{d}} = \frac{wC - \sum_{i=1}^{n} t_i}{w} \tag{2}$$

Then, the workload balance between workstations is formulated as:

$$WB = \frac{\sqrt{\sum_{k=1}^{w} \left(C - \sum_{i=1}^{n} x_{ik} t_i - \bar{\mathrm{d}}\right)^2}}{wC} \tag{3}$$

Equation 1 is a maximization function while Eq. 3 is a minimization function. The objective of the proposed TALBP model is defined as:

$$Maximize\ F = \alpha WE - \beta WB \tag{4}$$

where α and β are the weight for work efficiency and workload balance respectively.

3 The Proposed Method

P(*X*) = *P*₀; *S*(*X*) = *S*₀; /* *Initialize players and substitute players*
B = *best* (*P*(*X*)) /* *Initialize ball dribbler*
$P_b(X) = P(X)$ /* *initialize player's best position*
While *termination criteria not met*

 For *i = 1: p*

  If *random* ≤ *m*

   $X_t^i = move\_off(X_{t-1}^i)$
   If *random* ≤ *l*
    $X_t^i = move\_forward(X_t^i, X_b^i, B)$
   Endif
  Else

   $X_t^i = move\_forward(X_{t-1}^i, X_b^i, B)$
  Endif
 Endfor
 Update_ball_dribbler(*P*, *B*)
 If *random* < *k*

Subs (*P*, *S*)
Endif
Update_ player_best_position(*P*, P_b)
Update_subs_player_knowledge(*P*, *S*)
Endwhile

4 Implementation of the Proposed Method for TALBP

4.1 Initialization

In this paper, we adopt the COMSOAL heuristic method proposed by Arcus (1966) to encode the problems into the proposed method. In assigning tasks into a workstation, a modification of '*assignable task*' by Gamberini et al. (2006) is implemented as '*prioritize tasks*'. In a prioritize task, its predecessor tasks have been assigned and its processing time is shorter than the remaining workstation available time. Prioritize tasks can minimize the chance of creating long idle time due to opening new workstation.

The procedure for the initialization is as follow:

Step 1 Open the first mated-workstation. The left side workstation $w_l = 1$ while the right workstation $w_r = 2$. List all unassigned tasks *UT*
Step 2 From *UT*, list all prioritize tasks (*PT*). If $PT = \emptyset$, then set *PT* as list of tasks in which their predecessor have been assigned
Step 3 Select a task from *PT* based on the selection rules
Step 4 If the selected task has specific operations direction; put the task in the appropriate side. If the finish time of the task is less than the cycle time *C*, put the task in the current workstation, otherwise open new workstation based on the task specific operations direction. If the selected task can be placed in either side, select the side in which it completes early. If both sides have the same finish time, then select the side randomly
Step 5 Remove the selected task for *UT*
Step 6 If all tasks have been assigned, then stop, otherwise, go to step 2

In step 3, five selection rules are used by the same probability. (1) MAX-RPW that selects a task having the maximum Ranked Positional Weight (RPW). (2) MAX-TFOL that select a task having the maximum total successors. (3) MAX-FOL that selects a task having the maximum number of direct successors. (4) MAX-DUR that selects a task having the maximum operation time and (5) random selection.

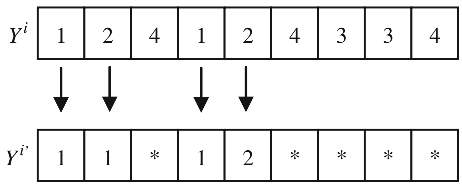


Fig. 1 *Move off* for TALBP

4.2 The Move Off

In this paper, the *move off* is performed by reassigning tasks start from the randomly selected mated-workstations. Assume the selected mated-workstation $r = 1$ (the mated-workstation consist of workstation 1 and 2), then the reassignment process is started from workstation 3. *The move off* procedure is illustrated in Fig. 1.

4.3 The Move Forward

In the *move forward,* the ball position $\boldsymbol{B}$, the current player position $\boldsymbol{Y^i}$ and the player best position $\boldsymbol{Y_b^i}$ are considered to decide the new player position. The *move forward* will transmit the tasks that are assigned in the same workstation in all the three position mentioned above ($\boldsymbol{B}$, $\boldsymbol{Y^i}$ and $\boldsymbol{Y_b^i}$) while the remaining tasks will be reassigned. In reassigning the tasks, '*critical task*' by Kim et al. (2009), is considered. Critical task is such a task in which at least one of its predecessors and one of its successors are assigned in the same pair of workstation. This implies than the critical task must be assigned in the same workstation with its predecessor and successor; therefore, it should be sequenced early.

5 Experimental Results and Discussion

Five benchmark problems, P12, P16, P24, P65, and P148 are used to measure the performance of the proposed method. Problems P12 and P24 can be found in Kim et al. (2000), while P16 is described in Kim et al. (2009). P 65 is formulated by Lee et al. (2001), while P148 is created by Bartholdi (1983). The modification of P148 as in Lee et al. (2001) is used where the processing time of tasks 79 and 108 were changed from 281 to 111 and from 383 to 43. The parameter of the proposed method was set as the following: probability of *move off* $m = 0.5$, probability of *move forward* after the *move off* $l = 0.3$ and the probability of substitution $k = 0.1$.

Table 1 Result for small size problems

Problem	C	LB	MIP	The proposed method		
				Mean	Min	Max
P12	5	5	**6**	**6.0**	6	6
	7	4	**4**	**4.0**	4	4
P16	16	6	**6**	**6.0**	6	6
	22	4	**4**	**4.0**	4	4
P24	18	8	**8**	**8.0**	8	8
	25	6	**6**	**6.0**	6	6

The experiments were run 10 times for each problem. The number of maximum objective function evaluation for P12 was 500, P16 and P24 were 5000, P65 was 10,000, and P148 was 20,000. The number objective function evaluation means the number of objective function being evaluated during the search process (Table 1).

For the small size problems, the proposed method is compared to the Mixed Integer Programming, which is an exact solution method. Columns *C* and *LB* represent the given cycle time and the lower bound respectively. The results of the experiments show that the proposed method achieved the optimal solution for all given problems (Table 2).

For the large size problems, the proposed method is compared to heuristic rules *H* and group assignment *G* proposed by Lee et al. (2001) and the 2-ANTBAL proposed by Simaria and Vilarinho (2009). The experiment results show that the proposed method clearly outperforms the heuristic rules and group assignment procedure as it produces better solution or at least the same, for all problems. When compared to the 2-ANTBAL, the proposed method perform better in

Table 2 Result for large size problems

Problem	C	LB	2-ANTBL (Simaria and Vilarinho 2009)			Lee et al. (2001)		The proposed method		
			Mean	Min	Max	H	G	Mean	Min	Max
P65	326	16	**17.0**	17	17	17.7	17.4	**17.0**	17	17
	381	14	14.8	14	15	15.7	15.0	**14.7**	14	15
	435	12	**13.0**	13	13	14.0	13.4	**13.0**	13	13
	490	11	12.0	12	12	12.1	12.0	**11.2**	11	12
	544	10	10.8	10	11	11.5	10.6	**10.2**	10	11
P148	204	26	**26.0**	26	26	27.8	27.0	**26.0**	26	27
	255	21	**21.0**	21	21	22.0	21.0	**21.0**	21	21
	306	17	18.0	18	18	19.3	18.0	**17.0**	17	18
	357	15	15.4	15	16	16.0	**15.0**	**15.0**	15	15
	408	13	14.0	14	14	14.0	14.0	**13.0**	13	13
	459	12	**12.0**	12	12	12.1	13.0	**12.0**	12	12
	510	11	**11.0**	11	11	12.0	**11.0**	**11.0**	11	11

6 problems, perform the same in 6 problems (mainly because the solutions are already the optimal solutions).

Generally, we can conclude that in term of the number of workstations, the proposed method outperforms the 2-ANTBAL proposed by Simaria and Vilarinho (2009) and both approached methods proposed by Lee et al. (2001).

6 Conclusions

In this study, we develop a new meta-heuristic method based on the integration of evolution algorithm and swarm intelligence algorithm to solve two-sided assembly line balancing problems. In order to obtain a good solution, we proposed a method that mimics the movement behavior of soccer player. It incorporates the information sharing mechanism as well as the evolution operators in its two basic movements, the *move off* and the *move forward*. The movements are used to balance the intensification and diversification.

The basic principle COMSOAL heuristic is adopted in the *move off* and *moves forward*. The prioritize tasks and critical task are implemented in the move off and move forward respectively. The superior performance of the proposed method was illustrated in the experiments results. The proposed method is restricted to simplified model of soccer player movements; therefore, more research is necessary to elaborate and improve the method. For further research, the proposed method can be implemented on mixed model and stochastic assembly lines.

References

Arcus A (1966) COMSOAL: a computer method of sequencing operations for assembly lines. Int J Prod Res 4:259–277

Askin RG, Standridge CR (1993) Modeling and analysis of manufacturing systems. Wiley, Florida

Bartholdi JJ (1983) Balancing two-sided assembly lines: a case study. Int J Prod Res 31:2447–2461

Boysen N, Fliedner M, Scholl A (2007) A classification of assembly line balancing problems. Eur J Oper Res 183(2):674–693

Gamberini R, Grassi A, Rimini B (2006) A new multi-objective heuristic algorithm for solving the stochastic assembly line re-balancing problem. Int J Prod Econ 102:226–243

Gutjahr AL, Nemhauser GL (1964) An algorithm for the line balancing problem. Manage Sci 11(2):308–315

Kim YK, Kim Y, Kim YJ (2000) Two-sided assembly line balancing: a genetic algorithm approach. Prod Plann Control 11:44–53

Kim YK, Song WS, Kim JH (2009) A mathematical model and a genetic algorithm for two-sided assembly line balancing. Comput Oper Res 36(3):853–865

Lee TO, Kim Y, Kim YK (2001) Two-sided assembly line balancing to maximize work relatedness and slackness. Comput Ind Eng 40(3):273–292

Nearchou AC (2011) Maximizing production rate and workload smoothing in assembly lines using particle swarm optimization. Int J Prod Econ 129(2):242–250

Özbakır L, Tapkan P (2011) Bees colony intelligence in zone constrained two-sided assembly line balancing problem. Expert Syst Appl 38(9):11947–11957

Özcan U (2010) (2010) Balancing stochastic two-sided assembly lines: a chance-constrained, piecewise-linear, mixed integer program and a simulated annealing algorithm. Eur J Oper Res 205(1):81–97

Purnomo HD, Wee HM (2012) Soccer game optimization: an innovative integration of evolutionary algorithm and swarm intelligence algorithm. In: Vasant P (eds) Meta-Heuristics optimization algorithms in engineering, business, economics, and finance. IGI Global, Pennsylvania

Simaria AS, Vilarinho PM (2009) 2-ANTBAL: an ant colony optimization algorithm for balancing two-sided assembly lines. Comput Ind Eng 56(2):489–506

Genetic Algorithm Approach for Multi-Objective Optimization of Closed-Loop Supply Chain Network

Li-Chih Wang, Tzu-Li Chen, Yin-Yann Chen, Hsin-Yuan Miao, Sheng-Chieh Lin and Shuo-Tsung Chen

Abstract This paper applies multi-objective genetic algorithm (MOGA) to solve a closed-loop supply chain network design problem with multi-objective sustainable concerns. First of all, a multi-objective mixed integer programming model capturing the tradeoffs between the total cost and the carbon dioxide (CO_2) emission is developed to tackle the multi-stage closed-loop supply chain design problem from both economic and environmental perspectives. The multi-objective optimization problem raised by the model is then solved using MOGA. Finally, some experiments are made to measure the performance.

Keywords Multi-objective · Genetic algorithm · Closed-loop supply chain

---

L.-C. Wang (✉) · S.-C. Lin
Department of Industrial Engineering and Enterprise Information, Tunghai University, Taichung 40704, Taiwan, Republic of China
e-mail: wanglc@thu.edu.tw

T.-L. Chen
Department of Information Management, Fu Jen Catholic University, New Taipei 24205, Taiwan, Republic of China
e-mail: chentzuli@gmail.com

Y.-Y. Chen
Department of Industrial Management, National Formosa University, Yunlin County 632, Taiwan, Republic of China
e-mail: yyc@nfu.edu.tw

H.-Y. Miao
Department of Electrical Engineering, Tunghai University, Taichung 40704, Taiwan, Republic of China

L.-C. Wang · H.-Y. Miao · S.-T. Chen
Tunghai Green Energy Development and Management Institute (TGEI), Tunghai University, Taichung 40704, Taiwan, Republic of China

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_18,

1 Introduction

Recent years, carbon asset became a critical subject to global enterprises. Global enterprises need to provide effective energy-saving and carbon-reduction means to meet the policies of Carbon Right and Carbon Trade (Subramanian et al. 2010). In this scenario, forward and reverse logistics have to be considered simultaneously in the network design of entire supply chain. Moreover, the environmental and economic impacts also need to be adopted and optimized in supply chain design (Gunasekaran et al. 2004; Srivastava 2007). Chaabane et al. (2012) introduce a mixed-integer linear programming based framework for sustainable supply chain design that considers life cycle assessment (LCA) principles in addition to the traditional material balance constraints at each node in the supply chain. The framework is used to evaluate the tradeoffs between economic and environmental objectives under various cost and operating strategies in the aluminum industry.

This paper applies multi-objective genetic algorithm (MOGA) to solve a closed-loop supply chain network design problem with multi-objective sustainable concerns. First of all, a multi-objective mixed integer programming model capturing the tradeoffs between the total cost and the carbon dioxide emission is developed to tackle the multi-stage closed-loop supply chain design problem from both economic and environmental perspectives. Then, the proposed MOGA approach is used to deal with multi-objective and enable the decision maker to evaluate a greater number of alternative solutions. Based on the MOGA approach, the multi-objective optimization problem raised by the model is finally solved.

The remainder of this paper is organized as follows. Section 2 introduces the multi-objectives closed-loop supply chain model and the proposed MOGA. Experiments are conducted to test the performance of our proposed method in Sect. 3. Finally, conclusions are summarized in Sect. 4.

2 Multi-Objective Closed-Loop Supply Chain Design

2.1 Problem Statement and Model Formulation

This section will firstly propose a multi-objectives closed-loop supply chain (MOCLSCD) model to discuss the relationship of forward and reverse logistics, the plant locations of forward and reverse logistics, the capacity of closed-loop logistics, and carbon emission issues. Next, decision makers have to determine the potential location and quantity of production and recycling units in forward and reverse logistics, furthermore, design the capacity and production technology level.

This investigation assumes manufacturers will recycle, reuse, and refurbish the EOL products though the RC process. The EOL product collection includes that product recycling from customers or used product markets. Any EOL products which cannot be used or recycled will leave the supply chain via disposal process.

Thus, a multi-stage and multi-factory closed-loop supply chain structure will be formed as Fig. 1.

Decision makers have to determine the potential location and quantity of recycling units, furthermore, design the capacity based on recycle quantity from customers as shown in Fig. 2a. The production unit capacities may expand or shrink due to uncertain material supply, customer demand, and recycling in Fig. 2b. Reverse logistics and capacity increasing result in more carbon emission in closed-loop supply chain than open-loop supply chain. Effective means such as eco-technologies or lean management are necessary for manufacturers to reduce carbon emission at a lower cost.

Based on the above assumptions and challenges, this paper will discuss the relationship of forward and reverse logistics, the plant locations of reverse logistics, the capacity of closed-loop logistics, and carbon emission issues. The proposed new closed-loop supply chain model is expected to reach the environmental and economical benefit by considering various levels of carbon emission manufacturing process and invested cost. The assumptions used in this model are summarized as follows:

1. The number of customers and suppliers and their demand are known.
2. Second market is unique.
3. The demand of each customer must be satisfied.
4. The flow is only allowed to be transferred between two consecutive stages.
5. The number of facilities that can be opened and their capacities are both limited.
6. The recovery and disposal percentages are given.

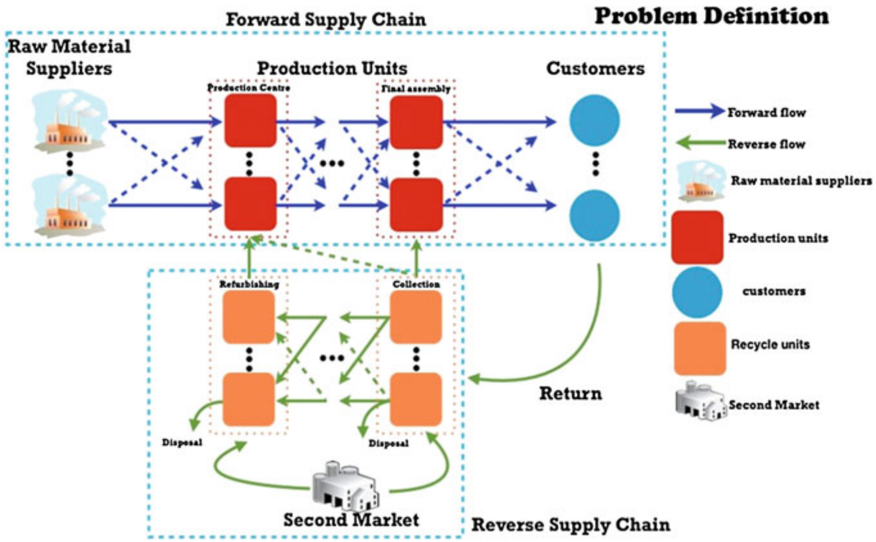


Fig. 1 The structure of sustainable closed-loop supply chain

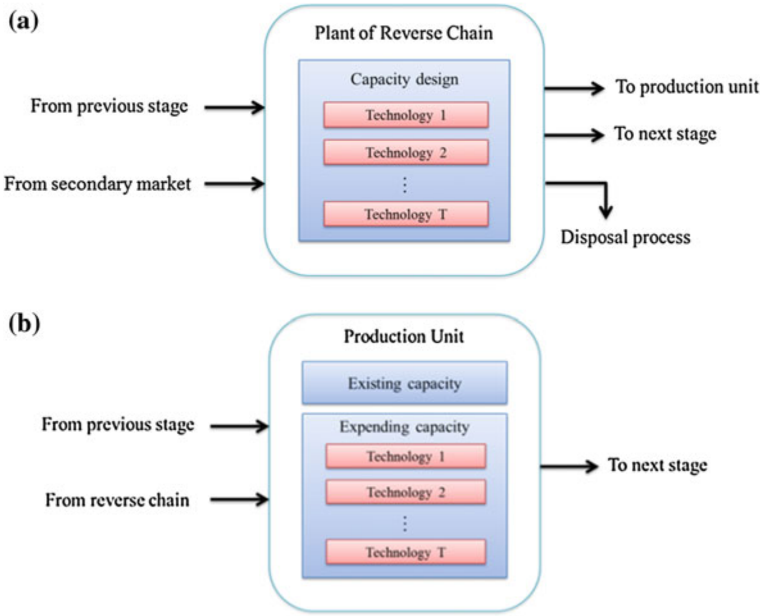


Fig. 2 The characteristics of closed-loop supply chain. **a** Recycling unit in reverse supply chain. **b** Production unit in forward supply chain

Multi-Objective Closed-Loop Supply Chain Design (MOCLSCD) Problem: The purpose of the MOCLSCD model aims to identify the trade-off solutions between the economic and environmental performances under several logistic constraints. The economic objective, $F_1 = PC + BC + MC + CEC + TC + DC$, is measured by the total closed-loop supply chain cost. The environmental objective, $F_2 = PCOE + BCOE + TCOE$, is measured by the total carbon (CO_2) emission in all the closed-loop supply chain.

Economic objective (F_1):

1. Total material purchasing cost (PC)
2. Total installation cost (BC)
3. Total production cost (MC)
4. Total capacity expansion cost (CEC)
5. Total transportation cost (TC)
6. Total disposal cost (DC).

Environmental objective (F_2):

1. Total production carbon emission (PCOE)
2. Total installation carbon emission (BCOE)
3. Total transportation carbon emission (TCOE).

Constraints:

1. Material supply constraints
2. Flow conservation constraints
3. Capacity expansion and limitation constraints
4. Transportation constraints
5. Domain constraints.

2.2 Multi-Objective Genetic Algorithm

In this section, a novel multi-objective genetic algorithm (MOGA) with ideal-point non-dominated sorting is designed to find the optimal solution of the proposed MOCLSCD model. First of all, the proposed ideal-point non-dominated sorting for non-dominated set is as follows.

a. Calculate $\left(F'_1, F'_2\right)_{x_i} = \left(\frac{F_1 - F_1^{\min}}{F_1^{\max} - F_1^{\min}}, \frac{F_2 - F_2^{\min}}{F_2^{\max} - F_2^{\min}}\right)$ and the distance $dist_{x_i} = \sqrt{F_1'^2 + F_2'^2}$ between $\left(F'_1, F'_2\right)_{x_i}$ and zero, where $(F_1, F_2)_{x_i}$ is an element in non-dominated set; $F_1^{\max}$ and $F_2^{\max}$ are the highest values of the first and second objectives among experiments; $F_1^{\min}$ are $F_1^{\min}$ the lowest values of the first and second objectives among experiments.
b. Sort the distances $dist_{x_i}, \forall i$

which leads to the proposed MOGA in the following.

1. Chromosome representation for initial population: The chromosome in our MOGA implementation is divided into three segments namely **Popen**, **Pcapacity**, and **Ptechnology**, according to the structure of the proposed MOCLSCD model. Each segment is generated randomly.
2. Flow assign and fitness evaluation: The flow assign between two stages depends on the values of the two objectives F_1, F_2. Respectively, the flow with minimum values of F_1, F_2 simultaneously will be assigned firstly. On the point of this view, the proposed ideal-point non-dominated sorting is performed again on the priority of flow assign. The fitness values of F_1 and F_2 are then calculated.
3. Crossover operators: Two-Point Crossover is used to create new offsprings of the three segments **Popen**, **Pcapacity**, and **Ptechnology**.
4. Mutation operators: The mutation operator helps to maintain the diversity in the population to prevent premature convergence.
5. Selection/Replacement strategy: The selection method adopts the (μ+λ) method suggested by Horn et al. (1994) and Deb (2001).
6. Stopping criteria: There are two stopping criteria proposed. Due to the time constraints in the real industry, the first stopping criterion of the proposed MOGA approach is the specification of a maximum number of generations. The algorithm will terminate and obtain the near-optimal solutions once the

iteration number reaches the maximum number of generations. In order to search better solutions without time-constraint consideration, the second stopping criterion is the convergence degree of the best solution. While the same best solution has not been improved in a fixed number of generations, the best solution may be convergent and thus the GA algorithm is automatically terminated (Fig. 3).

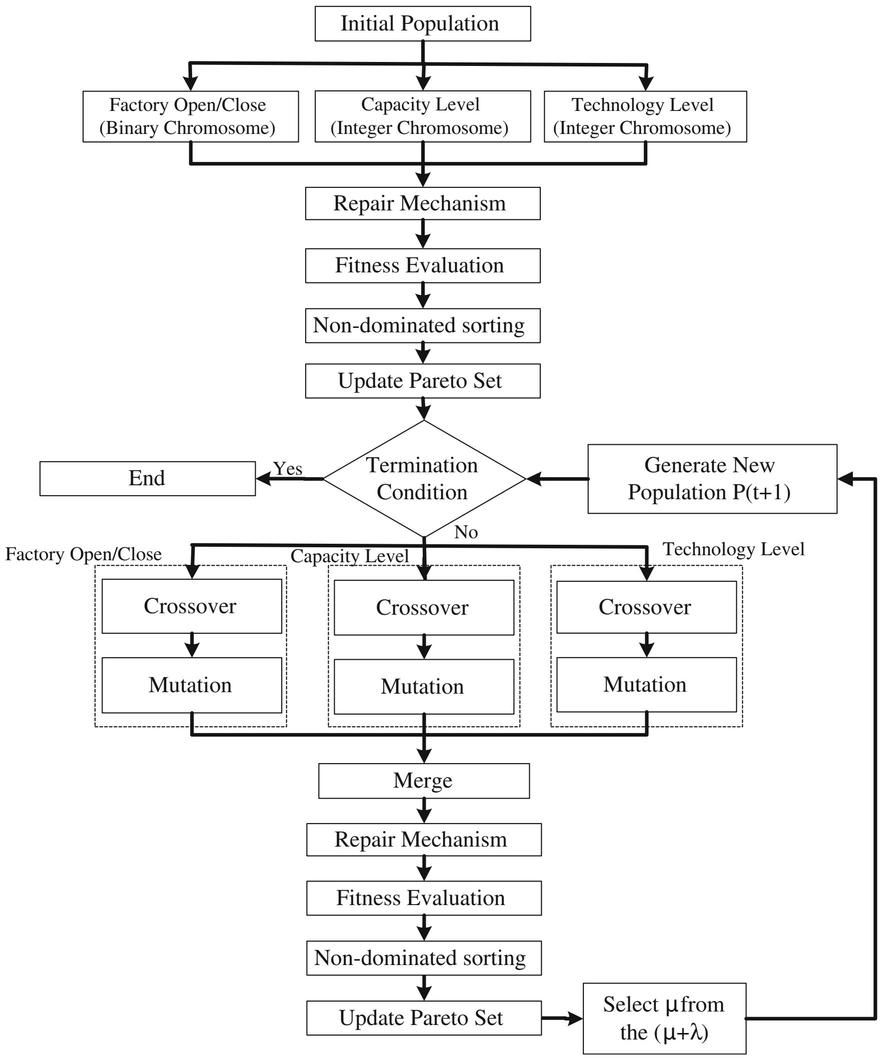


Fig. 3 Flow chart of the proposed multi-objective genetic algorithm (MOGA)

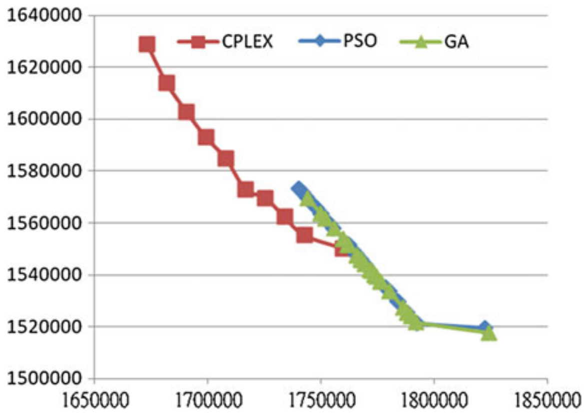


Fig. 4 Non-dominated set for CPLEX method, PSO method, and the propose MOGA

3 Experimental results

This section gives the experimental results. As an example, we implement the MOGA approach on the MOCLSCD model with 2 stages, 2 facilities in each stage, 4 capacity levels, and 4 technology levels. Figure 4 shows the non-dominated set for CPLEX method, PSO method, and the propose MOGA. Figure 5 shows the optimal 2 stages-2 facilities supply chain design results.

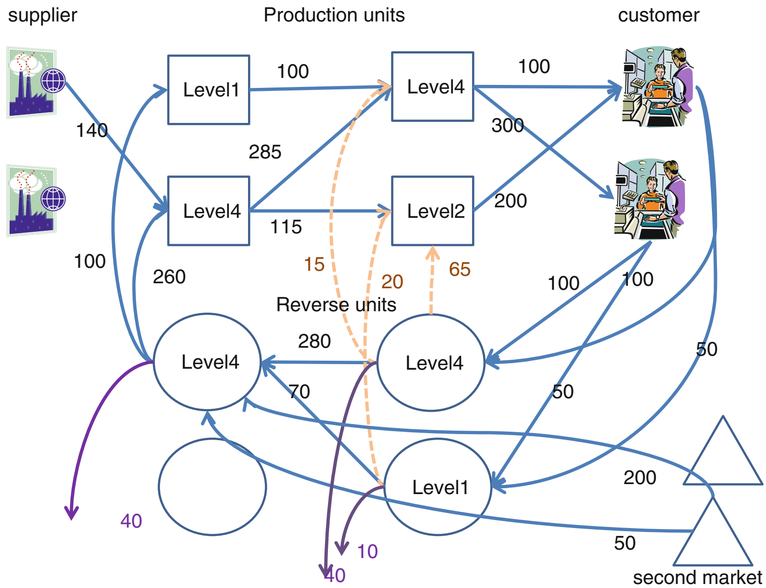


Fig. 5 Optimal 2 stages-2 facilities supply chain design

4 Conclusions

In this work, we firstly proposed a multi-objectives closed-loop supply chain (MOCLSCD) model. Next, a novel multi-objective genetic algorithm (MOGA) with ideal-point non-dominated sorting is used to solve the model. The experimental results show the efficiency of the proposed MOGA when comparing with CPLEX method and PSO method.

References

Chaabane A, Ramudhin A, Paquet M (2012) Design of sustainable supply chains under the emission trading scheme. Int J Prod Econ 135(1):37–49

Deb K (2001) A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II. IEEE Trans Evol Comput 6(2):182–197

Gunasekaran A, Patel C, McGaughey RE (2004) A framework for supply chain performance measurement. Int J Prod Econ 87(3):333–347

Horn J, Nafpliotis N, Goldberg DE (1994) A niched pareto genetic algorithm for multiobjective optimization. Paper presented at the IEEE world congress on computational intelligence

Srivastava SK (2007) Green supply-chain management: a state-of-the-art literature review. Int J Manage Rev 9(1):53–80

Subramanian R, Talbot B, Gupta S (2010) An approach to integrating environmental considerations within managerial decision-marking. J Ind Ecol 14(3):378–398

Replacement Policies with a Random Threshold Number of Faults

Xufeng Zhao, Mingchih Chen, Kazunori Iwata, Syouji Nakamura and Toshio Nakagawa

Abstract Most systems fail when a certain amount of reliability quantities have exceeded their threshold levels. The typical example is cumulative damage model in which a system is subjected to shocks and suffers some damage due to shocks, and fails when the total damage has exceeded a failure level K. This paper proposes the following reliability model: Faults occur at a nonhomogeneous Poisson process and the system fails when N faults have occurred, which could be applied to optimization problems in computer systems with fault tolerance, and we suppose that the system is replaced before failure at a planned time T. Two cases where the threshold fault number N is constantly given and is a random variable are considered, we obtain the expected cost rates and discuss their optimal policies.

Keywords Replacement · Constant threshold · Random threshold · Faults

X. Zhao (✉) · T. Nakagawa
Aichi Institute of Technology, Toyota, Japan
e-mail: g09184gg@aitech.ac.jp

T. Nakagawa
e-mail: toshi-nakagawa@aitech.ac.jp

M. Chen
Fu Jen Catholic University, New Taipei, Taiwan
e-mail: 081438@mail.fju.edu.tw

K. Iwata
Aichi University, Nagoya, Japan
e-mail: kazunori@vega.aichi-u.ac.jp

S. Nakamura
Kinjo Gakuin University, Nagoya, Japan
e-mail: snakam@kinjo-u.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_19,

1 Introduction

Most systems often fail when a certain amount of quantities due to various causes have exceeded a threshold level. The typical example is the cumulative damage model in which systems are subjected to shocks and suffer some damage due to shocks, and fail when the total damage has exceeded a failure level (Nakagawa 2007). This is called the cumulative process in stochastic processes (Cox 1962; Nakagawa 2011). There are continuous wear models in which the total damage increases with time t and the system fails when it has exceeded a failure level (Reynols and Savage 1971; Lehmann 2010). In some actual cases, an amount of damage due to each shock might not be estimated exactly, and so that, the total damage could not be estimated statistically. In these cases, we could estimate the damage on system only by counting the number of shocks up to present.

However, when shock occurrence becomes not so clear for counting and varies according to some stochastic process, we need to estimate its approximate cumulative distribution function. So that it will become much difficult to perform maintenance for this kind of failure mechanism. Take fault tolerance in computer systems (Adb-El-Barr 2007) as an example, the system will fail or be a low efficiency state when total number of faults exceeds some level, but this level is actually a non-transparent variable for system maintainers. There has been summarized many maintenance models to improve computer reliability in (Nakamura and Nakagawa 2010); However, almost all discussions have based on constant failure threshold level.

We propose that almost all failure thresholds are random for any failure mechanism, and this paper considers the following models: Faults occur at a nonhomogeneous Poisson process (Nakagawa 2011), and the system fails when n faults have occurred. We suppose that the system is replaced before failure at a planned time T and obtain analytically expected replacement cost rate and its optimal policy. A threshold number n in the above model might be actually uncertain, but could be estimated statistically by using the past data. When n is a random variable N, we obtain expected cost rate and make similar discussion of deriving optimal policy.

2 Model Formulation

We consider the following operating system: Faults of the system occur at a non-homogeneous Poisson process with a mean-value function $H(t) \equiv \int_0^t h(u)du$, and it fails when n $(n = 1, 2, \cdots)$ faults have occurred and undergoes only minimal repair before its failure. Letting $M(t)$ be the number of faults in $[0, t]$ (Nakagawa 2007),

$$H_j(t) \equiv \Pr\{M(t) = j\} = \frac{[H(t)]^j}{j!} e^{-H(t)} \quad (j = 0, 1, 2, \cdots), \tag{1}$$

and $E\{M(t)\} = H(t)$.

2.1 Constant n

Suppose that the system is replaced before failure at a planned time T $(0 < T \leq \infty)$, then the probability that the system is replaced at time T before fault $n(n = 1, 2, \cdots)$ is

$$\Pr\{M(T) \leq n-1\} = \sum_{j=0}^{n-1} H_j(T),$$

and the probability that it is replaced at fault n before time T is

$$\Pr\{M(T) \geq n\} = \sum_{j=n}^{\infty} H_j(T).$$

Thus, the mean time to replacement is

$$T \Pr\{M(T) \leq n-1\} + \int_0^T t d \Pr\{M(t) \geq n\} = \sum_{j=0}^{n-1} \int_0^T H_j(t) dt. \tag{2}$$

Therefore, the expected cost rate is

$$C_1(T; n) = \frac{c_N - (c_N - c_T) \sum_{j=0}^{n-1} H_j(T)}{\sum_{j=0}^{n-1} \int_0^T H_j(t) dt}, \tag{3}$$

where c_T = replacement cost at time T and c_N = replacement cost at fault n with $c_N > c_T$. Clearly,

$$C_1(T;\ \infty) \equiv \lim_{n \to \infty} C_1(T;\ n) = \frac{c_T}{T}, Z$$

which decreases with T from ∞ to 0.

When $n = 1$, $C_1(T; 1)$ agrees with the expected cost rates of an age replacement (Nakagawa 2005).

We find an optimal T_n^* $(0 < T_n^* \leq \infty)$ which minimizes $C_1(T; n)$ for a specified n $(1 \leq n < \infty)$. It can be easily seen that

$$C_1(0; \infty) \equiv \lim_{T \to 0} C_1(T; n) = \infty,$$
$$C_1(\infty; \infty) \equiv \lim_{T \to \infty} C_1(T; n) = \frac{c_N}{\sum_{j=0}^{n-1} \int_0^\infty H_j(t) dt}. \tag{4}$$

Differentiating $C_1(T; n)$ with respect to T and setting it equal to zero,

$$Q(T;n)\sum_{j=0}^{n-1}\int_0^T H_j(t)dt-\sum_{j=n}^{\infty}H_j(T)=\frac{c_T}{c_N-c_T}, \tag{5}$$

where

$$Q(T;n)\equiv\frac{h(T)H_{n-1}(T)}{\sum\limits_{j=0}^{n-1}H_j(T)},$$

which decreases strictly with n from $h(T)$ to 0. So that, the left-hand side of (5) goes to 0 as $n\to\infty$, i.e., T_n^* becomes large for large n.

Letting $L_1(T;n)$ be the left-hand side of (5),

$$L_1(0;n)\equiv\lim_{T\to 0}L_1(T;n)=0,$$

$$L_1(\infty;n)\equiv\lim_{T\to\infty}L_1(T;n)=Q(\infty,n)\sum_{j=0}^{n-1}\int_0^{\infty}H_j(t)dt-1,$$

$$L_1'(T;n)=Q'(T,n)\sum_{j=0}^{n-1}\int_0^T H_j(t)dt.$$

Therefore, if $Q(T;n)$ increases strictly with T and

$$Q(\infty,n)\sum_{j=0}^{n-1}\int_0^{\infty}H_j(t)dt>\frac{c_T}{c_N-c_T},$$

then there exists a finite and unique T_n^* $(0<T_n^*\le\infty)$ which satisfies (5), and the resulting cost rate is

$$C_1(T_n^*;\,n)=(c_N-c_T)Q(T_n^*;\,n). \tag{6}$$

Furthermore, it is assumed that $h(T)$ increases strictly for $n=1$ and increases for $n\geq 2$. Then, prove that $Q(T;\,n)$ increases strictly with T. It is trivial that $Q(T;\,1)$ increases strictly. For $n\geq 2$,

$$\left(\frac{[H(T)]^{n-1}/(n-1)!}{\sum_{j=0}^{n-1}\{[H(T)]^j/j!\}}\right)'$$
$$=\frac{h(T)\{[H(T)]^{n-2}/(n-1)!\}\sum_{j=0}^{n-1}(n-1-j)\{[H(T)]^j/j!\}}{\left(\sum_{j=0}^{n-1}\{[H(T)]^j/j!\}\right)^2}>0,$$

which implies that $Q(T;\,n)$ increases strictly.

2.2 Random N

Next, a threshold number n is not constant and is a random variable N, i.e., $\Pr\{N = n\} \equiv p_n (n = 1, 2, \cdots)$ and $P_n \equiv \sum_{j=1}^{n} p_j$, where $P_\infty = \sum_{j=1}^{\infty} p_j \equiv 1$. Then, the expected cost rate in (3) is easily rewritten as

$$C_1(T;\, N) = \frac{c_N - (c_N - c_T)\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} H_j(T)}{\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} \int_0^T H_j(t)dt}, \tag{7}$$

and (5) is

$$Q(T;N)\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} \int_0^T H_j(t)dt - \sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} H_j(T) = \frac{c_T}{c_N - c_T},$$

where

$$Q(T;\, N) \equiv \frac{h(T)\sum_{n=1}^{\infty} p_n H_{n-1}(T)}{\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} H_j(T)}.$$

If $Q(T;N)$ increases strictly with T and

$$Q(\infty;N)\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} \int_0^\infty H_j(t)dt > \frac{c_N}{c_N - c_T},$$

then there exists an optimal T_N^* $(0 < T_N^* < \infty)$ which satisfies above conditions, and the resulting cost rate is

$$C_1(T_N^*;\, N) = (c_N - c_T)Q(T_N^*;\, N). \tag{9}$$

It is assumed that $h_{n+1} \equiv p_{n+1}/(1 - P_n)(n = 0, 1, 2 \cdots)$, which is called the discrete failure rate (Nakagawa 2005), and increases strictly with n. This means that the probability of exceeding a threshold number N increases with the number of faults. Then, we prove (Nakagawa 2011) that

$$\frac{\sum_{n=1}^{\infty} p_n \{[H(T)]^{n-1}/(n-1)!\}}{\sum_{n=1}^{\infty} p_n \sum_{j=0}^{n-1} \{[H(T)]^j/j!\}} = \frac{\sum_{n=0}^{\infty} p_{n+1}\{[H(T)]^n/n!\}}{\sum_{n=0}^{\infty}(1 - P_n)\{[H(T)]^n/n!\}}$$

increases strictly with T.

Differentiating above equation with respect to T,

$$\frac{h(T)}{\left(\sum_{n=0}^{\infty}(1 - P_n)\{[H(T)]^n/n!\}\right)^2}\left\{\begin{aligned}&\sum_{n=1}^{\infty} p_{n+1}\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=0}^{\infty}(1 - P_j)\frac{[H(T)]^j}{j!}\\ &-\sum_{n=1}^{\infty}(1 - P_n)\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=0}^{\infty} p_{j+1}\frac{[H(T)]^j}{j!}\end{aligned}\right\}.$$

The expressions within the bracket of the numerator is

$$\sum_{n=1}^{\infty}\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=0}^{\infty}\frac{[H(T)]^{j}}{j!}(1-P_n)(1-P_j)(h_{n+1}-h_{j+1})$$
$$=\sum_{n=1}^{\infty}\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=0}^{n-1}\frac{[H(T)]^{j}}{j!}(1-P_n)(1-P_j)(h_{n+1}-h_{j+1})$$
$$+\sum_{n=1}^{\infty}\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=n}^{\infty}\frac{[H(T)]^{j}}{j!}(1-P_n)(1-P_j)(h_{n+1}-h_{j+1})$$
$$=\sum_{n=1}^{\infty}\frac{[H(T)]^{n-1}}{(n-1)!}\sum_{j=0}^{n-1}\frac{[H(T)]^{j}}{j!}(1-P_n)(1-P_j)(h_{n+1}-h_{j+1})(n-j)>0,$$

which implies that when h_{n+1} increases strictly, $Q(T;N)$ also increases strictly with T.

We have neglected the cost for minimal repair due to each fault. The expected number of minimal repair until replacement is

$$\sum_{j=0}^{n-1} jH_j(T)+(n-1)\sum_{j=n}^{\infty}H_j(T)=n-1-\sum_{j=0}^{n-1}(n-1-j)H_j(T).$$

Letting c_M be the cost for minimal repair, the expected cost rate in (3) is

$$\tilde{C}_1(T;n)=\frac{c_N-(c_N-c_T)\sum_{j=0}^{n-1}H_j(T)+c_M\left[n-1-\sum_{j=0}^{n-1}(n-1-j)H_j(T)\right]}{\sum_{j=0}^{n-1}\int_0^T H_j(t)dt}, \tag{11}$$

which agrees with that of the periodic replacement when $c_N=c_T$ (Nakagawa 2005). Furthermore, the expected cost rate in (7) is

$$\tilde{C}_1(T;N)=\frac{c_N-(c_N-c_T)\sum\limits_{n=1}^{\infty}p_n\sum\limits_{j=0}^{n-1}H_j(T)+c_M[n-1-\sum\limits_{j=0}^{n-1}(n-1-j)H_j(T)]}{\sum\limits_{n=1}^{\infty}p_n\sum\limits_{j=0}^{n-1}\int_0^T H_j(t)dt}. \tag{12}$$

As further studies, we could make similar discussions for deriving optimal policies which minimize the expected cost rates $\tilde{C}_1(T;n)$ and $\tilde{C}_1(T;N)$.

Table 1 Optimal T_n^* and T_N^* when $H(t) = t^2, p_n = pq^{n-1}$ and $n = 1/p$

n	$c_N/c_T = 2$		$c_N/c_T = 5$		$c_N/c_T = 10$	
	T_n^*	T_N^*	T_n^*	T_N^*	T_n^*	T_N^*
2	1.160	0.857	0.719	0.413	0.564	0.274
3	1.349	0.799	0.949	0.390	0.795	0.259
4	1.541	0.773	1.161	0.380	1.008	0.235
5	1.725	0.759	1.357	0.374	1.205	0.249
7	2.063	0.743	1.710	0.368	1.558	0.245
10	2.510	0.732	2.170	0.364	2.020	0.242
15	3.149	0.723	2.822	0.360	2.674	0.240
20	3.701	0.719	3.382	0.358	3.235	0.239
50	6.163	0.712	5.866	0.355	5.723	0.237

3 Numerical Example

Suppose that $p_n = pq^{n-1}(n = 1, 2, \cdots; 0 < p \leq 1)$ with mean $1/p$, and $h(t)$ increases strictly to $h(\infty) = \lim_{t\to\infty} h(t)$. Then, (8) is

$$h(T)\int_0^T e^{-pH(t)}dt - [1 - e^{-pH(T)}] = \frac{c_T}{c_N - c_T}, \tag{13}$$

whose left-hand side increases strictly with T from 0 to $h(T)\int_0^T e^{-pH(t)}dt - 1$. Therefore, if $h(\infty) > c_N/(c_N - c_T)\int_0^\infty e^{-pH(t)}dt$, then there exists a finite and unique T_N^* $(0 < T_N^* < \infty)$ which satisfies (13), and the resulting cost rate is

$$C_1(T_N^*; N) = (c_N - c_T)h(T_N^*). \tag{14}$$

It can be easily seen that T_N^* increases with p to the optimal time of an age replacement (Nakagawa 2005) for $p = 1$, because the left-hand side decreases with p.

Table 1 presents optimal T_n^* and T_N^* when $H(t) = t^2$, $p_n = pq^{n-1}$ and $n = 1/p$ for $c_N/c_T = 2, 5, 10$ and $n =$ 2, 3, 4, 5, 7, 10, 15, 20, 50.

4 Conclusions

We have discussed replacement models with constant and random threshold number of faults. That is, faults occur at a nonhomogeneous Poisson process and the system fails when a constant number n faults and random number N faults have occurred. We have supposed that the system is replaced before failure at a planned time T and obtained the expected cost rates and discussed their optimal policies. From numerical analysis, we have found that both optimal times T_n^* and T_N^* have the same properties with cost rate c_N/c_T but different for $n = 1/p$. Replacement models with random threshold failure level would be a more practical extension of classical methods, which could be done further in the following studies.

Acknowledgments This work is partially supported by Grant-in-Aid for Scientific Research (C) of Japan Society for the Promotion of Science under Grant No. 22500897 and No. 24530371; National Science Council of Taiwan NSC 100-2628-E-0330-002.

References

Abd-El-Barr M (2007) Reliable and fault-tolerant. Imperial College Press, London

Cox DR (1962) Renewal theory. Methuen, London

Lehmann A (2010) Failure time models based on degradation process. In: Nikulin MS et al (eds) Advances in degradation modeling. Birkhauser, Boston, pp 209–233

Nakagawa T (2005) Maintenance theory of reliability. Springer, London

Nakagawa T (2007) Shock and damage models in reliability theory. Springer, London

Nakagawa T (2011) Stochastic processes with applications to reliability theory. Springer, London

Nakamura S, Nakagawa T (2010) Stochastic Reliability Modeling, Optimization and Applications. World Scientific, Singapore

Reynols DS, Savage IR (1971) Random wear models in reliability theory. Adv Appl Probab 3:229–248

A Multi-Agent Model of Consumer Behavior Considering Social Networks: Simulations for an Effective Movie Advertising Strategy

Yudai Arai, Tomoko Kajiyama and Noritomo Ouchi

Abstract It is essential for a firm to understand consumer behavior in order to advertise products efficiently on a limited budget. Nowadays, consumer behavior is highly complex because consumers can get a lot of information about products from not only firm's advertising but also social networking services. The purposes of this study are to construct consumer behavior model considering social networks and to demonstrate an effective weekly advertising budget allocation in order to increase the number of adopters of products. First, we developed a multi-agent model of consumer behavior taking the movie market as an example. In our model, each agent decides whether or not to watch a movie by comparing the weighted sum of "individual preference" and "effects of advertising and word-of-mouth (WOM)" with "individual threshold." The scale-free network is used to describe social networks. Next, we verified the accuracy of the model by comparing the simulation results with the actual sales figures of 13 movies. Finally, we showed an effective weekly advertising budget allocation corresponding to movie type by simulations. Furthermore, it was demonstrated that the weekly advertising budget allocation gives greater impact on the number of adopters of products as social networks grow.

Keywords Consumer behavior · Multi-agent simulation · Decision making · Advertising strategy · Social networks · Movie market

Y. Arai (✉)
Graduate School of Science and Engineering, Aoyama Gakuin University,
5-10-1 Fuchinobe, Chuo-ku, Sagamihara-shi, Kanagawa 252-5258, Japan
e-mail: c5612119@aoyama.jp

T. Kajiyama · N. Ouchi
Department of Industrial and Systems Engineering, Aoyama Gakuin University, 5-10-1 Fuchinobe, Chuo-ku, Sagamihara-shi, Kanagawa 252-5258, Japan
e-mail: tomo@ise.aoyama.ac.jp

N. Ouchi
e-mail: ouchi@ise.aoyama.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_20,

1 Introduction

Understanding consumer behavior is essential for firms in order to advertise their products efficiently on a limited budget. Nowadays, consumer behavior is highly complex because consumers can get a lot of information about products from not only firm's advertising but also social networking services such as Twitter and Facebook.

Lots of studies have been made on consumer behavior models including diffusion models (e.g. Mansfield 1961; Bass 1969; Mahajan et al. 1990; Libai et al. 2009). However, there are few works that tried to develop the model incorporating social networks' effects. Meanwhile, there are several studies linking consumer behavior models and firms' strategies (e.g. Kamimura et al. 2006; Tilman et al. 2007). For example, Kamimura et al. (2006) demonstrated the effective way of weekly advertising budget allocation in the movie market. However, it does not consider the existence of social networks. In addition, the characteristics of movies are not considered although the effective way of weekly advertising budget allocation might depend on the characteristic of products.

The purposes of this study are to construct consumer behavior model considering social networks and to demonstrate an effective weekly advertising budget allocation in order to increase the number of adopters of products. In this study, we pick up consumer behavior in the movie market because it is strongly influenced by the effects of advertising and word-of-mouth (WOM).

Section 2 presents model construction. In Sect. 3, we demonstrate simulation results. Finally, Sect. 4 summarizes new findings, implications for firm's strategy.

2 Model Construction

In this study, we developed a consumer behavior model considering social networks' effects by using multi-agent simulation taking the movie market as an example. Multi-agent simulation can simulate the actions and interactions of autonomous agents with a view to assessing their effects on the system as a whole.

In our model, 1,000 agents are created in a grid size of 50 × 50 cells. Agent i decides whether or not to watch a movie at time t by comparing the weighted sum of "individual preference $\left(P_{i,t}\right)$" and "effects from advertising and WOM $\left(E_{i,t}\right)$" with "individual threshold (T_i)." By using weighted parameter (a_i), the condition where agent i decides to watch a movie is defined as depicted in inequality (1).

$$a_i \times P_{i,t} + (1 - a_i) \times E_{i,t} > T_i \tag{1}$$

"Individual preference $\left(P_{i,t}\right)$" represents agent i's degree of preference of the movie. $P_{i,t}$ is computed by Eq. (2).

$$P_{i,t} = (pb + adv + pre) * F^P(t) \times I_i^P \times D_i^P \tag{2}$$

where pb: the effect of production budget, adv: the effect of advertising budget, pre: the effect of the previous movie's sales figure, $F^P(t)$: variation of interest for a new movie over time, I_i^P: individuality of agent i, and D_i: dummy variable denoting whether or not agent i has an interest in the genre of the movie ($D_i = 1$ if agent i has an interest, $D_i = 0$ if agent i does not have an interest).

Only if agent i has an interest in the genre of the movie, individual preference is computed. $F^P(t)$ is a decreasing function of t. In our model, we set $F^P(t) = 0.94^t$ according to Kamimura et al. (2006).

"Effects of advertising and WOM $\left(E_{i,t}\right)$" is the sum of "effects of advertising $\left(A_{i,t}\right)$" and "effects of WOM $\left(W_{i,t}\right)$" as depicted in Eq. (3).

$$E_{i,t} = A_{i,t} + W_{i,t} \tag{3}$$

$A_{i,t}$ is computed by Eq. (4).

$$A_{i,t} = adv \times R^A \times I_i^A \times G^A(t) \tag{4}$$

where R^A: reliability of information source (mass media), I_i^A: agent i's susceptibility of advertising, $G^A(t)$: variation of advertising effect over time.

We set $G^A(t) = B^A \times F^A(t)$. B^A is a fixed value. $F^A(t) = 0.7\,(\mathrm{t}<0), F^A(t) = 0.94^t(t \geq 0)$, following to Kamimura et al. (2006). In Sect. 3.2, we change $F^A(t)$ corresponding to advertising budget allocation patterns.

Regarding $W_{i,t}$, in this study, we consider three resources of WOM; "neighbors," "Internet sites" and "social networks." Thus, $W_{i,t}$ is the sum of the effects of neighbors WOM $\left(\sum_{j=1}^{N_N} w_{i,j,t}\right)$, the effects of Internet WOM $\left(\sum_{k=1}^{N_I} w_{i,k,t}\right)$ and the effects of social networks WOM $\left(\sum_{l=1}^{N_S} w_{i,l,t}\right)$ as depicted in Eq. (5).

$$W_{i,t} = \sum_{j=1}^{N_N} w_{i,j,t} + \sum_{k=1}^{N_I} w_{i,k,t} + \sum_{l=1}^{N_S} w_{i,l,t} \tag{5}$$

where $w_{i,j,t}$, $w_{i,k,t}$, and $w_{i,l,t}$: the effect of WOM agent i received from agent j, k and l, respectively, N_N, N_I and N_S: the number of agents who can affect agent i's effects of neighbors WOM, Internet WOM and social networks WOM, respectively.

In this model, N_N and N_I are the number of agents who are within 3×3 cells, 21×21 cells around agent i, respectively. N_S is the number of agents who have a link with agent i and are within 21×21 cells around agent i.

The scale-free network (Barabashi and Albert 1999) can be used to describe social networks. We create the links between agents, which denote the social networks, by using the scale-free network.

$w_{i,j,t}$ is computed as depicted in Eq. (6). $w_{i,k,t}$ and $w_{i,l,t}$ are computed in a similar way.

Table 1 The differences of three WOM resources

	B^W	R^W
Neighbor	High (0.32)	High (2)
Internet site	Low (0.15)	Low (1)
Social networks	Medium (0.24)	Medium (1.5)

(): values used in the model

Table 2 Parameters for individual threshold

Category	Proportion (%)	α	β
Innovator	2.5	4	1
Early adopter	13.5	6	3
Early majority	34	9	6
Late majority	34	11	6
Laggards	16	13	3

$$w_{i,j,t} = \begin{cases} (pb + adv + pre) \times R^W \times O_j \times I_i^w \times G^W(t)(\textit{before release}) \\ RatingScore \times R^W \times O_j \times I_i^w \times G^W(t)(\textit{after release}) \end{cases} \tag{6}$$

where R^W: reliability of information source, I_i^W: agent i's susceptibility to WOM, O_j: agent j's ability to impart information, $G^W(t)$: variation of frequency of chats about the movie over time.

We set $G^W(t) = B^W \times F^W(t)$. B^W is a fixed value. $F^W(t) = e^t(t<0), F^W(t) = 0.94^t(t \geq 0)$, following to Kamimura et al. (2006). Because it can be considered that the values of B^W and R^W are different depending on the information sources, we set these parameters as shown in Table 1.

Individual threshold is computed by Eq. (7).

$$T_i = \alpha + \beta \times r \tag{7}$$

where α, β: coefficient determining individual threshold, r: an uniform random number between 0 and 1.

Agents are characterized as innovators, early adopters, early majority, late majority and laggards according to Rogers' diffusion theory (Rogers 1962). The values of α and β differ depending on these characteristics as shown in Table 2.

3 Simulations

3.1 Model Validation

We validated the proposed model by comparing the simulation results (S) with actual data (A) in terms of the cumulative number of movie viewers every week. As sample data, we selected 13 movies as listed in Table 3. They include the top five box-office movies in 2010 and "Kings Speech", the academy award for best

Table 3 List of 13 movies

Title	Sales figure	Production budget	Rating score
Toy story 3	$415,004,880	$200,000,000	8.84
Alice in wonderland	$334,191,110	$200,000,000	7.18
Iron man 2	$312,433,331	$170,000,000	7.27
The twilight saga: eclipse	$300,531,751	$68,000,000	6.86
Inception	$292,568,851	$160,000,000	8.25
Harry potter and the deathly hallows: part I	$294,980,434	$125,000,000	7.92
Shrek forever after	$238,319,043	$165,000,000	5.75
The book of eli	$94,822,707	$80,000,000	6.33
The social network	$96,619,124	$40,000,000	8.23
The town	$92,173,235	$37,000,000	8.54
Red	$90,356,857	$60,000,000	7.8
Percy jackson and the olympians: the lightning thief	$88,761,720	$95,000,000	7.03
The king's speech	$138,797,449	$15,000,000	8.25

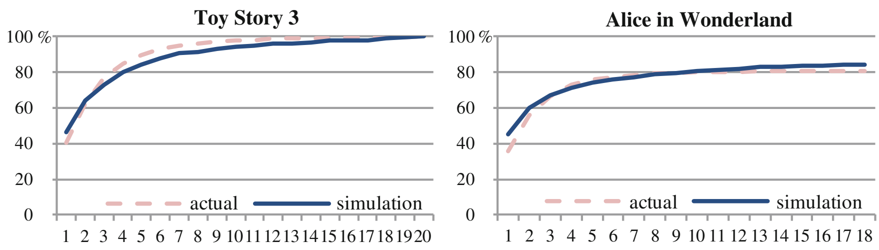


Fig. 1 Trends in actual data and simulation results

motion picture of 2010. The data in Table 3 are available at "The Numbers (http://www.the-numbers.com)". In addition, in our study "Rotten Tomatoes (http://www.rottentomatoes.com/)" was also referred.

We conducted simulations 30 times in each movie. Simulations period is from four weeks before the release date ($t = -4$).

Figure 1 shows examples of trends in cumulative adoption rate of actual data and simulation results. Cumulative adoption rate is calculated by dividing the number of cumulative movie viewers in each week by the total movie viewers of Toy Story 3, which number of total movie viewers is the largest.

Table 4 summarizes the mean error rate. The error rate (E) is computed by Eq. (8).

$$E^k = \frac{\left|S^k - A^k\right|}{A^k} \tag{8}$$

As shown in Table 4, mean error rates can be considered to be small. These results demonstrate that our proposed model can describe the actual consumer behavior.

Table 4 Mean error rates

Movie	Mean error rate (%)
Toy story 3	3.73
Alice in wonderland	3.99
Iron man 2	2.37
The twilight saga: eclipse	9.51
Inception	4.01
Harry potter and the deathly hallows: part I	3.60
Shrek forever after	8.56
The book of eli	6.60
The social network	9.43
The town	8.67
Red	7.07
Percy jackson and the olympians: the lightning Thief	6.24
The king's speech	11.40

3.2 Application to Advertising Strategy

To clarify the effective way of weekly advertising budget allocation, simulations were conducted by using proposed model. We set four patterns of advertising budget allocation, (1) focusing on around a release date (standard), (2) focusing on before a release date (before), (3) focusing on after a release date (after) and (4) same weight during period (constant), as demonstrated in Fig. 2.

Additionally, we divide movies into four types by consumers' expectation for a movie and rating score as shown in Table 5. Expectation is estimated by the effect of production budget, advertising budget and previous movie's sales figure. We analyze the impact of characteristic of movies on the number of movie viewers.

Furthermore, in order to clarify the impacts of social networks on the number of movie viewers, we set the following two conditions; (a) social networks WOM is not considered, (b) social networks WOM is considered.

Figure 3 compares the total number of movie viewers in each situation with the one in the case of (Type 1, Standard, (a) not considered).

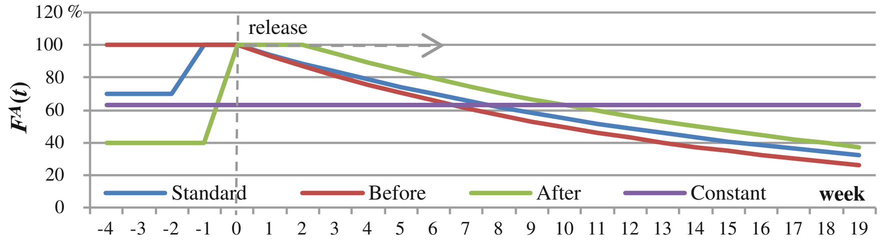


Fig. 2 Four patterns of advertising budget allocation

Table 5 Four movie types

Type	Expectation	Rating score
1	High	High
2	Low	High
3	High	Low
4	Low	Low

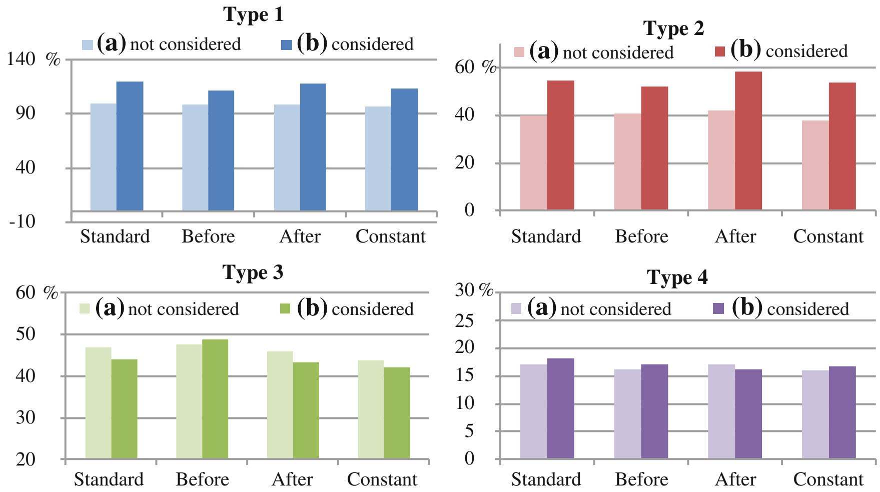


Fig. 3 The comparison of simulation results

In type 2, allocating the budget mainly after release is the best way, while standard allocation is the best way in type 1 and type 4. This might be because a positive WOM is stimulated by effects of advertising after release, and it leads more people to watch a movie. On the other hand, in type 3, allocating the budget mainly before release becomes the best allocation. This result suggests that it is effective to acquire lots of movie viewers by effects of advertising before negative WOM spreads.

In addition, the difference of number of movie viewers between allocation patterns becomes larger when social networks WOM is considered.

4 Conclusions

We constructed a consumer behavior model considering social networks and verified that our proposed model can describe the actual consumer behavior. Then we applied the model to an advertising strategy by conducting the simulation of effective weekly advertising budget allocation. As a result, we clarified that there are effective weekly advertising budget allocations corresponding to the characteristic of movie products. In addition, it was demonstrated that the difference of weekly advertising budget allocation give a lager impact on the number of adopters as social networks grow.

As future work, applying the model to other market should be required.

References

Barabasi AL, Albert R (1999) Emergence of scaling in random networks. Science 286:509–512

Bass FM (1969) A new product growth model for consumer durables. Manage Sci 15:215–227

Kamimura R, Masuda H, Arai T (2006) An agent-based model of consumer behaviour: application to the movie market. Jpn Ind Manage Assoc 57:450–469 (in Japanse)

Libai B, Muller E, Peres R (2009) The diffusion of services. J Mark Res 46(April):163–175

Mahajan V, Muller E, Bass FM (1990) New-product diffusion models in marketing: a review and direction for research. J Mark 54(January):1–26

Mansfield E (1961) Technical change and the rate of imitation. Econometric Soc 29(4):741–766

Rogers EM (1962) Diffusion of innovations. The Free Press, New York

Tilman AS, Gunter L, Jurgen R (2007) Agent-based simulation of consumer behavior in grocery shopping on a regional level. J Bus Res 60:894–903

Government Subsidy Impacts on a Decentralized Reverse Supply Chain Using a Multitiered Network Equilibrium Model

Pin-Chun Chen and I-Hsuan Hong

Abstract Government subsidies to reverse supply chains can play important roles in driving or curtailing the flows of recycled items. We examine the impacts of exogenous subsidies on recycled material flows in a decentralized reverse supply chains where each participant acts according to its own interests. We outline a multitiered model of the supply network from sources of scrap electronics, collectors, processors and demand markets. The individual behavior of each player is governed by participants' optimality conditions, which are mathematically transformed into a variational inequality formulation. The modified projection method is utilized for solving the equilibrium quantities and prices of each participant. We investigate the impact of alternate schemes of government subsidies on decisions of the equilibrium quantities, prices and the total amount collected. For the case studied in this paper, the best tier selection between collectors and processors for government subsidies in terms of the total collected amount is located in collectors in laptop reverse supply chains.

Keywords Reverse supply chain · Government subsidy · Variational inequality · Modified projection method

P.-C. Chen (✉) · I.-H. Hong
Institute of Industrial Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan
e-mail: r00546006@ntu.edu.tw

I.-H. Hong
e-mail: ihong@ntu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_21,

1 The Decentralized Reverse Supply Chain Network

Government provides subsidies for recycling in reverse supply chains for environmental consciousness and further usages. Collectors and processors can obtain subsidies from government as incentives which effectively assist in recycling and recovery of e-scrap products. In Taiwan, a semi-official organization supervised by the Environmental Protection Administration (EPA) collects processing fee and subsidizes the associated collectors and processors, yet the discussion on the appropriate subsidy target is neglected. Some research related to the government subsidized e-scrap reverse supply chain regarded the organization between the e-scrap source and the refurbished product demand market as only one party and some classed the recycling system into two or more parties, yet so far the allocation of government subsidies has been overlooked.

The purpose of this study is to analyze how to appropriately allocate government subsidies to collectors and processors in a reverse supply chain consisting of four tiers of decision makers: sources of e-scrap, collectors, processors, and demand markets. In Sect. 2, we present a four-tiered network equilibrium model for reverse supply chain management. In Sect. 3, the case study based on a laptop computer reverse production system in Georgia, United States is demonstrated and the impact of the government subsidy policies on recycled e-scrap products is discussed. The summary is drawn in Sect. 4.

2 The Multitiered Network Equilibrium Model for Decentralized Reverse Supply Chain Management

A multitiered network model is developed for investigating the impact of government subsidies on the behaviors of individual entities in a reverse supply chain. The network consists of four tiers of entities, including r sources of e-scrap products, m collectors, n processors and o demand markets. A source of e-scrap products is denoted by h. A collector is denoted by i, who collects e-scrap products and may further disassemble e-scrap products to separate components and materials from e-scrap products. A processor is denoted by j, who converts e-scrap products into more fungible commodities that are sold to customers in demand markets. Let S_{ij} denote the government subsidy that collector i can receive by selling e-scrap products collected to processor j, while S_{jk} denotes the government subsidy that processor j can receive by dissembling or refurbishing processes and then selling e-scrap products to demand market k.

The objective of the sources of e-scrap, collectors and processors is to maximize their own profits, while the customers in the demand markets have to satisfy the market equilibrium conditions. From definitions of variational inequality problem (Ben-Arieh 1999) and supply chain network Cournot-Nash equilibrium

(Nagurney and Yu 2012; Nagurney and Toyasaki 2005), we propose the variational inequality formulation to specifically discuss the government subsidy impacts on the total collected amount in a e-scrap reverse supply chain.

2.1 The Behavior of the Sources of E-scrap Products

The sources make profit from selling e-scrap products to collectors. Let q_{hj} denote the nonnegative amount of e-scrap products that is allocated from source h to collector i, where $h = 1,\ldots, r$; $i = 1,\ldots, m$. We denote the transaction cost between source h and collector i by c_{hj} and assume that

$$c_{hi} = c_{hi}(q_{hi}),\ h = 1,\ldots,r;\ i = 1,\ldots,m. \tag{1}$$

Each source receives revenue from selling e-scrap products to collectors. We let p^*_{1hi} denote the price that source h charges collector i for a unit of e-scrap products. Each source h seeks to maximize the total profit with the optimization problem by

$$\underset{p_{1hi},q_{hi}}{\text{Max}} \sum_{i=1}^{m} p^*_{1hi} q_{hi} - \sum_{i=1}^{m} c_{hi}(q_{hi}) \tag{2}$$

subject to

$$q_{hi} \geq 0,\ i = 1,\ldots,m. \tag{3}$$

Equation (2) states that a source's profit is equal to sales revenues minus the costs associated with transactions between sources and collectors.

2.2 The Behavior of the Collectors

Collectors purchase e-scrap products from the sources, and sell them to processors after sorting or dismantling e-scrap products. Collectors transact both with the sources and processors. Let q_{ij} denote the nonnegative amount of materials from collector i to processor j, where $i = 1,\ldots,m$; $j = 1,\ldots,n$. Each collector receives revenue from selling e-scrap products to processors after initial sorting or disassembling processes. We let p^*_{2ij} denote the price that collector i charges processor j for a unit of e-scrap products. In addition, we recall that the price p^*_{1hi} denotes the price that collector i pays source j for a unit of e-scrap products. We denote the transaction cost between collector i and processor j by c_{ij} and assume that

$$c_{ij} = c_{ij}(q_{ij}),\ i = 1,\ldots,m;\ j = 1,\ldots,n. \tag{4}$$

A transportation cost paid by collector i between each collector i and source h, denoted by $\hat{c}_{hi}$, and assume that

$$\hat{c}_{hi} = \hat{c}_{hi}(q_{hi}),\ h = 1, \ldots, r;\ i = 1, \ldots, m. \tag{5}$$

The cost to collect e-scrap products at collector i is denoted by c_i and is assumed to be

$$c_i = c_i\left(Q^2\right),\ i = 1, \ldots, m. \tag{6}$$

A collector can receive a government subsidy. We let S_{ij} denote the subsidy that collector i can receive by selling e-scrap products to processor j and assume that

$$S_{ij} = S_{ij}\left(q_{ij}\right),\ i = 1, \ldots, m;\ j = 1, \ldots, n. \tag{7}$$

A collector seeks to maximize the total profits and collector i's optimization problem can be formulated as

$$\underset{q_{hi}, q_{ij}}{\text{Max}} \sum_{j=1}^{n} p_{2ij}^{*} q_{ij} - \sum_{h=1}^{r} p_{1hi}^{*} q_{hi} - \sum_{j=1}^{n} c_{ij}\left(q_{ij}\right) - \sum_{h=1}^{r} \hat{c}_{hi}(q_{hi}) - c_i\left(Q^2\right) + \sum_{j=1}^{n} S_{ij}\left(q_{ij}\right) \tag{8}$$

subject to

$$\sum_{j=1}^{n} q_{ij} \le \sum_{h=1}^{r} q_{hi}, \tag{9}$$

$$q_{hi} \ge 0,\ h = 1, \ldots, r;\ q_{ij} \ge 0,\ j = 1, \ldots, n. \tag{10}$$

Equation (8) states that a collector's profit is equal to the sales revenue plus the subsidies minus the costs.

2.3 The Behavior of the Processors

Processors purchase e-scrap products from collectors, and sell them to the demand markets after processing e-scrap products. The processes include smelting or refining materials into pure metal streams (Sodhi and Reimer 2001) and refurbishing or recovering the e-scrap products. Let q_{jk} denote the nonnegative amount of materials that is allocated from processor j to demand market k where $j = 1,\ldots,n;\ k = 1,\ldots,o$.

Each processor receives revenue from selling processed e-scrap products to different demand markets. We let p_{3jk}^{*} denote the price that processor j charges consumers at demand market k for a unit of e-scrap products. The transaction cost between processor j and demand market k is denoted by c_{jk} and is assumed to be

$$c_{jk} = c_{jk}\left(q_{jk}\right),\ j = 1, \ldots, n;\ k = 1, \ldots, o. \tag{12}$$

We denote a transportation cost paid by processor j between processor j and collector i, denoted by $\hat{c}_{ij}$, and assume that

$$\hat{c}_{ij} = \hat{c}_{ij}\left(q_{ij}\right),\ i = 1, \ldots, m;\ j = 1, \ldots, n. \tag{13}$$

A processor has a processing cost to smelt, refine, refurbish or recover e-scrap products at processor j is denote by c_j and is assumed to be

$$c_j = c_j\left(Q^3\right),\ j = 1, \ldots, n. \tag{14}$$

A processor can receive a government subsidy. We let S_{jk} denote the subsidy that processor j can receive by selling one unit of processed e-scrap products to demand market k and assume that

$$S_{jk} = S_{jk}\left(q_{jk}\right),\ j = 1, \ldots, n;\ k = 1, \ldots, o. \tag{15}$$

A processor seeks to maximize its total profits and processor j's optimization problem can be formulated as

$$\underset{q_{ij}, q_{jk}}{\text{Max}} \sum_{k=1}^{o} p_{3jk}^{*} q_{jk} - \sum_{i=1}^{m} p_{2ij}^{*} q_{ij} - \sum_{k=1}^{o} c_{jk}\left(q_{jk}\right) - \sum_{i=1}^{m} \hat{c}_{ij}\left(q_{ij}\right) - c_j\left(Q^3\right) + \sum_{k=1}^{o} S_{jk}\left(q_{jk}\right) \tag{16}$$

subject to

$$\sum_{k=1}^{o} q_{jk} \leq \sum_{i=1}^{m} q_{ij}, \tag{17}$$

$$q_{ij} \geq 0,\ i = 1, \ldots, m;\ q_{jk} \geq 0,\ k = 1, \ldots, o. \tag{18}$$

Equation (16) states that a processor's profit is equal to the sales revenue plus the subsidies minus the costs.

2.4 The Demand Markets and the Equilibrium Conditions

Consumers at demand markets transact with processors. We denote the transportation cost between demand market k and processor j by $\hat{c}_{jk}$, and assume that

$$\hat{c}_{jk} = \hat{c}_{jk}\left(q_{jk}\right),\ j = 1, \ldots, n;\ k = 1, \ldots, o, \tag{19}$$

We assume that the demand function of demand market k is

$$d_k = d_k(p_4),\ k = 1, \ldots, o, \tag{20}$$

where p_4 is the vector of the collective price of demand markets, and we denote the price of demand market k by p_4.

The equilibrium conditions for consumers at demand market k are identical to the well-known spatial equilibrium conditions (Nagurney et al. 2002) and are dictated by the following conditions for all processors.

$$p^*_{3jk} + \hat{c}_{jk}\left(q_{jk}\right)\begin{cases} = p^*_{4k}, & \text{if } q^*_{jk} > 0, \\ \geq p^*_{4k}, & \text{if } q^*_{jk} = 0, \end{cases} \tag{21}$$

$$d_k\left(p^*_4\right)\begin{cases} = \sum_{j=1}^{n} q^*_{jk}, & \text{if } p^*_{4k} > 0, \\ \leq \sum_{j=1}^{n} q^*_{jk}, & \text{if } p^*_{4k} = 0. \end{cases} \tag{22}$$

Conditions (21) guarantee that the transaction isn't unprofitable; Conditions (22) guarantee that demand is feasible. The modified projection method (see Ben-Arieh 1999; Ceng et al. 2010; Nagurney and Zhang 1997; Zeng and Yao 2006) is utilized to solve the proposed variational inequality formulation.

3 Case Study of the Laptop Computer Reverse Supply Chain

3.1 *Case Study Overview and Data Input*

Based on Hong et al. (2012), we model the laptop computer reverse supply chain in Georgia as a four-tier network, which consists of twelve sources of e-scrap, twelve collectors, three processors and three demand markets. Table 1 gives the detailed geographical information about the four tiers in Georgia's case.

Given the ground and ocean transportation costs from Hong et al. (2012), we estimate the unit transportation costs between tiers. We use the information given

Table 1 The geographical information of the laptop computer reverse supply chain

Node type	Node	State/country	County/city
Sources of e-scrap (tier 1) and collectors (tier 2)	$S_1 = C_1$	Georgia	Gordon
	$S_2 = C_2$	Georgia	White
	$S_3 = C_3$	Georgia	DeKalb
	$S_4 = C_4$	Georgia	Meriwether
	$S_5 = C_5$	Georgia	Oconee
	$S_6 = C_6$	Georgia	Bibb
	$S_7 = C_7$	Georgia	Richmond
	$S_8 = C_8$	Georgia	Chattahoochee
	$S_9 = C_9$	Georgia	Toombs
	$S_{10} = C_{10}$	Georgia	Dougherty
	$S_{11} = C_{11}$	Georgia	Ware
	$S_{12} = C_{12}$	Georgia	Chatham
Processors (tier 3) and demand markets (tier 4)	$P_1 = D_1$	Georgia	Marietta
	$P_2 = D_2$	Tennessee	Nashville
	$P_3 = D_3$	Nigeria	Lagos

Table 2 The impact of subsidy on total material flows

Total material flows (laptop unit)	Scenario 1 $a = 0$ $b = 2.88$	Scenario 2 $a = 2.88$ $b = 0$	Scenario 3 $a = 1.44$ $b = 1.44$	Scenario 4 $a = 2.88$ $b = 2.88$
1. $b_{4k} = -1$; $b_{-4k} = 0, 0$	5332.06	6367.92	5724.42	6403.08
2. $b_{4k} = -1$; $b_{-4k} = -0.5, -0.5$	2774.51	3280.59	2980.51	3349.53
3. $b_{4k} = -1$; $b_{-4k} = -0.8, -0.5$	2346.70	2770.19	2506.48	2843.15
4. $b_{4k} = -1$; $b_{-4k} = -0.8, -0.8$	2006.60	2379.20	2161.50	2446.50
5. $b_{4k} = -1$; $b_{-4k} = -1, -1$	1625.89	1972.08	1773.92	2037.92

in Khetriwal et al. (2009) to estimate the unit collection cost, unit processing cost and transaction cost, and data in Yoshida et al. (2009) to estimate market demand.

We assume that demand functions are linear functions with a slope vector $b = [b_{4k}\, b_{-4k}]$ and a constant intercept a, where b_{4k} denotes the coefficient of price in demand market $k = 1, 2, 3$ and b_{-4k} denotes the coefficients of prices exporting to others. We vary b_{-4k} as five different combinations to study the impact of other demand markets on the total material flow. The demand functions are $d_k(p_4) = -0.973\, p_{4k} + b_{-4k}\, p_{-4k} + 580$, $k = 1, 2, 3$. We define the government subsidy in a linear form and assume that the subsidy functions for collector i and processor j are $S_{ij} = aq_{ij}$, $i = 1, 2,\ldots,12$; $j = 1, 2, 3$, $S_{jk} = bq_{jk}$, $j = 1, 2, 3$; $k = 1, 2, 3$, where a and b are indicated in Table 2.

3.2 *Case Study Result and the Impact of Subsidies on Flows*

We investigate the impact of government subsidies on the total collected amount, where the government only puts the subsidy at collectors (Scenario 1), processors (Scenario 2), both equally at collectors and processors (Scenario 3), and at collectors and processors with a double subsidy (Scenario 4). The corresponding total material flows under each scenario with different combinations on demand functions are shown in Table 2.

4 Summary

We investigate the individual behaviors of a decentralized reverse supply chain system, and formulate the general network as a variational inequality problem to obtain the equilibrium prices and material flows between tiers. From a large-scale case study, we construct a multitiered reverse supply chain network of laptop computers in Georgia, USA under four different subsidy scenarios. Several insights are drawn: (1) government subsidies efficiently encourage collectors and processors to recycle and remanufacture scrap laptop computers; (2) a higher level of subsides results in a higher total collection flow; (3) the scenario allocating all subsidies to collectors (upstream) outperforms the scenario allocating subsidies to processors (downstream) in terms of the total flow.

Acknowledgments This work was supported in part by the National Science Council, Taiwan, under Grant NSC99-2221-E-002-151-MY3.

References

Ben-Arieh D (1999) Network economics: a variational inequality approach, 2nd edn. Kluwer, Dordrecht

Ceng LC, Hadjisavvas N, Wong NC (2010) Strong convergence theorem by a hybrid extra gradient-like approximation method for variational inequalities and fixed point problems. J Glob Optim 46(4):635–646

Hong IH, Ammons JC, Realff MJ (2012) Examining subsidy impacts on recycled WEEE material flows. In: Goodship V, Stevels A (ed) Waste Electrical and Electronic Equipment (WEEE) Handbook, 1st edn. Woodhead Publishing, Cambridge, UK

Khetriwal DS, Kraeuchi P, Widmer R (2009) Producer responsibility for e-waste management: key issues for consideration—Learning from the Swiss experience. J Environ Manage 90(1):153–165

Nagurney A, Toyasaki F (2005) Reverse supply chain management and electronic waste recycling: a multitiered network equilibrium framework for e-cycling. Transp Res Part E 41(1):1–28

Nagurney A, Yu M (2012) Sustainable fashion supply chain management under oligopolistic competition and brand differentiation. Int J Prod Econ 135(2):532–540

Nagurney A, Zhang D (1997) Projected dynamical systems in the formulation, stability analysis, and computation of fixed-demand traffic network equilibria. Transp Sci 31(2):147–158

Nagurney A, Dong J, Zhang D (2002) A supply chain network equilibrium model. Transp Res Part E 38(5):281–303

Sodhi MS, Reimer B (2001) Models for recycling electronics end-of-life products. OR Spectrum 23(1):97–115

Yoshida A, Tasaki T, Terazono A (2009) Material flow analysis of used personal computers in Japan. Waste Manage (Oxford) 29(5):1602–1614

Zeng LC, Yao JC (2006) Strong convergence theorem by an extragradient method for fixed point problems and variational inequality problems. Taiwanese J Math 10(5):1293–1303

A Capacity Planning Method for the Demand-to-Supply Management in the Pharmaceutical Industry

Nobuaki Ishii and Tsunehiro Togashi

Abstract In the pharmaceutical industry, in order to secure a reliable supply of drags, the manufacturer tends to possess a production capacity much higher than the market demand. However, because of the severe competition and increasing product variety, the demand-to-supply management, which strategically supplies products to the market based on a collaborative strategy with the sales function and the production function in order to maximize profit, becomes a critical issue for any manufacturer in regards to improving his competitiveness and sustainability. In this paper, we propose a capacity planning method and a tool, developed with an engineering consulting company that can be used to support the demand-to-supply management in the pharmaceutical industry. The method synthesizes an initial manufacturing process structure and the capacity of each process unit based on the demand forecast and candidate equipment specifications at the first step. Then it improves the process structure in a step-by-step fashion at the second step. The developed tool supports the development and evaluation of the process structure from the perspective of the utilization of each process unit, investment cost, operation cost, and so on. We show the effectiveness of the developed method and the tool through a case study.

Keywords Demand-to-supply management · Engineering economy · Facilities planning

N. Ishii (✉)
Faculty of Information and Communications, Bunkyo University, 1100 Namegaya, Chigasaki 2538500 Saitama, Japan
e-mail: ishii@shonan.bunkyo.ac.jp

T. Togashi
CM Plus Corporation, 6-66 Sumiyoshi, Naka-Ku, Yokohama 2310013, Japan
e-mail: togashi@cm-plus.co.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_22,

1 Introduction

Over the last several decades, manufacturing industries have faced big changes in the business environment such as increasing global competition, increasing demand uncertainties, and so on. To survive and succeed in this severe business environment, manufacturing industries have been keen to improve their competitiveness with the introduction of advanced manufacturing technologies. For instance, SCM (Supply Chain Management) (Simchi-Levi et al. 2008) is expected to shorten lead times, reduce inventory levels, increase sales, and improve their capability to quickly respond to the market.

However, the shorted lead times, reduced inventory levels, and increased sales do not always attain the profit maximization. As Matsui (2009) pointed out by using the pair-strategic chart, the collaborative decision making among different functions, especially the sales function and the production function, is necessary to attain the profit maximization. Thus, most industries have recognized that the demand-to-supply management, which strategically supplies products to the market based on a collaborative strategy with the sales function and the production function in order to maximize profit, is critical for implementing successful SCM and for establishing a sustainable company in today's business environment.

It is also the same in the pharmaceutical industry. In the past, in order to secure a reliable supply of drags, the pharmaceutical manufacturer possessed a production capacity much higher than the market demand. Strong demand and long product life cycles also justify such excess capacity. However, the increase of cost and term length in the research and development of new drugs in the market carries substantial risk in the pharmaceutical industry. In addition, because of the popularity of generic drugs, most pharmaceutical manufacturers are under increasing pressure to change from mass production to small-lot production, and also to reduce manufacturing cost. For these reasons, successful implementation of the demand-to-supply management is a critical issue in the pharmaceutical industry. In particular, the advanced capacity planning for flexible production in response to the demand variation is required.

In this paper, we propose a capacity planning method and a tool, jointly developed by an engineering consulting company, CM Plus Corporation in Yokohama, Japan, intended to support the demand-to-supply management in the pharmaceutical industry. The method synthesizes an initial manufacturing process structure and the capacity of each process unit based on the demand forecast and candidate equipment specifications at the first step. Then it improves the process structure in a step-by-step fashion at the second step. The developed tool supports the development and evaluation of the process structure from the perspective of the utilization of each unit, investment cost, operation cost, and so on. We show the effectiveness of the developed method and the tool through a case study.

2 Overview of the Demand-to-Supply Management and Capacity Planning

One of the goals of demand-to-supply management is to improve corporate sustainability under today's uncertain and unforeseeable market conditions. The overall framework of demand-to-supply management consists of the business lifecycle management, the demand-to-supply strategic management, and demand-to-supply management (Hayashi et al. 2009) as depicted in Fig. 1.

The business lifecycle management creates products and markets, and designs a business plan from a long-term strategic perspective. Any company must decide the right withdrawal time from the market of matured products. The system for the long-term strategic perspective supports decisions for product release and revision as well as decisions for product portfolio management to improve corporate sustainability.

The demand-to-supply strategic management creates the demand development plan and the supply system plan, which are made based on the collaborative work by the sales function and the production function for maximizing profit from a mid-term perspective. The demand development plan includes the marketing strategy, pricing strategy, etc. The supply system plan includes the structure of production system, capacity expansion, outsourcing, etc.

From the short-term perspective, the demand-to-supply management creates the collaborative demand-to-supply plan, based on the strategic map developed using the concept of a pair-matrix table (Matsui 2002). The collaborative demand-to-supply plan is used to control the production rate as well as demand rate to maximize the profit in the uncertain business environment. An application software tool for the collaborative demand-to-supply planning, called the *planner*, is

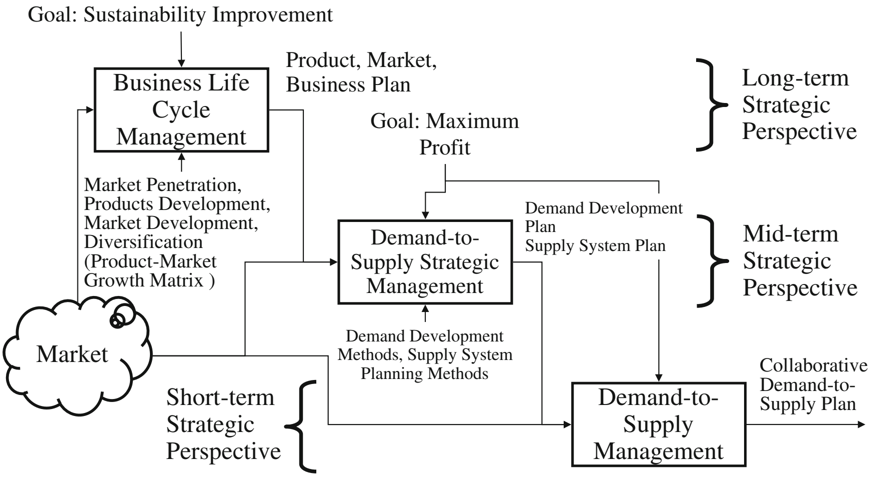


Fig. 1 An overall framework for demand-to-supply management

designed and demonstrated (Matsui et al. 2006; Hayashi et al. 2009). In most companies, Enterprise Resource Planning (Monk and Wagner 2008) has been widely implemented for corporate core information systems since the middle of the 1990s. ERP is a type of software application that fully integrates core business functions, including transaction processing, management information, etc. However, most ERP packages do not include the concept of demand-to-supply management. The *planner* is expected to complement the demand-to-supply management functions with EPR.

As a supply system planning method in the demand-to-supply strategic management from a mid-term strategic perspective, Ishii et al. (1997) developed a process synthesis method in consideration of the product lifecycle scenario and equipment reliability. Ishii (2004) developed a heuristic procedure for planning flexible production systems. Matsui et al. (2007) applied the procedure to making a mid-term supply system plan. In addition, Ohba et al. (2013) analyzed a rate of utilization on process unit for maximizing profit from the demand-to-supply strategic management perspective. However, those methods show no procedure and tool to design and assess the process structure and capacity in detail.

The capacity planning method and the tool explained in this paper are developed to design and evaluate the process structure and capacity of each process unit for the pharmaceutical manufacturing process. It works within the supply system planning method in the demand-to-supply strategic management from a mid-term strategic perspective. The tool supports the design and evaluation of the process structure from the perspective of utilization of each unit, investment cost, operation cost, and so on.

3 A Capacity Planning Method

The capacity planning method consists of the steps as shown in Fig. 2.

Product mix analysis evaluates the middle-term demand forecast on products. Material balancing calculates the quantities of raw materials required and products produced in consideration of the standard yield ratio in each process unit. Material balances provide the basic data for sizing equipment. Lot sizing determines production lot size of each product, and equipment allocation selects equipment in each process unit. Since lot sizing affects the number of changeovers and required capacity of each process unit, lot sizing and equipment allocation must be decided concurrently. Operation analysis evaluates the utilization, production time, and so on based on the lot sizing and equipment allocation of each lot in each process unit.

The method determines an initial manufacturing process structure and capacity of each process based on the demand forecast from product mix analysis and specifications in the equipment list at the first step. Then it improves the process structure in a step-by-step fashion at the second step by changing lot sizing and equipment allocation repeatedly until the utilization, production time, and lot size

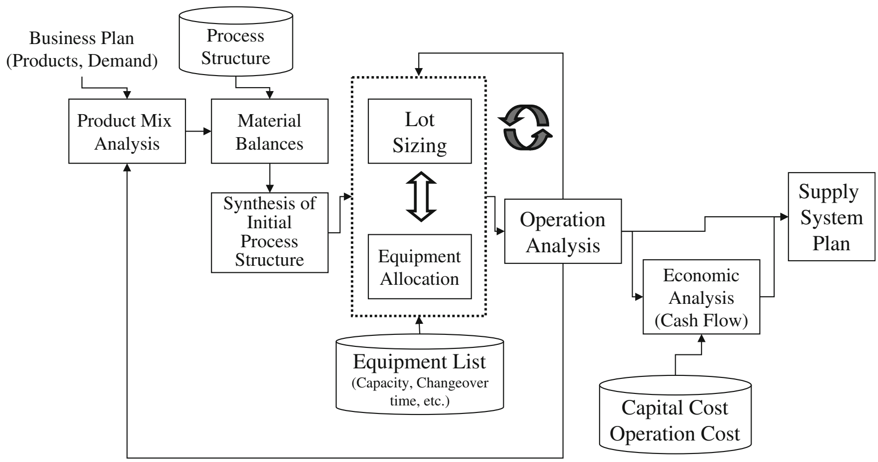


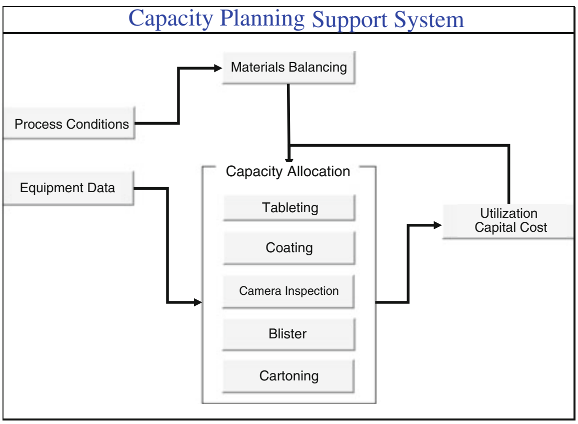
Fig. 2 An overall framework of capacity planning method

are validated in the operation analysis. When the utilization, production time, and lot size are not validated, the product mix analysis is reconsidered so as to match feasible supply capacity.

Figure 3 shows the structure of the capacity planning tool, which is jointly developed by CM Plus Corporation in Yokohama, Japan and Bunkyo University, based on the pharmaceutical manufacturing model.

The tool, where the pharmaceutical manufacturing process is embedded, has the capability to synthesize an initial manufacturing process structure and the capacity of each process unit, and to simulate the utilization, production time, and lot size. It also provides supports for validating lot sizing and equipment allocation in each process unit, and for improving the process structure.

Fig. 3 Structure of the capacity planning tool



4 An Example Problem

In this paper, we use the drag manufacturing process for solid dosage forms, shown in Fig. 4, as an example problem for demonstrating the effectiveness of the developed capacity planning method and the tool.

In this example, we assume 16 products are manufactured from four kinds of tablets. Namely, final products are diversified by the packaging variation as shown in Fig. 5. The amount of total annual production assumed 2,100 million tablets (MM Tablet). In addition, the amount of annual production of each product is shown in Table 1. The equipment specifications to be selected by the capacity planning method are assumed as shown in Table 2.

Table 3 shows the capacity plan, i.e., selected equipment and the number products for manufacturing in each process unit, allocated by the developed capacity planning method and the tool. In addition, utilization of equipment is shown in Table 3. In this case, the process structure is made so as to attain around 85 % utilization by the minimum investment cost.

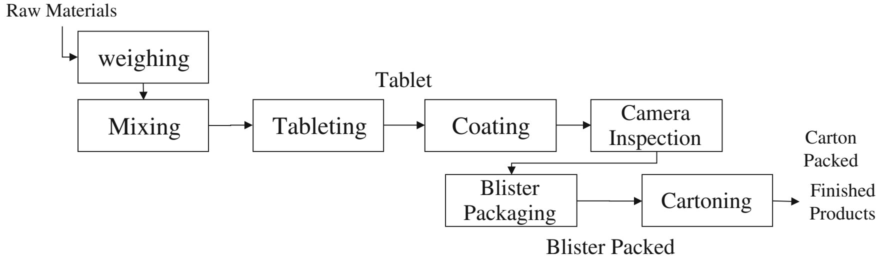


Fig. 4 A drug manufacturing process for solid dosage forms

Fig. 5 Diversification of final products

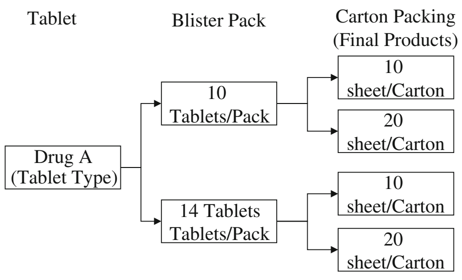


Table 1 Annual production of each product

Product			Annual production (MM Tablet/Year)	Conversion (Tablet/Carton)
Tablet	Blister type (Tablet/Pack)	Carton type (Sheet/Carton)		
X	10	A: 10; B: 20	A: 300; B: 200	A: 100; B: 200
	14	A: 10; B: 20	A: 300; B: 200	A: 140; B: 280
Y	10	A: 10; B: 20	A: 200; B: 100	A: 100; B: 200
	14	A: 10; B: 20	A: 200; B: 100	A: 140; B: 280
Z	10	A: 10; B: 20	A: 100; B: 100	A: 100; B: 200
	14	A: 10; B: 20	A: 50; B: 50	A: 140; B: 280
W	10	A: 10; B: 20	A: 50; B: 50	A: 100; B: 200
	14	A: 10; B: 20	A: 50; B: 50	A: 140; B: 280

Table 2 Equipment list

Process	Equipment	Capacity	Unit	Changeover (Hr/Co)	Investment cost (MMJPY)
Tableting	#1 Tablet press	1,667	Tablet/Min.	0.5	31
	#2 Tablet press	3,333		1.0	50
	#3 Tablet press	6,667		1.5	80
Coating	#1 Coater	660,000	Tablet/Cycle	6.0	94
	#2 Coater	937,500		6.0	120
	#3 Coater	1,875,000		6.0	195
Camera inspection	#1 Camera inspection	2,000	Tablet/Min.	0.5	37
	#2 Camera inspection	4,000		1.0	60
	#3 Camera inspection	6,000		1.5	80
Blister packaging	#1 Blister packer	3,000	Tablet/Min.	1.0	62
	#2 Blister packer	6,000		2.0	100
Cartoning	#1 Cartoner	100	Carton/Min.	0.5	32
	#2 Cartoner	200		1.0	53
	#3 Cartoner	300		1.5	70

Table 3 A Capacity Plan (T:Tablet C:Carton Y:Year)

Process	Equipment	No. of equipment	No. of allocated Products	Production (MM T/Y)	Utilization (%)	
					Production	Changeover
Tableting	#3 Tablet press	6	4	2,645	68.9	14.1
Coating	#3 Coater	4	4	2,381	39.7	39.7
Camera inspection	#2 Camera inspection	2	2	510	66.4	6.25
	#3 Camera inspection	4	2	1,632	70.9	14.1
Blister pack	#1 Blister packer	1	2	202	70.2	10.0
	#2 Blister packer	5	6	1,919	66.6	19.0
Carton	#3 Cartoner	1	16	14 (MM C/Y)	50.2	28.1

5 Conclusion

In this paper, we proposed a capacity planning method and a tool, jointly developed by an engineering consulting company, CM Plus Corporation in Yokohama, Japan, intended to support the demand-to-supply management in the pharmaceutical industry. The method synthesizes an initial manufacturing process structure and the capacity of each process unit based on the demand forecast and candidate equipment specifications of each process unit at the first step. Then it improves the process structure in a step-by-step fashion at the second step. We showed the effectiveness of the developed method and the tool through a case study.

There are several issues that require future development. For example, an algorithm to find optimum lot sizing and equipment allocation simultaneously should be developed. In addition, the function that evaluates the process structure using production scheduler should be developed to improve the accuracy of the capacity plan.

References

Hayashi A, Ishii N, Matusi M (2009) A theory and tools for collaborative demand-to-supply management in the SCM Age. Oper Suppl Chain Manage 2:111–124

Ishii N, Fuchino T, Muraki M (1997) Life cycle oriented process synthesis at conceptual planning phase. Comput Chem Eng 21:S953–S958

Ishii N (2004) A heuristic procedure for planning flexible production systems for competitive supply chains. Paper presented at the 1st international congress on logistics and SCM systems, Waseda University, Tokyo, 2004

Matsui M (2002) A management game theory: economic traffic, leadtime and pricing setting. J Jpn Ind Manage Assoc 53:1–9

Matsui M, Takahashi Y, Wang Z (2006) A construction and theory of the manager-aided planner for collaborative demand and supply. J Jpn Ind Manage Assoc 57:120–131

Matsui M, Nakamura T, Ishii N (2007) A demand-to-supply development system for sustainable business strategies and a case study. J Jpn Ind Manage Assoc 58:307–316

Matsui M (2009) Manufacturing and service enterprise with risks. Springer, New York

Monk EF, Wagner BJ (2008) Concepts in enterprise resource planning, 3rd edn. Course Technology, Boston

Ohba M, Matsui M, Ishii N, Yamada T (2013) Case study of generalized material flow cost accounting in consideration of a rate of utilization. Submitted to UTCC International journal of business and economics

Simchi-Levi D, Kaminsky P, Simchi-Levi E (2008) Designing and managing the supply chain: concepts, strategies and case studies. Irwin McGraw-Hill, New York

Storage Assignment Methods Based on Dependence of Items

Po-Hsun Kuo and Che-Wei Kuo

Abstract According to historical customer orders, some items tend to be ordered at the same time, i.e., in the same orders. The correlation of items can be obtained by the frequency of these items present at the same orders. When the dependent items are assigned to adjacent storage locations, order pickers will spend less time to complete customer orders, compared to the other storage assignment which treats items independently. This research provides optimization models to make sure that the storage locations of highly dependent items are nearby. Although the provided nonlinear integer programming can be transformed to a linear integer model, it is still too complex to deal with large problems. For a large number of items, two heuristic algorithms are proposed according to properties of optimal solutions in small problems. Numerical experiments are conducted to show the results of the proposed algorithms with the comparison of the random and class-based storage assignment.

Keywords Storage assignment · Item dependence · Order picking · Optimization models · Heuristic algorithms

1 Introduction

Order picking is one of the most popular research topics regarding warehouse operations since time and labors used are much more intense compared to the other operations in the warehouse (Heragu 1997). Therefore, significantly reducing cost

P.-H. Kuo (✉) · C.-W. Kuo
Industrial Management, National Taiwan University of Science and Technology, #No. 43, Sec. 4, Keelung Road., Da'an District, Taipei City 106, Taipei, Taiwan
e-mail: phkuo@mail.ntust.edu.tw

C.-W. Kuo
e-mail: grandtheftauto.gta@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_23,

in order picking processes will result in significant improvement in the supply chain. One way to make this improvement is to develop a more efficient storage assignment method. Traditional methods existed for storage assignment policies in warehouses are random storage, class-based storage, and dedicated storage. The class-based storage and dedicated storage locate fast-moving items close to I/O point so that the distance involved in picking routes can be reduced. In a unit load order picking perspective, class-based and dedicated storage are indeed effective because items are independent. However, when all items in an order should be retrieved together, the distances between these items become critical, but class-based and dedicated storage which only consider independent item demands are less effective.

This research focuses on the importance of item correlations as a way of reducing the total travel distance in one picking route. The proposed optimization model ensures that items which tend to be ordered together are located nearby. However, due to the complexity of the problem, it is practically not easy to obtain optimal solutions for large problems. Therefore, following some properties of the optimal solutions in small problems, two heuristic algorithms are proposed to deal with large problems. Finally, numerical experiments are conducted to compare the performances between proposed heuristic algorithms and traditional storage assignment policies such as random and class-based storage.

2 Literature Review

The storage part of a warehouse consists of SKU-department assignment, zoning, and storage location assignment. The decisions regarding to SKU-department assignment are assigning items to different warehouse departments and space allocation. In a warehouse with zones, the assignment of SKUs to zones and pickers to zones are also important issues. The storage location assignment can have various decisions to make according to policies used in each warehouse, such as random, class-based and dedicated storage.

A number of methods of order picking can be employed in a warehouse, such as single-order picking, batching and sort-while-pick, batching and sort-after-pick, single-order picking with zoning, and batching with zoning (Yoon and Sharp 1996). Each order picking method consists of some or all of the following basic steps: batching, routing and sequencing, and sorting Gu et al. (2007).

According to Tompkins et al. (2003), order picking is the process of picking products from the storage locations to fill customer orders, and is known as the most important activity in warehouses. Surveys have shown that order picking consumes more than 50 % of the activities in a warehouse. It is therefore not surprising that order picking is the single largest expense in warehouse operations (Heragu 1997).

The most common objective of order-picking systems is to maximize the service level subject to resource constraints such as labor, machines, and capital

(Goetschalckx and Ashayeri 1989). Also, short order retrieval times imply high flexibility in handling late changes in orders. Minimizing the order retrieval time (or picking time) is, therefore, a need for any order-picking system.

There are numerous ways to assign products to storage locations within the storage areas. Three most frequently used storage assignment are: random storage, dedicated storage, and class-based storage. For the importance of reducing order picking time, however, traditional literatures miss the issue of dependence in customer demand. It has come to our attention that if items in the same order are located as close to one another as possible, the travel distance could be significantly reduced. Rosenwein (1994) describes an optimization model that identifies clusters of warehouse items that tend to be ordered together. Jane and Laih (2005) construct a model using a similarity measurement which measures the co-appearance of any two items in customer orders, and then develop a heuristic algorithm to balance the workload among all pickers in different zones. Unlike any other clustering or family grouping literatures where a storage area is separated into several clusters and random assignment is applied within the clusters, this paper focuses on assigning related items as close as possible to achieve minimum travel distance during one single pick.

3 Model Establishment

Travel distance will decrease if these correlated items are located around each other. The proposed method is to assign these items close to each other so the order picker can travel a shorter distance while retrieving multiple items during one picking route. This paper focuses on single block, single-level warehouses with manual order picking operations in which the order picker walks or drives in the pick area to retrieve items. Picked items are placed on a pick device and the order picker takes it with him/her and proceeds to the next item. Every storage location has the same size, and the length and width of a storage location are the same. The I/O point is located at the left lower corner of the warehouse.

Notation used in the optimization model and heuristic algorithms is listed as follows:

N Number of items = Number of locations in the warehouse

a, b Index of items, $a,b \in \{1, 2,3,\ldots,N\}$

i, j Index of locations, $i, j \in \{1,2,3,\ldots,N\}$

$$X_{a,i} = \begin{cases} 0, & \textit{If item a is not assigned to location i} \\ 1, & \textit{If item a is assigned to location i} \end{cases}$$

$$X_{b,j} = \begin{cases} 0, & \textit{If item b is not assigned to location j} \\ 1, & \textit{If item b is assigned to location j} \end{cases}$$

$D_{i,\,j}$ Distance from location i to location j

$P_{a,\,b}$ Probability of both item a and b being requested in the same order, which can be obtained from the co-appearance frequency of a and b in the warehouse's historical data.

The major existed storage policy which also considers item popularity is class-based storage. The reason why this model is developed is that an order may contain more than one item. When there are multiple items in an order, it is not suitable for class-based storage because the probability of all items being in the same class is low. The items in an order may be located across the warehouse, in order to reduce the travel distance involved in an order, the correlations of any two items become important information. In this model, the correlation information of two items a and b, $P_{a,\,b}$, is considered. This information can be obtained from the co-appearance frequency of any two items in same orders from the warehouse's historical statistic data. The reason of using exactly two items' correlation and not three or more items' correlation is that the problem will become too complex and virtually impractical to solve. If only one item frequency is considered, it will be the same as class-based storage.

$$\text{Minimize} \sum_{a<b} \sum_{i \neq j} P_{a,b} \cdot D_{i,j} \cdot Y_{a,b,i,j} \tag{1}$$

$$\text{Subject to} \sum_{i} X_{a,i} = 1, \ \ a = 1, \ 2, \ldots, N \tag{2}$$

$$\sum_{a} X_{a,\,i} = 1, \ \ i = 1, \ 2, \ldots, N \tag{3}$$

$$Y_{a,\,b,\,i,\,j} \leq X_{a,\,i}, \ \ a<b \in (1, \ldots, \ N), \ \ i \neq j \in (1, \ \ldots, N) \tag{4}$$

$$Y_{a,\,b,\,i,\,j} \leq X_{b,\,j}, \ \ a<b \in (1, \ldots, N), \ \ i \neq j \in (1, \ldots, N) \tag{5}$$

$$\sum_{a} \sum_{b} \sum_{i} \sum_{j} Y_{a,\,b,\,i,\,j} = N(N-1)/2 \tag{6}$$

$$Y_{a,\,b,\,i,\,j} \geq 0, \ \ a<b \in (1, \ldots, N), \ \ i \neq j \in (1, \ldots, N) \tag{7}$$

The objective of the model, (1), is to assign items with higher correlations as close as possible. Equations (2) and (3) indicate that item a will be located in one of the storage locations, and location i is occupied by one of N items. Equations (4) and (5) are required because $Y_{a,\,b,\,i,\,j}$ cannot exceed either $X_{a,\,i}$ or $X_{b,\,j}$ due to the assumption that the variables are binary. Given that the constant N is the total number of items or locations in the warehouse, as Eq. (6) shows, the sum of all $Y_{a,\,b,\,i,\,j}$ should be exactly the number of all possible combinations of any two items or locations, that is C_2^N. Otherwise, all $Y_{a,b,i,j}$'s will be zero due to the minimization objective.

The problem can relate to a knapsack problem because the decision of the problem is whether an item needs to be put in a location or not. A knapsack problem is an example of a NP-complete problem and a knapsack problem can be solved in pseudo-polynomial time by dynamic programming. However, any single item has limited optional locations (based on the properties provided) because the decision for the assigned locations will affect the objective function value. In other words, multiple locations lead to a large number of possible solving combinations and increase the complexity of the problem. As a result, the problem is NP-hard. It is clear that finding optimal solutions to large problems will take a lot of time. Therefore, two algorithms are developed to find heuristic solutions of large problems.

In Algorithm 1, the warehouse is transformed into one-dimensional scale before the assigning process begins. The reason is to reduce the number of situations of any two locations with equal distances in the two-dimensional warehouse. After the assignment is finished, the one-dimensional assignment result is transformed back to its original two-dimensional warehouse locations. As a result, if the warehouse shape is closer to one-dimension scale, for instance, flat and wide, algorithm 1 will be more effective.

Algorithm 1

1. Number the location closest to I/O as 1.
2. Number the other storage locations based on the sequence of $D_{1,j}$, $j \neq 1$. After the numbering scheme, the two-dimensional warehouse becomes one-dimensional scale.
3. Assign items A and B with least popularities to location 1 and location N. The set of assigned items is $S = \{A, B\}$.
4. Assign item C with the largest popularity to the central location of the sequence. $S = S + C$.
5. Search for the first gap from location 1. The gap indicates that locations between the assigned items X and Y are not occupied.
6. Assign item i with the maximal value of $P_{X,i} + P_{Y,i}$, $i \neq S$ to the center of the gap. $S = S + i$ (the new assigned item).
7. If all items are assigned, go to step 8. Otherwise, go to step 5.
8. Transform the one-dimensional scale to the original warehouse configuration.

In algorithm 1, the distance factor of the objective function is simplified by transforming the warehouse into one-dimensional sequence. However, this procedure does not accurately interpret the meaning of the objective function that both correlation probability (P) and distance (D) should be considered at the same time. Therefore, another algorithm, algorithm 2, is developed to check the effect of considering both factors simultaneously.

Algorithm 2

1. Assign items A and B with least popularities to location 1 and N, where location 1 is closest to I/O and location N is furthest from I/O. The set of assigned items is $S = \{A, B\}$.

2. Assign item C with the largest popularity to the central location. $S = S + C$.
3. Assign item i to location l with $\underset{i \notin S, l \notin l_S}{Min} \sum_X \sum_{l_X} P_{X,i} \cdot D_{l_X,l}$ for all unassigned items i and locations l. $X \in S$ (assigned items), and the location of assigned item X is $l_X \in l_S$ (occupied locations), $S = S + i$ (the new assigned item).
4. Repeat step 3 until all items are assigned.

4 Numerical Examples

In this section, a set of small examples with 8 items are presented. Three $P_{a,b}$ matrixes are randomly generated from 0 to 0.5. The shapes of warehouses used in the example are 2 × 4 and 4 × 2 (columns × rows), and the configuration of parameters w_a (the width of each pick aisle), w_c (the width of each cross aisle), and w_s (the length and width of one storage location) are listed in Table 1. In the example, the optimal solutions obtained from AMPL optimization software are presented to compare with both algorithms and random and class-based storage.

In the above examples, algorithm 2 performs better than algorithm 1 in the 2 × 4 cases, and algorithm 1 does better than algorithm 2 in the 4 × 2 case. The reason might be the shape property mentioned in Sect. 3, algorithm 1 will be more effective if the warehouse is wide and flat.

Compared to the optimal solutions, the algorithms appear to have very small differences, and the other storage policies also have small differences. The reason for such small differences might be the objective function containing too much information so that the improvement in the algorithms is hard to see.

Table 1 Examples of a warehouse with 8 items

Config.	Results					
		Random	Class-based	Alg. 1	Alg. 2	Optimum
2 × 4	Pab 1	1.92958	2.11296	1.93996	1.86759	1.7025
$w_s = w_c = 1$	Pab 2	2.03775	1.78435	1.84521	2.0022	1.64872
$w_a = 2$	Pab 3	1.95539	2.03687	1.85773	1.84422	1.63214
4 × 2	Pab 1	4.26611	5.0153	3.81442	3.84555	3.66269
$w_s = w_c = 1$	Pab 2	4.27593	3.84111	3.76357	3.86013	3.57586
$w_a = 2$	Pab 3	4.26611	3.94976	3.59457	3.96918	3.35801
2 × 4	Pab 1	3.29724	3.5391	3.29698	2.96615	2.91804
$w_s = w_c = 2$	Pab 2	3.52026	3.08925	3.05077	2.96401	2.81039
$w_a = 3$	Pab 3	3.35083	3.56994	3.09147	3.25288	2.73515

5 Conclusions

This research wants to improve the efficiency of order picking processes. Order picking is one of the most expensive operations in the warehouse. Therefore, it is also a critical part of the warehouse, even in the supply chain. One way to improve the order picking processes is to enhance the efficiency of storage assignment policies. In this research, a linear integer programming model is developed to ensure the highly related items are located nearby. As mentioned in Sect. 3, this model is NP-hard, so it is very difficult to solve large problems. Therefore, two heuristic algorithms are proposed to deal with large problems. After the algorithms are proposed, the data results are compared with random and class-based storage policies.

In this research, the distance function in Sect. 3 provides a way to obtain the shortest distance between any two locations in the warehouse, which can be very useful in developing storage assignment policies. Furthermore, the main difference from the other literatures is that this research considers items' correlations. Unlike the clustering assignment methods, there is no cluster in the developed assignment methods. Every item is assigned to the location according to certain calculations in order to shorten the distances between correlated items. The information of interrelated items is an important factor to optimize storage assignment methods, and applying this information to improve order picking process is the main contribution of this research.

References

Goetschalckx M, Ashayeri J (1989) Classification and design of order picking systems. Logistics World June, pp 99–106

Gu J, Goetschalckx M, McGinnis LF (2007) Research on warehouse operation: a comprehensive review. Eur J Oper Res 177:1–21

Heragu SS (1997) Facilities design. PWS Publishing Company, Boston

Jane CC, Laih YW (2005) A clustering algorithm for item assignment in a synchronized zone order picking system. Eur J Oper Res 166:489–496

Rouwenhorst B, Reuter B, Stockrahm V, van Houtum G, Mantel R, Zijm W (2000) Warehouse design and control: framework and literature review. Eur J Oper Res 122(3):515–533

Tompkins JA, White JA, Bozer YA, Frazelle EH, Tanchoco JMA (2003) Facilities planning. Wiley, Hoboken

Yoon CS, Sharp GP (1996) A structured procedure for analysis and design of order pick systems. IIE Trans 28:379–389

Selection of Approximation Model on Total Perceived Discomfort Function for the Upper Limb Based on Joint Moment

Takanori Chihara, Taiki Izumi and Akihiko Seo

Abstract The aim of this study is to formulate the relationship between the total perceived discomfort of the upper limb and perceived discomforts of each degree of freedom (DOF). The perceived discomforts of each DOF were formulated as functions of the joint moment ratio based on the results of previous study, and then the function approximation model for the total perceived discomfort was investigated. The summary score of the rapid upper limb assessment (RULA), which is assumed as the total perceived discomfort, and the perceived discomforts of each DOF were taken as the objective and explanatory variables respectively. Three approximation models (i.e., the average, maximum, and radial basis function (RBF) network) were compared in terms of the accuracy of predicting the total perceived discomfort, and the RBF network was selected because its average and maximum error were lowest.

Keywords Perceived discomfort · Function approximation · RULA · Radial basis function network · Psychophysics · Biomechanics

1 Introduction

The physical workload should be evaluated quantitatively and objectively so as to design a work environment that reduces the workload and prevents musculoskeletal disorders. In addition, the time that can be allocated to improve work

T. Chihara (✉) · A. Seo
Tokyo Metropolitan University, 6-6, Asahigaoka, Hino, Tokyo, Japan
e-mail: chihara@sd.tmu.ac.jp

A. Seo
e-mail: aseo@sd.tmu.ac.jp

T. Izumi
Graduate School of Tokyo Metropolitan University, 6–6, Asahigaoka, Hino, Tokyo, Japan
e-mail: izumi-taiki@sd.tmu.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_24,

environments are decreasing with each passing year, in conjunction with the shortening of the development period. That is, an ergonomic physical load evaluation should be performed effectively in a short time. Biomechanical analysis evaluates the physical load based on the equilibrium of force with a rigid link model of the human body (Chaffin et al. 2006). The reactive moment on each joint against external forces (hereafter referred to as "the joint moment") is regarded as the indicator of physical load. The joint moment can be calculated by computer simulation such as commercial digital human software (LaFiandra 2009); therefore, the evaluation with biomechanical analysis can be applied to the efficient ergonomic design of work environment (Chaffin 2007).

In our previous study, we formulated the relationship between the perceived discomfort and joint moment for twelve joint motion directions of the upper limb (Chihara et al. 2013). However, the study has not investigated the evaluation method for total perceived discomfort of multiple joint moments. The total perceived discomfort function should be formulated so as to determine the order of multiple design solutions of work environment. Several observational methods such as RULA and OWAS are used to assess the total physical workload (McAtamney and Corlett 1993; Karhu et al. 1977). These methods are easy to use, but they cannot perform detailed evaluation of total workload, because their worksheets roughly classify the postures of workers and lifting weights. In addition, the observation methods consider only the weight of load handled, but they do not consider the direction of force.

The objective of the present study was to formulate the relationship between the total perceived discomfort of the upper limb and perceived discomforts of each joint motion. The biomechanical analysis was performed based on the classification of postures and load in the RULA. The summary score of RULA was set as the objective variable, and the perceived discomforts of each degree of freedom (DOF) were set as the explanatory variables. The response surfaces of total perceived discomfort were approximated by three different approximation models: the average, maximum, and radial basis function network (RBF) (Orr 1996). The accuracy of response surfaces was compared, and the proper approximation model was investigated.

2 Method

2.1 Selection of Calculating Condition from RULA

The calculating conditions of biomechanical analysis (i.e., the posture of the upper limb and the weight of load handled) were determined based on the posture and load classification of the RULA. In the RULA method, the sub-summary scores are calculated for the two groups: the arm and wrist (Group A), and the neck, trunk, and leg (Group B). Then the summary score is calculated by sum of the two

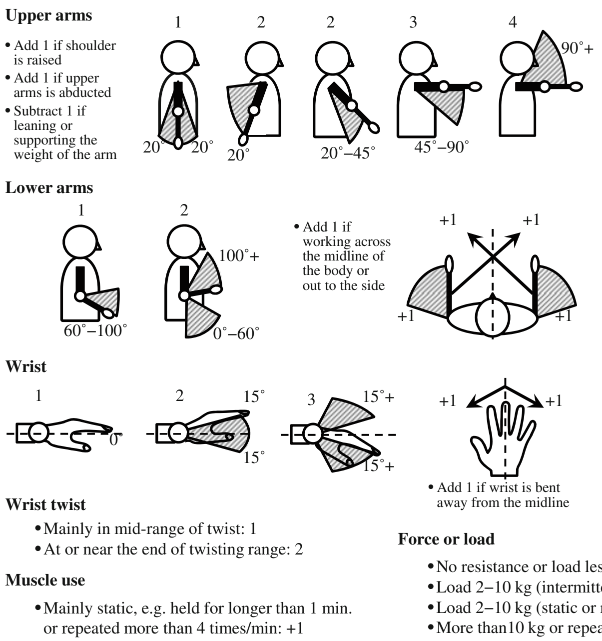


Table for upper limb posture

Upper arm	Lower arm	Wrist 1		Wrist 2		Wrist 3		Wrist 4	
		Wrist twist 1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Fig. 1 RULA sheet for the arm and wrist (Group A) (*Source* McAtamney and Corlett (1993) RULA: a survey method for the investigation of work-related upper limb disorders, Appl Ergon, 24(2), 91–99)

sub-summary scores. In this study, we focused on the total perceived discomfort of the upper limb; hence, the criteria of Group A in the RULA were used to select the calculating conditions. The calculation of sub-summary score for Group A consists of four parts on the upper limb posture (i.e., the upper arm position, lower arm position, wrist position, and wrist twist), one part on duration of muscle use, and one part on the amplitude of load handled. Each part has several ranges which are assigned a score as shown in Fig. 1. First, the score for the posture part is determined based on the worksheet for the posture score shown in Fig. 1. The scores for the duration of muscle use and the amplitude of load are added to that of the posture part, and then the sub-summary score for the upper limb is obtained.

In this study, the levels of each part for the biomechanical analysis were determined as shown in Table 1. Among the six parts of Group A, the wrist twist and the duration of muscle use were ignored, because these conditions have not been considered in the previous research (Chihara et al. 2013). With respect to the remaining four categories, we selected the almost middle value of the ranges as the levels for calculating conditions. In addition, to cover all scores of RULA efficiently, the one condition was selected when the multiple conditions had the same score. Then, the five, three, four and three levels were determined for the upper arm position, lower arm position, wrist position, and amplitude of load handled respectively; thus, the number of calculating conditions was 180. It should be note

Table 1 Calculating conditions of biomechanical analysis

Category	Items of each category	Level 1	Level 2	Level 3	Level 4	Level 5
Upper arm	Flexion angle of shoulder joint (deg)	0	0	65	135	135
	Abduction angle of shoulder joint [deg]	0	45	0	0	45
Lower arm	Flexion angle of elbow joint (deg)	80	120	120	NA	NA
	Internal rotation angle of shoulder joint (deg)	0	0	40	NA	NA
Wrist	Flexion angle of wrist joint (deg)	0	10	50	50	NA
	Ulnar deviation angle of wrist joint (deg)	0	0	0	30	NA
Force	Load (N)	0	59	137	NA	NA

that the sub-summary score of calculating conditions depicted in Table 1 range from 1 to 10. In addition, the sub-summary score is normalized to [0, 1], and the normalized score is used as the objective variable for the function approximation.

2.2 Biomechanical Analysis for Selected Conditions

The biomechanical analyses were conducted for the selected 180 conditions so as to calculate the joint moments. The digital human model for the analysis was constructed based on the 50 percentile of Japanese male (Kouchi and Mochimaru 2005). That is, 171 cm in body height and 63.7 kg in body weight. The joint moments for each DOF were calculated by the biomechanical analysis. Then the calculated joint moments were divided by the maximum joint moment of each joint motion direction (hereafter referred to as "the joint moment ratio r ($r = [0, 1]$)"). Here, the maximum joint moments that human can exert were quoted from Chaffin et al. (2006). The perceived discomfort of each joint motion direction was calculated by the following equations (Chihara et al. 2013):

$$f_1(r) = \frac{0.986}{1 + \exp\{-7.56(r - 0.354)\}} \quad (1)$$

$$f_2(r) = \frac{0.978}{1 + \exp\{-9.93(r - 0.234)\}} \quad (2)$$

where f_1 and f_2 denote the perceived discomfort scores for except the elbow flexion and the elbow flexion respectively. In addition, it should be note that f_1 and f_2 range from 0 to 1; and the higher score indicates the higher physical load. In this study, the upper limb has 6 DOF: the three DOF of the shoulder joint (i.e., extension–flexion, adduction–abduction, and internal rotation–external rotation), one DOF of the elbow joint (i.e., extension–flexion), and two DOF of the wrist joint (i.e., extension–flexion and ulnar deviation–radial deviation). Therefore, the perceived discomforts of six DOF were calculated.

2.3 Approximation of Total Discomfort Function and Evaluation of Appropriate Model

We assume that the total discomfort is dominated by the average of discomforts of each DOF in the range that the discomforts of each DOF are relatively low. However, the total discomfort may be dominated by the maximum value of discomforts of each DOF in the range that one or more discomforts of each DOF is relatively high. In addition, it is possible that the relationship between the total discomfort and the discomforts of each DOF is a weakly nonlinear function. Therefore, in this study, the three function approximation models were used: the average model, maximum model, and RBF. The RBF performs well in terms of accuracy and robustness, irrespective of the degree of nonlinearity (Jin et al. 2001). Among the three models, the average and maximum models are set as follows:

$$T = \frac{a \cdot \sum_{i=1}^{6} w_i}{6} \tag{3}$$

$$T = a \cdot \max_i w_i \tag{4}$$

where T and w_i denote the total perceived discomfort (i.e., the objective variable) and the perceived discomfort of ith DOF (i.e., the explanatory variable), respectively, and a is regression coefficient. The normalized sub-summary score of RULA is set as the objective variable, and the perceived discomforts of the upper limb are set as the explanatory variables. The regression coefficient is obtained by the least-square method. The parameters proposed by Kitayama and Yamazaki (2011) are adopted for the prediction by the RBF. Please refer to Orr (1996) about the details of RBF. In addition to all calculating conditions, the response surfaces were approximated for two groups of calculating conditions that were divided based on the amplitude of discomforts of each DOF. In this study, the calculating conditions was divided into the low discomfort group that the all discomfort scores of each DOF below 0.5, and the high discomfort group that one or more discomfort scores exceeds 0.5.

The accuracy of the three response surfaces were compared by the average absolute error (AAE). The AAE for ith function model was calculated as follows:

$$AAE_i = \frac{\sum_{j=1}^{n} \left| T_j - \hat{T}_{ij} \right|}{n} \tag{5}$$

where, T_j and $\hat{T}_{ij}$ denote the normalized sub-summary score and the approximated total perceived discomfort for j-th calculating condition of the biomechanical analysis n is the number of the calculating conditions that are used for constructing the response surfaces. The AAEs of response surfaces are compared between the three approximation models. One-way ANOVA was conducted at the 5 % significance level, and post hoc tests were carried out to compare the three models.

Table 2 Regression coefficient of the average and maximum models

Approximation models	Low group	High group	All
Average	3.53	1.70	1.79
Maximum	1.86	0.745	0.783

3 Result

The total perceived discomfort was predicted by using the calculating data of the low discomfort group, high discomfort group, and all data. Here, low group and high group had 77 and 103 data respectively. Table 2 shows the regression coefficients of the average and maximum models for each data set group. The result of ANOVA shows that there is the main effect of approximation model irrespective of the data set groups. Figure 2 shows the AAE of the three approximation models. Among the three models, the AAE of RBF is significantly lower than that of the average and maximum models irrespective of the data set group. Compared with the average and maximum models, in the case of low group, there is no significant difference, but the AAE of the average model is lower than that of the maximum model. In contrast, in the case of high group, the AAE of the maximum group is lower than that of the average model with 1 % significant level. Moreover, in the case of all calculating data, the AAEs of the average and maximum models are almost the same.

4 Discussion

According to Fig. 2, the accuracy of the average model is greater than that of the maximum model in the case of low discomfort group. Therefore, in the range that the discomforts of DOF are relatively low, the total discomfort is more affected by the average of discomforts of each DOF than by the maximum value of them. In

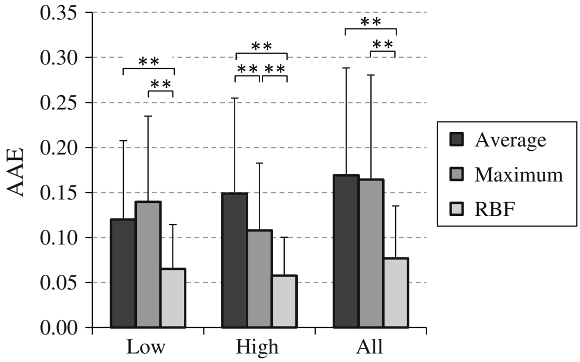


Fig. 2 Comparison of average absolute error between the three approximation model

addition, the accuracy of the maximum model is greater than that of the average model in the case of high discomfort group; hence, the total discomfort is affected by the maximum value of the discomforts of each DOF in the range that the discomforts of DOF are relatively high. This is consistent with the premise that the relationship between the total discomfort and discomforts of each DOF varies by the amplitude of discomforts of each DOF.

The AAEs of RBF are lower than that of the average and maximum models irrespective of the amplitude of perceived discomfort. The RBF can predict nonlinear functions with good accuracy; therefore, the relationship between the total perceived discomfort and discomforts of each DOF may be nonlinear. In addition, the RBF shows the best accuracy in the case of all calculating condition. The AAE of the RBF for the all condition is approximately 8 %, so that the response surface predicted by the RBF perhaps has the sufficient accuracy. Thus, the RBF is preferable approximation method as the total perceived discomfort function among the three approximation models. However, lots of data sets are required to construct the response surface with sufficient accuracy by using the RBF. Therefore, when the sufficient number of data sets can be obtained, the RBF is recommended. However, when a number of data sets are hardly obtained, the average and maximum models may be used depend on the amplitude of discomforts of each DOF. That is, when the discomforts of each DOF are relatively low, the average model is recommended; conversely, when they are relatively high, the maximum model is recommended.

5 Conclusions

In this study, function approximation model for the total perceived discomfort of the upper limb is investigated. The major findings are as follows:

1. In the range that the discomforts are relatively low, the average model provides better fit as the total perceived discomfort function than the maximum model. Conversely, in the range that the discomforts are relatively high, the maximum model provides better fit than the average model.
2. The AAE of the RBF is the lowest among the three function approximation models irrespective of the data set group. Therefore, the RBF is the preferable approximation model among the three models.

Acknowledgments This work was supported by JSPS KAKENHI Grant Number 24760123.

References

Chaffin DB (2007) Human motion simulation for vehicle and workplace design. Hum Factors Ergon Manuf 17(5):475–484

Chaffin DB, Andersson GBJ, Martin BJ (2006) Occupational biomechanics, 4th edn. Wiley, New York

Chihara T, Izumi T, Seo A (2013) Perceived discomfort functions based on joint moment for various joint motion directions of the upper limb. Appl Ergon. doi:10.1016/j.apergo.2013.04.016

Jin R, Chen W, Simpson TW (2001) Comparative studies of metamodeling techniques under multiple modeling criteria. Struct Multidisc Optim 23(1):1–13

Karhu O, Kansi P, Kuorinka I (1977) Correcting work postures in industry: a practical method for analysis. Appl Ergon 8(4):199–201

Kitayama S, Yamazaki K (2011) Simple estimate of the width in Gaussian kernel with adaptive scaling technique. Appl Soft Comput 11(8):4726–4737

Kouchi M, Mochimaru M (2005) AIST Anthropometric database, national institute of advanced industrial science and technology. H16PRO 287. http://riodb.ibase.aist.go.jp/dhbodydb/91-92/. Accessed 15 May 2013 (in Japanese)

LaFiandra M (2009) Methods, models, and technology for lifting biomechanics. In: Duffy VG (ed) Handbook of digital human modeling. CRC Press, New York, pp 8-1–8-27

McAtamney L, Corlett EN (1993) RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon 24(2):91–99

Orr MJL (1996) Introduction to radial basis function networks. http://anc.ed.ac.uk/rbf/papers/intro.ps.gz. Accessed 15 May 2013

Waiting as a Signal of Quality When Multiple Extrinsic Cues are Presented

Shi-Woei Lin and Hao-Yuan Chan

Abstract While quality of a product or a service is considered one of the most important factors that influence consumer satisfaction, evaluating and determining product or service quality can be difficult for many consumers. People thus usually rely on extrinsic cues or surrogate signals of quality to tackle the information asymmetry problems associated with product/service quality. Unfortunately, research which has empirically documented the link between quality signals and perceived quality focus mainly on the situation where there exists only a single extrinsic cue. This study aims to investigate the interaction effect between multiple cues or signals on perceived quality. In particular, "waiting" or "queuing" in this study is no longer treated as a phenomenon that solicits disutility or negative emotions, but considered a signal of quality that has positive effect on consumer evaluation or satisfaction. Furthermore, this study hypothesized that the "waiting" can only be a positive signal under some specific situations especially when other quality signals (i.e., price and guidance) co-exist, and used experiments to rigorously test the hypotheses. By considering multiple cues simultaneously, this study lead to a better understanding of when and to what extent waiting can be use as a quality signal, and thus extend the original theory proposed by other researchers.

Keywords Perceived quality · Satisfaction · Signaling · Wait · Price

---

S.-W. Lin (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan, Japan
e-mail: shiwoei@mail.ntust.edu.tw

H.-Y. Chan
College of Management, Yuan Ze University, Taiwan, Japan
e-mail: s1007126@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_25,

1 Introduction

Although many researchers have empirically verified the causal effect between product quality and customer satisfaction and/or willingness to buy (Baker et al. 2002; Cronin and Taylor 1992), pointed out that the quality of a product or service is sometimes very difficult to observe or evaluate objectively and customers usually relies on some extrinsic cues or signals to determine the quality (Boulding et al. 1993). In the literature related to the signals or indicators of quality, one of the most common themes focuses on the positive relationship between price and perceived quality, as well as the contextual or situational factors that may moderate this relationship. Near 100 relevant studies in the past 30 years have been reviewed and summarized by Brucks et al. (2000).

Other than the effects of price or brand name, Giebelhausen et al. (2011) proposed and experimentally showed that waits can also function as a signal of quality. After all, it is easy to find circumstances in which consumers are willing to wait. However, the relationship between waiting and quality perception of a product or service is relatively unclear, compared to the relationship between price or brand name and perceived quality. In traditional management point of view and in most academic literature, waiting is usually described as a phenomenon that cause negative emotions of consumers and have negative impacts on consumers' evaluation of products or services (Berry et al. 2002; Hui and Tse 1996; Baker and Cameron 1996). However, in recent years, business practitioners and marketing managers may deliberately create "must wait" situation or even deliberately increase the waiting time. For example, store may provide only limited space for waiting so that the customers must line up on the sidewalk. Giebelhausen et al. (2011) provided an explanation for this phenomenon. They believed that letting customer wait can increase the perceived quality (of a product or service), satisfaction, and intention to buy. In other words, while waiting may have negative emotional impact, it can also be treated as a positive signal of quality.

Although many theoretical and empirical research have been conducted to explore or investigate variables that can be used as signals of quality, most of the investigations focus on investigating one specific factor. However, several signals of quality usually exist simultaneously in the real world business practices. The one-factor-at-a-time approach used in previous studies may overlook important interactions between different signals. For example Monroe and Krishnan (1985) found that the effect of price on quality perception is moderated by the variable brand name. Without a factorial experiment design, this interaction cannot be easily identified.

Thus, in this study, we use a similar paradoxical view of waiting proposed by Giebelhausen et al. (2011) to study the positive effect of waiting on quality perception and purchase intention. In particular, we intend to investigate the interactions between wait and price, and try to determine that whether effect of wait as a indicator of quality will be suppressed or be strengthened when the signal of price is considered concurrently.

By using rigorous experiments to verify the main and interactions effects of wait and price, the main contribution of the present research include: (1) confirm that waits can have a positive impact on quality perception and at the same time identify the underlying mechanism through which the effect operates to make sure the effect is not caused by other confounding factors or lurking variables, (2) experimentally evaluate the signal effect of wait under different prices to test whether the "economic value of wait" is moderated by price, which is a commonly used signal and is sometimes called a "surrogate for quality" in the absence of other information. This study thus lead to a better understanding of when and to what extent waiting can be use as a quality signal, and thus extend the original theory proposed by other researchers.

2 Methods

2.1 Research Model

Based on the literature review, price and waiting may function as signals for quality when there is information asymmetry between buyers and sellers (Spence 2002; Volckner and Hofmann 2007; Giebelhausen et al. 2011). Furthermore, Kirmani and Rao (2000) pointed out that a customer usually consider several intrinsic and extrinsic cues or signals (e.g., price, warranty, country of origin, brand name) simultaneous to form his/her quality perception when evaluating the quality of a product or a service. However, there may be some interaction effects between various cues or signals of quality. Miyazaki et al. (2005) suggested that when the information presented in two or more signals is consistent, these signaling factors may complement each other, further increasing a customer's quality perception. On the other hand, if the information from multiple signals is inconsistent, Miyazaki et al. (2005) suggested that the signal containing negative information may become more dominant.

Therefore, this study aims to examine whether there is an interaction effect between extrinsic quality signals price and wait. In particular, we are also interested in investigating the effect of waits on quality perception and satisfaction when it is co-existed with different signals or under different contexts. Based on the research framework, we summarized the four hypotheses proposed as follows.

Hypothesis 1 There is a positive main effect of a wait such that quality perception will be greater when a wait is present than when a wait is absent.

Hypothesis 2 There is a positive main effect of price such that quality perception will be greater for the high-priced product (or service) than the low-priced product (or service).

Hypothesis 3 There is an interaction between price and the presence of a wait. In particular, for a low price service, the presence of a wait increases perceived quality. However, for a high price service, the presence of wait has smaller effect on perceived quality.

Hypothesis 4 Perceived quality function as a mechanism by which price and the presence of a wait influences purchase intentions.

2.2 Design and Participants

According to the literature, consumers usually rely on the extrinsic cues or alternative signals to determine the quality of a product or a service when there is no sufficient information (about the product or service) available or when the product or service quality is ambiguous. This study thus focuses on the cases where the consumers are making their first-time consumption and are not very familiar with the product or service.

In particular, the experiment design of this study allow participants (i.e., consumers) received two signals (price and wait) simultaneously. Furthermore, different contexts (the scenario related to the product or service consumption) are constructed to mimic the realistic consumption environments. A survey are finally employed to collect the measures of quality perception and satisfaction of the participants, and statistical tests were conducted to determine whether proposed hypotheses can be supported by the data.

This study use a two-factor within-subject experimental design. To avoid the carry-over effect and to make participants less easy to see the whole picture of the experiment (and avoid the possible biases that may have caused), two different decision contexts are considered in this study. Both decision contexts is related to restaurant service settings, but one is serving the western style food and the other is serving the Japanese noodle soup. The study utilized a 2 (price: high, low) × 2 (wait: absent, present) design. The price levels or the levels of stimuli are based on the market research of the general price range of the same products or services in Taiwan, and different menus each containing a sequence of dishes are designed and presented to the participants. The low-price and high-price settings for the menu of steak house (western style food) are around NT$200 and NT$1200, respectively. The low-price and high-price settings for the menu of Japanese noodle house are around NT$100 and NT$300, respectively. For manipulating the factor of wait in the experiment, in the "wait absent" condition, the scenario indicated that the waiting area was empty and the customer can be seated right away. However, in the "wait present" condition, the customer is notified that no more reservation can be taken and he/she need to wait 25–30 min to be seated.

While the within-subject design employed in this study has the strength of making experiment more efficient, there are also threats to the internal validity of this design such as the carry over or order effects. It is possible that effects from previous treatments (scenario) may still be present when testing new treatment (scenario), thus affecting or biasing the outcome. One solution to the problem of carryover effects is to counterbalance the order of treatment levels. Thus, different subjects are randomly assigned to different scenarios in different orders.

3 Preliminary Results

SPSS statistical package was used to perform the analysis. Quality perception measures of participants were analyzed by means of the two-way within-subject ANOVA with two levels of price (high, low) and two levels of wait (absent, present). All main effects were found to be statistically significant. The main effect of price showed that high price led to higher quality perception than did low price, $F(1, 171) = 25.930$, $p < 0.01$). The main effect of wait also showed that the presence of wait led to higher quality perception than did the absence of wait, $F(1, 171) = 28.622$, $p < 0.01$). Our hypotheses 1 and 2 are supported by the preliminary results of the data analysis.

On the other hand, Although we hypothesize that here is an interaction between price and the presence of wait (partially based on Miyazak (Miyazaki et al. 2005)), the interaction effect between price and wait on quality perception was not significant ($F(1, 171) = 0.244$, $p = 0.622$). In particular, while we suggested for a low price service, the presence of a wait increases perceived quality, and for a high price service, the presence of wait has smaller effect on perceived quality, no significant trend were identified. The seemly parallel interaction plots also confirmed this finding.

4 Conclusion

Multiple signals or cues of quality usually exist simultaneously in the real world business practices, but most of the study conducted in this field use the one-factor-at-a-time approach by focusing on one specific factor. In this study, We intend to investigate the important interactions between different signals which were usually over-looked. In particular, we aim to investigate interactions between wait and price, and try to determine that whether effect of wait as a indicator of quality will be suppressed or be strengthened when the signal of price is considered concurrently.

Although significant price and wait effects were found in our analysis, showing that both price and wait can function as signals of quality. The interaction effect between price and wait on quality perception was not significant. Other variables or moderators, such as the consumer's motivation, might need to be taken into consideration to further clarify this issue.

Acknowledgments This work is partially supported by the National Science Council of Taiwan under grant number NSC101-2410-H-011-034-MY2. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the sponsors.

References

Baker J, Cameron M (1996) The effects of the service environment on affect and consumer perception of waiting time: an integrative review and research propositions. J Acad Market Sci 24:338–349

Baker J, Parasuraman A, Grewal D, Voss GB (2002) The influence of multiple store environment cues on perceived merchandise value and patronage. J Marketing 66:120–141

Berry LL, Seiders K, Grewal D (2002) Understanding service convenience. J Marketing 66:1–17

Boulding W, Kalra A, Staelin R, Zeithaml VA (1993) A dynamic process model of service quality: from expectations to behavioral intentions. J Marketing Res 30:7–27

Brucks M, Zeithaml VA, Naylor G (2000) Price and brand name as indicators of quality dimensions for consumer durables. J Acad Market Sci 28:359–374

Cronin JJ, Taylor SA (1992) Measuring service quality: a reexamination and extension. J Marketing 56:55–68

Giebelhausen M, Robinson S, Cronin J (2011) Worth waiting for: increasing satisfaction by making consumers wait. J Acad Market Sci 39:889–905

Kirmani A, Rao AR (2000) No pain, no gain: A critical review of the literature on signaling unobservable product quality. J Marketing 64:66–79

Hui MK, Tse DK (1996) What to tell consumers in waits of different lengths: an integrative model of service evaluation. J Marketing 60:81–90

Miyazaki AD, Grewal D, Goodstein RC (2005) The effect of multiple extrinsic cues on quality perceptions: a matter of consistency. J Consum Res 32:146–153

Monroe KB, Krishnan R (1985) The effect of price on subjective product evaluations. Perceived quality: how consumers view stores and merchandise. J Marketing Res 28:209–232

Spence M (2002) Signaling in Retrospect and the Informational Structure of Markets. Am Econ Rev 92:434–459

Völckner F, Hofmann J (2007) The price-perceived quality relationship: A meta-analytic review and assessment of its determinants. Market Lett 18:181–196

Effect of Relationship Types on the Behaviors of Health Care Professionals

Shi-Woei Lin and Yi-Tseng Lin

Abstract Human's behavior and attitude can be highly influenced by two types of relationship, communal relationship and exchange relationship, and the moral-oriented social norms and the money-oriented market norms applied mechanically in these two relationships, respectively. While there is a great deal of general literature discussing the effect of relationship types on interpersonal interaction, there are limited number of studies focusing on the relationship types between organizations and their members and whether the introduction of monetary incentives affect the relationship types. Taking healthcare industry as an example, this study aims to explore how the types of relationship (communal vs. exchange relationship) between hospitals and medical staffs influence their attitude. Furthermore, we also want to investigate whether different types of reward (monetary vs. nonmonetary incentives) provided by hospitals affect or alter the types of relationships a medical staff originally had. We expect the results of this study can provide some suggestions for designing compensation plan in healthcare industry and important general managerial implications to managers in other industries.

Keywords Communal relationship · Exchange relationship · Social norm · Incentive · Healthcare industry

S.-W. Lin (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: shiwoei@mail.ntust.edu.tw

Y.-T. Lin
College of Management, Yuan Ze University, Taipei, Taiwan
e-mail: s1007116@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_26,

1 Introduction

In human society, whether it is about the interaction of the interpersonal relationship in our daily life or about the consumption, competition and cooperation in business practices, our behavior and attitude can be highly influenced by the social factors such as the two main types of relationship, communal relationship and exchange relationship. Because these two relationship types can be differentiated based on the underlying norms or motivation for giving benefits to the partner, the moral-oriented social norms and the money-oriented market norms can thus be applied mechanically in the communal relationship and exchange relationship, respectively.

Clark and Mills (1979) is considered the first article to propose the qualitative distinction between communal and exchange relationships. Since then, researchers in psychology, sociology, and business have been conducted many studies to experimentally or empirically investigate how the communal relationship and exchange relationship influence the patterns of human behavior. Clark and Mills (1993) experimentally demonstrate the validity of the distinction between the communal of relationship and exchange relationship relations. Furthermore, while Clark and Mills (1979, 1993) suggested that the two major relationships are mutually exclusive. Johnson and Grimm (2010) put forward a different viewpoint. They think communal relationship and exchange relationship are not diametrically opposed to each other and are not located at the different ends of the spectrum of the relationship. In other words, Johnson and Grimm (2010) believe that in the pursuit of different personal goals, an individual person is indeed possible to possess both relationships.

In addition to the discussion and investigation of basic concepts and characteristics of the two types of relationships, many researchers have also examined the impact of the introduction of the monetary reward on the communal and exchange relationships. For example, Heyman and Ariely (2004) found that money (or even when people were subliminally primed to think about money) will make people feel more self-sufficient, and thus become more isolated and become (more selfish) and less willing to help others. Heyman and Ariely (2004) also found that as long as the emphasis is on monetary rewards or exchanges, the market norms will be triggered automatically. They further pointed out that social norm is usually the motivations that really can drive the members in an organization to maximize their efforts.

Early research related to communal and exchange relationships focuses more on investigating the relationships between people (e.g., in the study of friendship and love). In recent years, researchers have extend the theoretical framework and these two types of relationships to explore and explain the relationship formed between people and brands (see, for example, Aggarwal 2004). Heyman and Ariely (2004) discussed another possible extension of this framework to the relationship between an organization and people within the organization. It should be noted, however, that there have been few attempts to test the effects of (organization) relationship norms on employee's attitude and behavior.

In the healthcare industry, in light of recent major changes in the medical marketplace make the health care administrators focus more on the efficiency of the operations of a health care institutes. The efficiency may be achieved by more stringent control and more immediate monetary incentives for performance of the health care professionals. The relationship between health care professionals and the organizations (or administrations) thus gradually shift from communal relationship to exchange relationship. This study thus aim to investigate how the financial incentives and non-financial incentives affects work attitude or behavior of health care workers (e.g., physicians, nurses) with different relationship norms.

In particular, this study use an experiment to explore how the types of relationship (communal vs. exchange relationship) between hospitals and medical staffs influence their attitude. Furthermore, we also investigate whether different types of reward (monetary vs. nonmonetary incentives) provided by hospitals affect or alter the types of relationships a medical staff originally had. This study adopt the psychology priming skills to trigger the relationship norms between the medical staffs and organizations, and use a questionnaire as a measure scale to evaluate the participants responses or evaluation of the organization's action (reward).

By experimentally testing the motivational crowding effect in health care professionals, this study intends to check whether the extrinsic motivators such as monetary incentives can undermine intrinsic motivation. After all, if the relationship norm and incentives are inconsistent, the crowding out effect may actually lower the performance when extra incentives are provided. We expect the results of this study can provide some suggestions for designing compensation plan in healthcare industry and important general managerial implications to managers in other industries.

2 Conceptual Framework and Experiment

2.1 Conceptual Framework and Hypothesis

The conceptual model being proposed in this study is that healthcare professionals (i.e., employees of a healthcare institute) evaluate the healthcare institute and its actions depending upon whether the actions violate or conform to the norm of their relationship (with the organization). However, it is important to note that employee-organization relationships are different from interpersonal relationships in several respects. For example, healthcare professionals' relationships with institutes almost always involve some degree of monetary exchange.

The study thus examine participants' (i.e., doctors' and nurses') reactions to being provided different types of incentives (monetary or financial incentives vs. non-monetary incentives) offered by the organization. The participants were first exposed to a description of a prior relationship between a doctor or a nurse and a hypothetical hospital. These descriptions were used to trigger either the communal or exchange relationships and the norms associated with these relationships. Next, the scenario described the hospital's incentive scheme (i.e., rewards) for the extra effort made by the medical professionals. The very timely and direct pecuniary reward in response to the extra effort violates the norms of communal relationship, but conform to the norms of exchange relationship. Based on the conceptual framework discussed above, several hypothesis are formulated as follows.

Effect of relationship type on the attitude of health care professionals toward the hospital

Based on the review of the literature, this study suggests that the relationship type between a health care professionals and the hospital will affect the attitude and the evaluation of the medical staffs on the organization. Hence, the following hypotheses are proposed:

Hypotheses 1 Relationship types have a significant impact on the health care professionals' attitude and evaluation of the hospital.

Hypotheses 1a Relative to health care professionals in an exchange relationship, those in a communal relationship with the hospital will evaluate the hospital more positively.

Effect of relationship type on the attitude of health care professionals toward different incentive or rewarding scheme

This study also suggests that the conformity and violation between relationship norms and the organization's actions (or strategies) will have significant impacts on the health professionals evaluation of the actions (or strategies) of the organization. In other words, when monetary rewards is provided, it is predicted that the communal medical staffs evaluate this rewarding policy negatively relative to exchange type medical staffs. Hypotheses 2a, 2b are as thus proposed as follows:

Hypothesis 2a Relative to subjects (i.e., healthcare professionals) in an exchange relationship, those in a communal relationship with an organization (i.e., hospital) will evaluate the monetary reward more negatively than when a non-monetary reward scheme is imposed.

Hypothesis 2b Relative to subjects (i.e., healthcare professionals) in an exchange relationship, those in a communal relationship with an organization (i.e., hospital) will evaluate the organization more negatively than when a non-monetary reward scheme is imposed.

2.2 Designs and Experiments

The experiment was a 2 × 2 between-subject design with Relationship Type (communal, exchange) and Reward Type (monetary incentive, non-monetary incentive) as the between-subject conditions. Although doctors and nurses are both work for the benefits of patients, their duties in a hospital can be quite different. The underlying mechanism of relationship building and the effects of relationship norms on their attitude or behavior might also be different. Thus, we conducted separate experiments to test the effects on doctors and nurses. They are, in total, 80 doctors and 80 nurses from hospitals in Taiwan were recruited through notices posted on the web site. The experiment (read the scenario and answer the questions) usually took about 10 min.

The questionnaire used to measure subjects' or participants' attitude or behaviors is divided into three parts. The first part exposed a description of the (prior) relationship between the healthcare professional and a hypothetical hospital. When reading this description, the participant was asked to projected himself or herself into the condition of the scenario. In other words, the description was served as a stimulus of priming and was aimed at triggering the relationship norms. After the description, several questions were used to check the success or failure of priming. The second part is the description of the incentive scenarios or incentive schemes proposed by the hospitals (which may conform or violate the relationship norms of specific groups of participants). At the end of second part, participants responded to questions about the evaluation of the hospital's incentive scheme and the evaluation measure of the hospital, which are aimed at testing hypotheses discussed above. All items in part 2 were measured on a seven-point scale. Finally, the third part include demographic variables used for measure the characteristics of the participants as well as the characteristics of the healthcare institute where the participant works.

3 Preliminary Results

3.1 Manipulation Check

After the participants were exposed to the relationship manipulations, they were administered a questionnaire designed to assess the effectiveness or success of priming (i.e., the relationship manipulation). We found that after priming, communal participants felt that the organization gives them warm feelings, the organization cares about the needs of their employees, and the employees in the organization are happy to help others without asking for an instant and comparable benefits for return. To further assess whether the relationship manipulations actually occurred, the participants were asked to imagine the hospital coming alive and becoming a person. Most of the communal participants considered their relationship with the organization as "friend".

Similarly, we found that after priming, exchange participants felt that they pay more attention to their own interests than the overall interests of the hospital, and they carefully calculate their gain and loss to make sure they get fair salaries. When these exchange participants were asked to imagine the hospital coming alive and becoming a person, most of them considered their relationship with the organization as "businessman". Thus, the manipulation check showed that the priming for both the communal relationship and exchange relationship (and the corresponding norms) was successful.

3.2 Reaction to Incentive Scheme and Overall Evaluation of the Hospital

There are, in total, six questions used to evaluate participants' evaluation of the incentive scheme proposed by the hospital and the hospital as a whole. Both measures (each created by combining three questions) achieved reasonable reliability and validity. The results showed that when there is a conflict or violation between the relationship norms and incentives (e.g., communal relationship norm and monetary incentive scheme or exchange relationship norm and non-monetary incentive scheme), participants tend to evaluate the scheme and the hospital as a whole relatively negative. On the contrary, the conformity of relationship norms and incentive schemes lead to relatively positive evaluations. These findings are consistent with what are predicted by the conceptual model.

4 Conclusions

Taiwan's brain drain is considered one of the most alarming threats to its sustainable development. In healthcare industry, the brain drain issue is even more serious. The administrators or managers of healthcare organization needs to shoulder its share of responsibility by creating a more attractive environment for doctors and nurses. According to the results of this study, incentive schemes can be effective mainly when they are conform with the underlying relationship norms of the doctors and nurses. A poor incentive system without taking relationship norms into consideration thus may decrease the healthcare professionals' evaluation of the hospital, their job satisfaction and their organizational commitment in the long run.

The results of this study thus can provide some guidelines for designing incentive schemes in healthcare industry and offer important general managerial implications to managers in other industries.

Acknowledgments This work is partially supported by the National Science Council of Taiwan under grant number NSC101-2410-H-011-034-MY2. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the sponsors.

References

Aggarwal P (2004) The effects of brand relationship norms on consumer attitudes and behavior. J Consum Res 31:87–101
Clark MS, Mills JR (1979) Interpersonal attraction in exchange and communal relationships. J Pers Soc Psychol 37:12–24
Clark MS, Mills JR (1993) The difference between communal and exchange relationships—what it is and is not. Pers Soc Psychol Bull 19:684–691
Heyman J, Ariely D (2004) Effort for Payment—A tale of two markets. Psychol Sci 15:787–793
Johnson JW, Grimm PE (2010) Communal and exchange relationship perceptions as separate constructs and their role in motivations to donate. J Consum Psychol 20:282–294

A Simulation with PSO Approach for Semiconductor Back-End Assembly

James T. Lin, Chien-Ming Chen and Chun-Chih Chiu

Abstract This paper studies a dynamic parallel machine scheduling problem in a hybrid flow shop for semiconductor back-end assembly. The facility is a multi-line, multi-stage with multi-type parallel machine group, and orders scheduled with different start time. As a typical make-to-order and contract manufacturing business model, to obtain minimal manufacturing lead time as main objective and find an optimal assignment of production line and machine type by stage for each order as main decisions. Nevertheless, some production behavior and conditions increase the complexity, and including order split as jobs for parallel processing and merged completion for shorten lead time. Complying quality and traceability requirement so each order only can be produced from one of qualified line(s) and machine type(s) and all jobs with the same order can only be produced in same assigned line and machine type with stochastic processing time. Lead time is counted from order start time to completion, including sequence dependent setup times. As a NP-hard problem, we proposed a simulation optimization approach, including an algorithm, particle swarm optimization (PSO) to search optimal assignment which achieving expected objective, a simulation model to evaluate performance, and combined with optimal computing budget allocation (OCBA) to reduce replications. It provides a novel applications using simulation optimization for semiconductor back-end assembly as a complex production system.

J. T. Lin (✉) · C.-M. Chen · C.-C. Chiu
Department of Industrial Engineering and Engineering Management,
National Tsing Hua University, Hsinchu, Taiwan, ROC
e-mail: jtlin@ie.nthu.edu.tw

C.-M. Chen
e-mail: d937811@oz.nthu.edu.tw

C.-C. Chiu
e-mail: vhasb3210@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_27,

Keywords Dynamic parallel machine scheduling · Simulation optimization · Particle swarm optimization · Optimal computing budget allocation · Semiconductor back-end assembly

1 Introduction

The semiconductor industry was originally highly integrated from IC design to manufacturing by integrated device manufacturers (IDMs). However, this industry has been decentralized approximately for thirty years because of technological differences, core business focus, and cost scale. The industry was split into the IC design house (i.e. fabless), which focuses on the value creation of IC functions for devices or applications, manufacturing also separate wafer foundry and probe (or wafer sort) as front-end, and assembly and final test as back-end. Back-end assembly is the process to pick up die from wafer and package integrated circuits (ICs), which are key components of most electronic devices. The back-end assembly may be an offshore of IDM or an individual company serves as a virtual factory for fabless and IDM. The lead time of front-end is relative longer than back-end and customers will request back-end assembly to provide a short but robust lead time service to absorb fluctuation instead of physical ICs inventory. It becomes the key as an order winner in this kind of typical make-to-order (MTO) and contract-manufacturing model.

Some criteria of order winner are delivery reliability and speed. In general, back-end assembly adopt bottleneck scheduling to schedule the start time and estimate ship of date but more challenges from practice is that bottleneck shifting. There are two reasons caused. The first one is parallel processing of jobs. There are too many jobs split by order for shorten lead time. The second is dynamic routing with conditions for these jobs. While lots of jobs in the production system, each job has alternatives in production line and machine type, and thus the possibility of bottleneck shifting is raised. In this research we proposed a methodology using simulation optimization by particle swarm optimization. We aim to obtain minimal manufacturing lead time through optimal assignment of production line and machine type for each order. Before proposed it, the production system of back-send assembly is stated below and problem statement in later section.

1.1 System Description of Back-End Assembly

The production system of back-end assembly is a classical product layout. Through these processes, the die in the wafer will be picked up and packaged as IC. The typical main assembly operations include multiple stages as Fig. 1. "Tape", "back grind", "de-tape/mount" and "saw" are the wafer base operations.

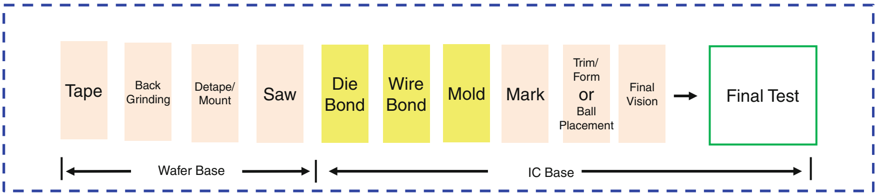


Fig. 1 Main operations of back-end assembly

After these operations, the die on the wafer are able to pick up at "die bond" stage. "Die bond" attaches a die to a substrate or lead frame by using adhesives. In the "wire bond" stage, the lead is bound, the die is held, and the substrate or lead frame is linked by using gold or copper wires, thus connecting the die to the outer circuit. In the "mold" stage the circuits of components are molded to protect them from outside forces and strengthen their physical characteristics. "Mark," "trim/ form" or "ball placement," and "final vision" are straightforward operations that complete the assembly process (Zhang et al. 2007).

The input of the production system is wafer. Considering quality traceability, the wafer with a specific lot number and each lot number has around twenty five wafers based foundry process. Customers will release the order to back-end assembly with identified demand quantity and wafers lot numbers as input. Back-end assembly will schedule them the start time using bottleneck (normally is wire bonder) scheduling daily. Considering management span, a flow shop will set five hundreds to one thousand wire bonders, i.e. if demand is over than the line size, there will be another production line as product layout base, and thus there will be a multi-line environment. As previous description, a lot of stages are in production line. Each stage has different machine types with different numbers cause of precision level of product specification or equipment technology evolution. During the process, the order split size is based on movement quantity of a job. In general, the movement quantity is determined by how many die in a magazine which contains some pieces of lead frame or substrate which contains some pieces of die. Thus, a lot of jobs spilt from orders are in the system. The system output is IC. From system management, manufacturing lead time is one of system performance indicator. The complexity comes from these jobs with alternatives in line and machine type selection as dynamic routing.

2 Problem Statement

From system description, some characteristics are summarized by three perspectives. The first is physical layout, including numbers of production line and numbers at each stage by machine type and line. It is also a system constraint by capacity view. The second is product attributes, including capability, split size rules and processing times. Capability means that each product can be produced in specific line and machine time from qualification concept. Split size rule is to determine movement quantity of a job so that the jobs of an order can be parallel processed for lead time shorten. Processing time is defined by product and machine type at each stage. It is a stochastic times with a distribution. The third is related with the physical entity flow in the system. An order introduced some information demand quantity, start time and product type. Once an order enters into production line, the whole lots are wafer base before die bond stage. After die bond, the order is split as a job per predefined split rule and identified by a serial number based on original order number. As variety order size and predefined split rule, each order generated different numbers of job and parallel processed in the production system. For traceability and quality concerns, each job not only constrained into predefined (qualified) line and machine type for production but also has to keep same line and machine type for the same order. Only all jobs completed, and the order completed to count manufacturing lead time. During process, if jobs between in and out are different product type, and there will be a sequence dependant setup times.

Even there are lots of stages in production system, the most critical stages with regard to manufacturing lead time are die bond, wire bond and molding. We will include these three stages as our study assumption. A lot of orders and jobs in the production system and constrained by capacity, capability and physical entity flow rules. The decisions are order assignment to which production line and to which machine type for their counter jobs and obtain minimal average manufacturing lead time.

3 Literature Review

More attentions on dynamic scheduling since the production system with some events, like processing time is non-deterministic, loading limit and dynamic routing (Suresh et al. 1993). This problem is an extension of hybrid flow shop scheduling problem (HFSSP). Ribas et al. (2010) recently reviewed published papers about this topic and classified the HFSSP from the production system and solution procedure perspectives. As a NP-hard problem, simulation optimization is a general approach. Carson and Maria (1997) defined simulation optimization as the process of finding the best input variable values among the possibilities without explicitly evaluating each value. The use of heuristic methods such as GA, evolutionary strategy, simulated annealing, tabu search, or simplex search is common. Chaari et al. (2011) adopted the genetic algorithm (GA) for the demand uncertainty of robust HFSSP. Chaudhry and Drake (2009) used the GA for machine scheduling and worker assignment to minimize total tardiness. Chen and Lee (2011) presented a GA-based job-shop scheduler for a flexible multi-product, parallel machine sheet metal job shop. Anyway, simulation approach consumed times since the system is stochastic. To reduce simulation times, Chen et al. (2000), Chen and Lee (2011) proposed optimal computing budget allocation (OCBA) as the ultimate simulation resource and applied in product design (Chen et al. 2003).

The PSO algorithm shares many similarities with evolutionary computation techniques such as GAs. It was proposed by Kennedy and Eberhart. The system is initialized with a population of random solutions and searchers for optima by updating generations. However, unlike GA, the PSO algorithm has no evolutionary operators, such as crossover and mutation. In the PSO algorithm, the potential solutions, called particles, move through the problem space by following the current optimum particles. Kuo and Yang (2011) compared GA and PSO based algorithm and found the PSO is better than GA base.

4 Proposed Methodology and Illustration

4.1 Simulation Optimization Methodology Based PSO Combined with OCBA

As Fig. 2, we proposed a simulation optimization methodology based on PSO combined with OCBA to find the optimal assignment achieving our objective. We apply PSO as our searching engine for optimization and apply a simulation tool to evaluate performance or fitness. We also apply OCBA for simulation replications reduction. The basic steps are stated as below:

Step 1: *Parameters setting for PSO and OCBA*

The parameters of PSO include population size, weight, learning factor c1 and c2. For OCBA, parameters are initial replications of simulation (n_0), total simulation budget (T), incremental replications (Δ) and P{CS}*.

Step 2: *Initial population*

According the parameter of population size, it generated multiple alternatives for further evaluation.

Step 3: *Evaluation of performance or fitness and combined with OCBA*

There are three sub-steps. The first is to evaluate all alternatives of initial population using n_0 times of replications for each one. The second is to calculate P{CS} and check if reach the P{CS}*. If achieved, go to step 4 or do more replications based on Δ and continue to the second sub-step.

Step 4: *Update the Pbest and Gbest*

For each particle, it will generate a new fitness and compared with before, and the better one is the Pbest; for particle, it will find the best Pbest as Gbest.

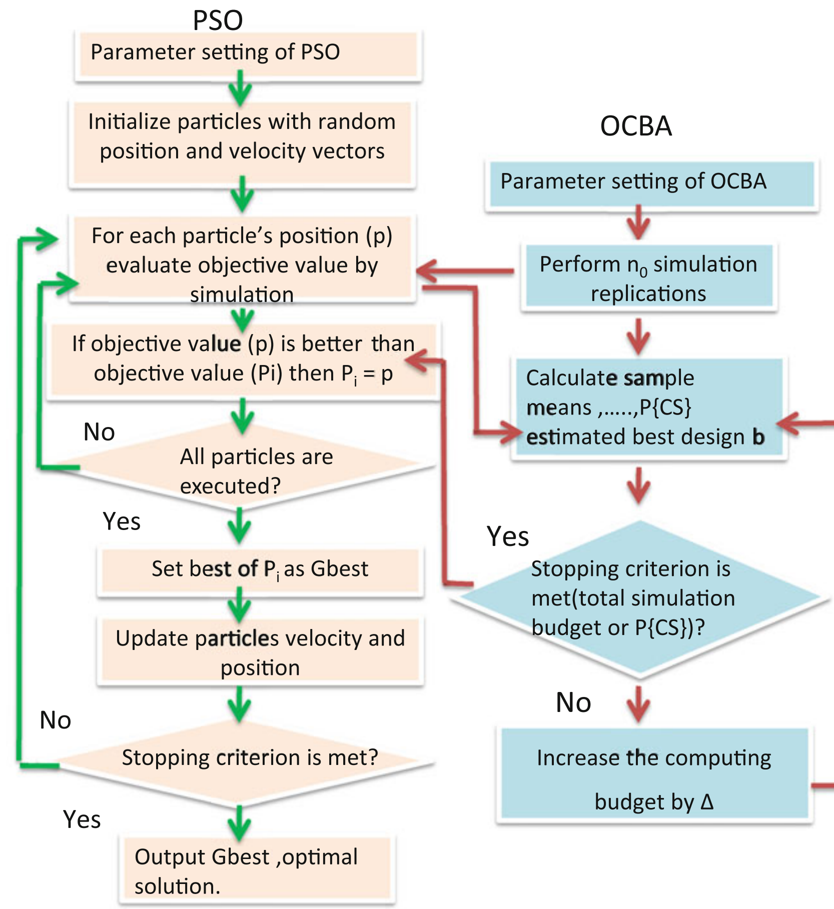


Fig. 2 Simulation optimization methodology based on PSO combined with OCBA

Step 5: *Update velocity and position according to* Eq. (1) *and* (2)

Each particle was updated for velocity and position.

$$v_{i,new} = w \cdot v_{i,old} + c_1\, rand() \cdot (P_i - X_{i,old}) + c_2\, rand() \cdot (G - X_{i,old}) \quad (1)$$

$$X_{i,new} = X_{i,old} + v_{i,new} \quad (2)$$

Step 6: *Check if met condition of termination*

As the loop, while if it met condition of termination. In general, the generation of PSO or T reached. If it is not optimal, go to step.

4.2 Encoding and Decoding Design

The PSO is normally adopted in a continuous space. As our study, it is discrete type so we have to encode using a special approach for encoding and decoding. We use a matrix table to define all alternatives in line assignment and machine type assignment for each order in Tables 1, 2 and 3. In the Fig. 3, we separate two segments for line and machine type assignment. First segment means line assignment for each order; and second one means machine assignment by die bonder, wire bonder and mold system for each order. Using order 2 as an example, original line assign number is 1.2, refers table x, it was decoded as line 2. For machine type, the original number for wire bonder is 1.3, round up to 2. Since it is assigned in line 2, so refers table z, it was decoded as machine type, DB4.

4.3 Illustration by Simple Case

The simple case includes three orders and related parameters were set: w = 0.8; c1 = 1; c2 = 2; n_0 = 10; Δ = 100; T = 300; P{CS} = 0.9. Available line(s) and machine type(s) list as Tables 1, 2 and 3. We adopt three approaches and compared their performance of manufacturing lead time and replications in Table 4.

Table 1 Available line assignment for orders

	Order 1	Order 2	Order 3
Numbers of available line	1	2	1
Position 1	Line 2	Line 1	Line 1
Position 2	–	Line 2	–

Table 2 Available machine type assignment for orders in line 1

	Order 1			Order 2			Order 3		
Stage	DB	WB	MD	DB	WB	MD	DB	WB	MD
Numbers	3	2	2	2	2	3	1	3	2
Position 1	DB1	WB1	MD1	DB1	WB2	MD2	DB3	WB1	MD2
Position 2	DB2	WB3	MD4	DB2	WB3	MD3	–	WB3	MD4
Position 3	DB3	–	–			MD4	–	WB4	–

Table 3 Available machine type assignment for orders in line 2

	Order 1			Order 2			Order 3		
Stage	DB	WB	MD	DB	WB	MD	DB	WB	MD
Numbers	1	3	2	2	2	1	2	2	3
Position 1	DB2	WB2	MD1	DB1	WB1	MD3	DB2	WB2	MD1
Position 2	–	WB3	MD2	DB4	WB3	–	DB4	WB3	MD2
Position 3	–	WB4	–	–	–	–	–	–	MD4

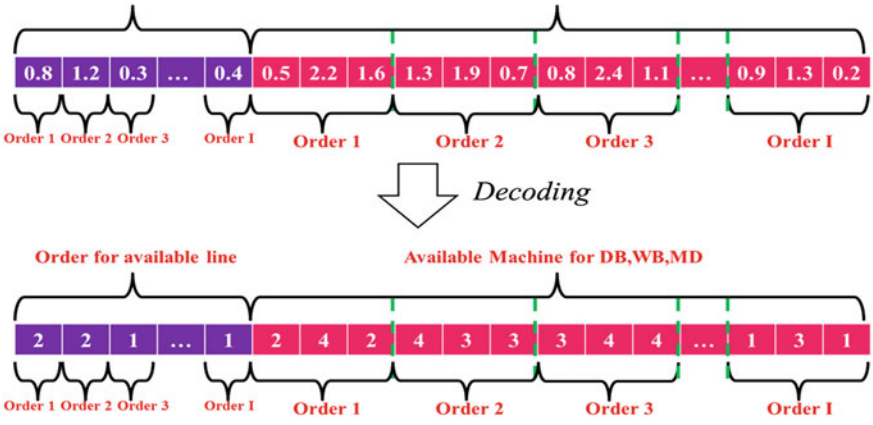


Fig. 3 Encoding and decoding illustration

Table 4 Comparison among different approaches

Approaches	Assignment	Lead time (s)	Replications	p-value
Exhaustive method	(1,1,2,2,3,1,1,4,1,3,3,6)	123563.2	306900	–
PSO	(2,1,2,4,3,6,1,4,5,3,3,6)	124379.7	54900	0.067355879
PSO + OCBA	(2,1,1,4,3,6,2,4,1,3,3,1)	124477.4	34740	0.076163638

Compared with exhaustive method

PSO can find an optimal solution but less replication. If it is combined with OCBA, it reduced more replications. Both PSO base approaches are statistically significant differences compared with exhaustive method by t-test. The p-value is greater than 0.05.

5 Conclusions

This is a NP-hard problem since the system is complex with many characteristics of back-end assembly, especially faced a dynamic routings with sequence dependent setup times. Simulation is visible so practitioners preferred but lack of optimization, and it also has concerns on long replications cause of stochastic properties. As our study, it conquers the weakness and obtains a good result without statistically significant differences with exhaustive method. This study inspired us to apply this methodology in system performance improvement if the system behavior, constraints, objectives and decision variables and optimization approach can be well defined. As a simulation base approaches, it also can compare more scenarios and explore the influence on other performance like utilization, delivery robustness and predict coming bottleneck shifting issue heads up some actions. It is helpful for practitioners using academic approach to improve system performance. It also provides opportunity to find more insights in relationship between system performance and system characteristics.

References

Carson Y, Maria A (1997) Simulation optimization: methods and Applications In: Proceedings of the 1997 winter simulation conference, pp 118–126

Chaari T, Chaabane S, Loukil T, Trentesaux D (2011) A genetic algorithm for robust hybrid flow shop scheduling. Int J Comput Integr Manuf 24(9):821–833

Chaudhry IA, Drake PR (2009) Minimizing total tardiness for the machine scheduling and worker assignment problems in identical parallel machines using genetic algorithms. Int J Adv Manuf Technol 42:581–594

Chen CH, Donohue K, Yucesan E, Lin J (2003) Optimal computing budget allocation for Monte Carlo simulation with application to product design. Simul Model Pract Theory 11:57–74

Chen CH, Lee LH (2011) Stochastic simulation optimization—an optimal computing budget allocation. World Scientific Publishing Co. Ptd. Ltd, Singapore

Chen CH, Lin J, Yucesan E, Chick SE (2000) Simulation budget allocation for further enhancing the efficiency of ordinal optimization. Discrete Event Dyn Syst 10:251–270

Kuo RJ, Yang CY (2011) Simulation optimization using particle swarm opti algorithm with application to assembly line design. Appl Soft Comput 11:605–613

Ribas I, Leisten R, Framinan JM (2010) Review and classification of hybrid flow shop scheduling problems from production system and a solutions procedure perspective. Comput Oper Res 37:1439–1454

Suresh et al (1993) Dynamic scheduling—A survey of research. Int J Prod Econ 32:53–63

Zhang MT, Niu S, Deng S, Zhang Z, Li Q, Zheng L (2007) Hierarchical capacity planning with reconfigurable kits in global semiconductor assembly and test manufacturing. IEEE Trans Autom Sci Eng 4(4):543–552

Effect of Grasp Conditions on Upper Limb Load During Visual Inspection of Objects in One Hand

Takuya Hida and Akihiko Seo

Abstract Automated visual inspection systems based on image processing technology have been introduced to visual inspection processes. However, there are still technical and cost issues, and human visual inspection still plays a major role in industrial inspection processes. When a worker inspects small parts or products (e.g., lens for digital cameras, printed circuit boards for cell phones), they suffer from an upper limb load caused by handling objects in one hand and maintaining this awkward posture. Such workload causes damage to the hands, arms, and shoulders. So far, few studies have elucidated the effect of upper limb loads. Therefore, we conducted an experiment where the subjects were assumed to be visually inspecting small objects while handling them with one hand, and investigated the effect of grasp conditions on the upper limb load during tasks. We used electromyography, the joint angle, and subjective evaluation as evaluation indices. The results showed that the upper limb load due to the grasp condition differed depending on the upper limb site. Therefore, it is necessary to consider not only the muscle load but also the awkward posture, the duration of postural maintenance, and subjective evaluation when evaluating the upper limb load during such tasks.

Keywords Visual Inspection · Muscle Load · Joint Angle · Awkward Posture

T. Hida (✉) · A. Seo
Graduate School of System Design, Tokyo Metropolitan University, 6-6 Asahigaoka, Hino-shi, Tokyo 191-0065, Japan
e-mail: hida-takuya1@sd.tmu.ac.jp

A. Seo
e-mail: aseo@sd.tmu.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_28,

1 Introduction

Visual inspection is a method to certify the quality of products in industries (Cho et al. 2005). By visual inspection, an inspector evaluates the surface characteristics of objects. These characteristics are divided into two types: one that can be defined and detected as a physical quantity, and the other that cannot. The latter type can only be evaluated by human, and there remain major needs for human visual inspection.

Ergonomics research has been trying to alleviate the physical and mental workloads that inspectors suffer from. Those loads come from the long time of fixation of sight on objects and maintenance of working posture (Liao and Drury 2000). Inspectors stay sitting and use a microscope or a magnifier (Yeow and Sen 2004). These are mainly mental work which results in mental workload (Lee and Chan 2009) and visual fatigue (Jebaraj et al. 1999). Additionally, in recent years, there is another style of inspection which involves grasping and handling of parts or products by the inspector. Repetitive motions, maintenance of the elevation of upper limb, and awkward postures are observed in this new style, which are suspected to cause more upper limb disorders than in the traditional style of inspection.

The authors have so far conducted researches on the upper limb load during inspections with handling of objects (Hida and Seo 2012; Hida et al. 2013a, b). This research targets the visual inspection of rather small objects (e.g., camera lenses and printed circuit boards of cellular phone). This sort of work does not overload the musculoskeletal system of the inspector thanks to the small weight of the objects. However, there are still considered to cause large workload on the upper limb as it involves handling of objects by one hand and maintenance of the elevation of upper limb. In order to clarify this workload, we conducted an experiment where the subjects were assumed to be visually inspecting small objects while handling them with one hand, and investigated the effect of grasp conditions on the upper limb load during tasks. We used electromyography, joint angle, and subjective evaluation as evaluation indices.

2 Method

2.1 Subject

The subjects were 6 healthy male and 6 healthy female university students with no pain in their upper limbs. The means and standard deviations of age, height, and body mass were 22.5 ± 0.8 years, 166.6 ± 10.7 cm, and 55.8 ± 12.4 kg, respectively. All the subjects were right-handed. The experiment was conducted on the right upper limb.

Fig. 1 Work posture

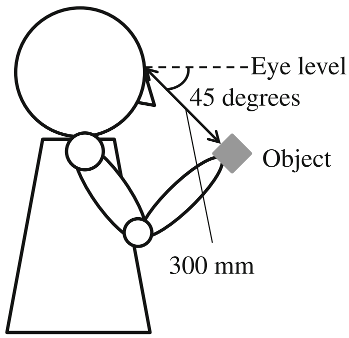
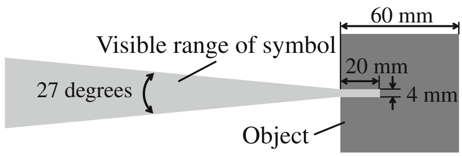


Fig. 2 Visible range of symbol



2.2 Experimental Procedure

The subjects grasped an inspection object at 45 degrees downward from the eye level with right hand in a sitting posture (see Fig. 1). The shape of the object was a cube with a side length of 60 mm and a weight of 8 g. The object had a hole which was 4 mm in diameter and 20 mm in depth. One symbol out of five was placed at the bottom of the hole. As it was at the bottom, visible range of symbol was limited (see Fig. 2). The subjects were asked to inspect the object visually and read out the shape of the symbol. Experimental conditions were divided into six grasp types (see Fig. 3). These were randomized to eliminate the effect of the order.

2.3 Measurement Data and Analysis Method

In this research, surface electromyography (called EMG) was used to evaluate the muscle load of the upper limb by the upper limb motion. The percentage of maximum voluntary contraction (%MVC) was calculated using the ratio of muscle

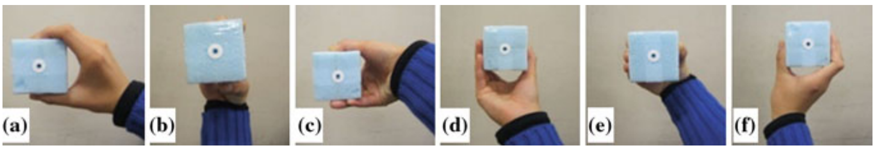


Fig. 3 Grasp types

activity for a task to the MVC. Moreover, joint angle was measured to evaluate the joint load of the upper limb by postural maintenance. In addition to these quantitative evaluations, subjective evaluation was also collected. We applied an analysis of variance (ANOVA) for each measurement value. The factors were subject and grasp type. In addition, Tukey's test was employed as a follow-up test of the main effect. The significance level was set at 5 % for both tests.

(1) EMG

EMG was measured by using an active electrode (SX230-1000; Biometrics Ltd.). The muscle measurement sites of EMG were as follows: upper part of the trapezius muscle, clavicular part of the pectoralis major muscle, middle part of the deltoid muscle, the biceps brachii muscle, the round pronator muscle, the flexor carpi ulnaris muscle, the extensor carpi radialis longus muscle, and thenar muscle. Upper part of the deltoid muscle performs elevation of scapula; clavicular part of the pectoralis major muscle performs flexion and adduction of shoulder joint; middle part of the deltoid muscle performs abduction of the shoulder joint; the biceps brachii muscle performs flexion of elbow joint; the round pronator muscle performs pronation of forearm; the flexor carpi ulnaris muscle performs flexion and adduction of wrist joint; the extensor carpi radialis longus muscle performs extension and abduction of wrist joint; and the thenar muscle performs abduction, adduction, flexion, and opposition of thumb (Criswell 2010). Using all of the above EMG sites, we were able to evaluate the upper limb load during the task.

The measured EMG was converted to %MVC for each muscle. The muscle load was then evaluated by means of the average of %MVC for each subject.

(2) Joint angle

To measure the joint angle, we used 3D sensor (9 Degrees of Freedom Razor IMU; SparkFun Electronics). This sensor can measure triaxial terrestrial magnetism, triaxial acceleration, and triaxial angular velocity. The measurement position were upper arm, forearm and back of the hand. It is possible to calculate each joint angle from sensor orientation and inclination angle.

(3) Subjective evaluation

Subjective fatigue was evaluated in four body areas: neck, shoulder, elbow, and wrist. In addition, overall subjective fatigue of upper limb and difficulty of taking a posture were also evaluated. The range of rating scale is 1 (feel no fatigue at all or feel no difficulty at all) to 5 (feel highly fatigued or feel so difficult).

3 Result and Discussion

3.1 EMG

Figures 4, 5, and 6 show %MVC of clavicular part of the pectoralis major muscle, the flexor carpi ulnaris muscle, and the extensor carpi radialis longus muscle respectively. Every measurement of %MVC showed a significant main effect with respect to grasp types.

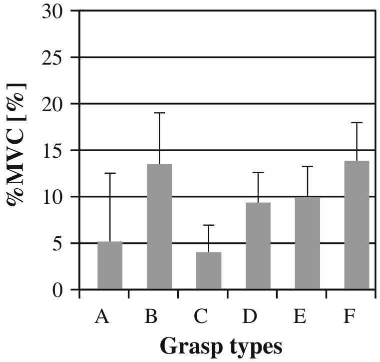


Fig. 4 %MVC of clavicular part of the pectoralis major m

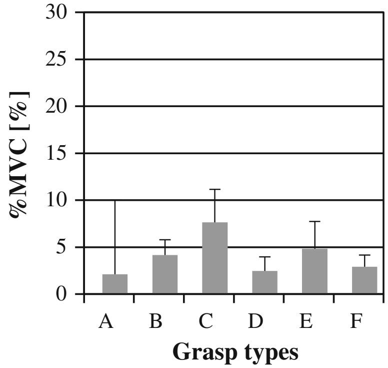


Fig. 5 %MVC of the flexor carpi ulnaris m

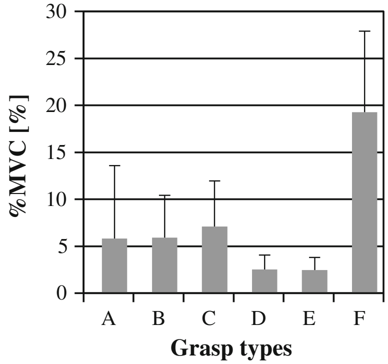


Fig. 6 %MVC of the extensor carpi radialis longus m

The %MVC of the clavicular part of the pectoralis major muscle was greater with the grasp types B and F. These grasp types require the subject to place his/her forearm in parallel to his/her midline. We consider this to be the cause of the observed higher muscle load, as the clavicular part of the pectoralis major muscle performs the horizontal flexion of shoulder joint. The %MVC of the flexor carpi

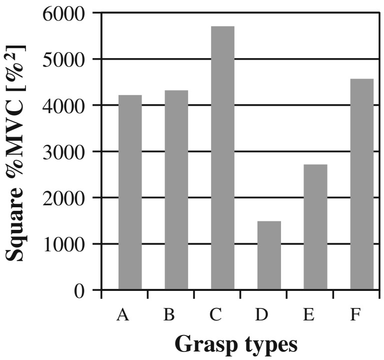


Fig. 7 Square sum of %MVC

ulnaris muscle was the greatest with the grasp type C. The grasp type C requires the subject to keep his/her line of sight perpendicular to the surface to be inspected by means of the ulnar and palmar flexion of wrist joint. These movements are performed by the flexor carpi ulnaris muscle, hence the observed highest load. The %MVC of the extensor carpi radialis longus muscle was the greatest with the grasp type F. The grasp type F requires the subject to keep his/her line of sight perpendicular to the surface to be inspected by means of the radial and dorsal flexion of wrist joint. These movements are performed by the extensor carpi radialis longus muscle, hence the observed highest load.

As above, the body site where muscle load is greater is different by means of grasp type. Therefore we have to evaluate these values synthetically, not individually. To achieve it, we calculated the square sum of all the %MVCs for each level, and took the sum as the evaluation index of the integral workload of the upper limb muscles (see Fig. 7). As the result of this calculation, the grasp type C had the greatest value for the square sum, and the grasp type D had the least. Therefore, with respect to EMG, we can see that the grasp type D has the least workload on muscles, and we recommend it.

3.2 Joint Angle

In order to evaluate the joint angle, we do not deal with each measurement at an individual joint, but define a value of cumulative displacement of joint angles and use it. The definition goes as follows. First we take, for each joint, the difference between the joint angle of a neutral position and the joint angle of working posture. Note that the joint may have more than one degrees of freedom (DOFs); in that case, each DOF has its own neutral position and we take the difference for each neutral position. Second, we take the absolute values of the differences. The cumulative displacement is then defined to be the sum of these absolute values. Details of the DOFs for joints are as follows. Shoulder joint has three DOFs (abduction–adduction, flexion–extension, and internal-external rotation), elbow

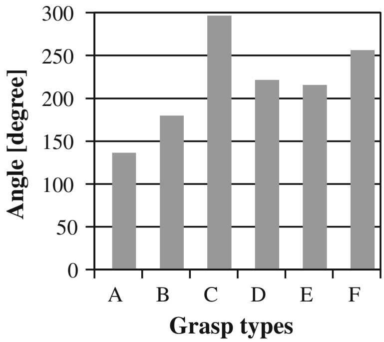


Fig. 8 Cumulative displacement of joint angle

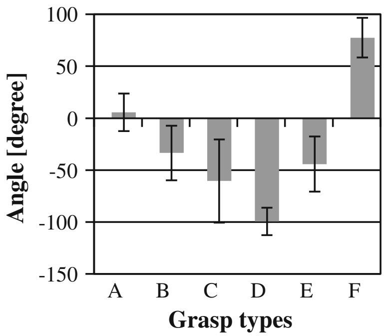


Fig. 9 Pronation-supination angle

joint has one DOF (flexion–extension), forearm has one DOF (pronation-supination), and wrist joint has two DOFs (radial-ulnar flexion and palmar- dorsal flexion). We give the values of cumulative displacement in Fig. 8. Figure 9 gives the pronation-supination angles of forearm.

As a result, the cumulative displacement was the greatest for the grasp type C and the least for the grasp type A. Looking into each joint, the grasp type C had the greatest displacement along all the DOFs of shoulder joint and along one DOF of wrist joint.

3.3 Subjective Evaluation

Figure 10 shows the subjective fatigue of the overall upper limb. Figure 11 shows the difficulty of taking a posture. Both subjective evaluations indicated the highest score with the grasp type C, and the lowest with the grasp type A. With the grasp type C, the trend of the subjective evaluation was consistent with the trend of EMG or joint angle.

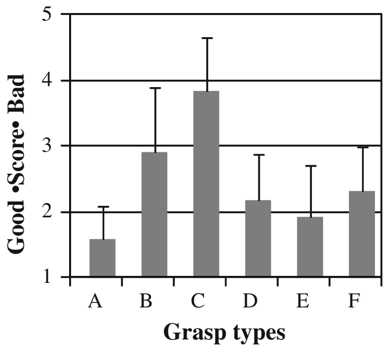


Fig. 10 Subjective fatigue of the overall upper limb

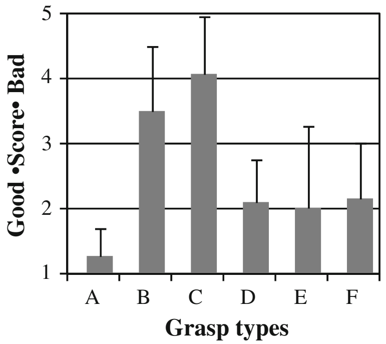


Fig. 11 Difficulty of taking a posture

3.4 Comprehensive Evaluation

Three evaluation indices above coincide with others about the source of the greatest workload on the upper limb, which is the grasp type C. It is clear from this fact that the grasp type C should be avoided as it is the worst in terms of muscle load, working posture, and subjective evaluation. On the other hand, these indices give different answers about the best grasp type which poses the least upper limb load. Namely, the grasp type D was the best in terms of muscle load, and the grasp type A was the best in terms of working posture and subjective evaluation.

This difference can be reasoned by the pronation-supination angle of forearm (see Fig. 9). With the grasp type D, supination angle is almost at the maximum range of motion although muscle load is small. This large movement of forearm should have affected negatively on working posture and subjective evaluation. In other words, the grasp type D is the best if muscle load alone is evaluated, while the grasp type A is recommended after taking into account the loads on joints by supination, subjective load, and the difficulty of taking working posture.

4 Conclusions

We conducted an experiment on the upper limb load during a sort of human visual inspection which involves the grasping of the object with one hand. We evaluated six different types of grasp. The evaluation indices were electromyography, joint angle, and subjective evaluation. As a result, the grasp type C was evaluated to be the worst and we recommend to avoid it. The best and recommended grasp type differed between evaluation indices. It was grasp type D in terms of muscle load, and grasp type A in terms of working posture and inspector's subjective evaluation. Therefore, in order to evaluate the workload of inspection and similar prolonged light load works, there would always be a need for the subjective evaluation of posture taking and keeping.

References

Cho CS, Chung BM, Park MJ (2005) Development of real-time vision-based fabric inspection system. IEEE Trans Ind Electron 52(4):1073–1079

Criswell E (ed) (2010) Cram's introduction to surface electromyography, 2nd edn. Jones and Bartlett Publishers, Massachusetts

Hida T, Seo A (2012) Development of evaluation function for estimating upper-limb load during visual inspection. Proceedings of the 13th Asia pacific industrial engineering and management systems conference, Phuket, Thailand, 2–4 December 2012

Hida T, Chihara T, Seo A (2013a) Effect of object size and grasp position on upper limb load during visual inspection (in Japanese). J Japan Ind Manag Assoc 63(4):217–244

Hida T, Chihara T, Seo A (2013b) Effect of speed and scanning direction on upper limb load during visual inspection (in Japanese). J Japan Ind Manag Assoc 64(2):1–8

Jebaraj D, Tyrrell RA, Gramopadhye AK (1999) Industrial inspection performance depends on both viewing distance and oculomotor characteristics. Appl Ergon 30(3):223–228

Lee FC, Chan AH (2009) Effects of magnification methods and magnifier shapes on visual inspection. Appl Ergon 40(3):410–418

Liao MH, Drury CG (2000) Posture, discomfort and performance in a VDT task. Ergonomics 43(3):345–359

Yeow PH, Sen RN (2004) Ergonomics improvements of the visual inspection process in a printed circuit assembly factory. Int J Occup Saf Ergon 10(4):369–385

A Process-Oriented Mechanism Combining Fuzzy Decision Analysis for Supplier Selection in New Product Development

Jiun-Shiung Lin, Jen-Huei Chang and Min-Che Kao

Abstract The selection of well-performed supplier involved in new product development (NPD) is one of the most important decision issues in the contemporary industrial field, in which the collaborative design is common. This paper proposes a systematical process-oriented mechanism combining fuzzy arithmetic operations for solving supplier selection problem in the NPD stage. In the proposed mechanism, the Design Chain Operations Reference model (DCOR) developed by Supply Chain Council (SCC) is adopted to describe NPD processes between the business and the candidate suppliers. These processes are deployed by four-level framework, including the top level, the configuration level, the process element level, and the implementation level. Then, the design structure matrix (DSM) is used to analyze the process relationship based on the results from the implementation level. The original DSM is partitioned by the Steward's method to get reordered DSMs with the interactive process information with respect to the metrics provided by the DCOR. The fuzzy decision analysis is executed to obtain the weighted aggregated scores with respect to the DCOR metrics and to select the best suppliers for different components. Finally, a practical case in Taiwan is demonstrated to show the real-life usefulness of the proposed mechanism.

Keywords New product development (NPD) · Supplier selection · DCOR · Design structure matrix (DSM) · Fuzzy decision analysis

J.-S. Lin (✉) · M.-C. Kao
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei, Taiwan, Republic of China
e-mail: jslin@mail.mcut.edu.tw

M.-C. Kao
e-mail: kao_mio@yahoo.com.tw

J.-H. Chang
Department of Logistics Management, Tungnan University, New Taipei, Taiwan, Republic of China
e-mail: jhchang@mail.tnu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_29,

1 Introduction

Dramatically global competition and consumers' needs diversity have resulted in shortening product life cycle and increasing complexity in new product development (NPD). To maintain competitive advantages, many companies have placed an emphasis on cultivating the core competences of product development. Selecting the best suppliers involved early in the NPD stage, which is also called the early supplier involvement (ESI), plays a strategic role in the degree to which an organization is able to achieve its goal of developing a new product. Apparently, it is a major factor in customer satisfaction, product quality, cost reduction, risk sharing (Johnsen 2009). Therefore, developing a mechanism to select well-performed suppliers involved early in the NPD stage is one of the most important decision issues in the contemporary industrial field.

In the past several decades, the supplier selection problem has received considerable attention from both practitioners and researchers (De Boer et al. 2001; Ho et al. 2010). From the viewpoint of contemporary supply chain management, many companies regard their suppliers as partners, not adversaries. Hence, an interesting topic relating to the ESI has gradually received more attention in the past two decades. Obviously, the supplier selection involved in the NPD stage is essentially the multi-criteria decision-making (MCDM) process. In many real-world situations, the MCDM process usually involves uncertainty. Zadeh (1965) was first to present fuzzy set theory. This theory provided a good methodology for handling imprecise and vague information. Kumar et al. (2004) provided a fuzzy goal programming approach for solving a vender selection problem with three objectives. Tang et al. (2005) applied the fuzzy synthesis evaluation method to assess the design scheme in part deployment process. They determined eight influencing factors for facilitating the selection of suppliers involved in NPD projects. Carrera and Mayorga (2008) considered three indicators: supplier characteristics, supplier performance, and project characteristics. They applied modular fuzzy inference system to the supply chain for the selection of suitable suppliers engaged in the NPD. Oh et al. (2012) proposed a decision-making framework using a fuzzy expert system in portfolio management for dealing with the uncertainty of the fuzzy front-end of product development.

Most previous researches on supplier selection involved in the NPD did not consider interactive process information among the design chain members. To integrate this information into the decision of selecting the best suppliers involved in the NPD, this paper proposes a process-oriented mechanism combining fuzzy arithmetic operations for solving supplier selection problem in the NPD stage, in which simultaneously takes the interactive process information and linguistic information into consideration in the decision-making process. The proposed mechanism can provide practitioners with selecting the best suppliers involved early in the NPD stage.

2 Description of the NPD Process Information

Implementing a NPD project requires the team consisting of members from a variety of companies at different locations. They work together to solve specific product issues and exchange information each other. Hence, a well-defined information exchange and communication platform is necessary for the members involved in NPD collaboration so as to achieve the synergy. In 2006, Design Chain Operation Reference Model (DCOR) was first introduced by Supply Chain Council (SCC). The DCOR can be adequately used as a platform for the design chain partners.

The DCOR is a process-oriented four-level deployment architecture, as illustrated in Fig. 1. The Level 1, called the top level/process types, consists of five management processes (i.e., plan (P), research (R), design (D), integrate (I), and amend (A)). The Level 2, called the configuration level/process Categories, includes product refresh, new product, and new technology. For example, based on the research (R) process of the Level 1, the processes of the level 2 are divided into three categories: research product refresh (R1), research new product (R2), and research new technology (R3). The Level 3, called the process element level/ decompose processes, deployed from the Level 2, includes input, output, metrics, and best practices. According to the company's requirements, these processes are deployed to the Level 4, called the implementation level/decompose process elements.

The DCOR also defines five process performance metrics that can be used as indices for selecting the best suppliers in the NPD stage. The five metrics are (1) reliability, (2) responsiveness, (3) agility, (4) cost, and (5) asset. Each metric includes several sub-metrics (Nyere 2009). The DCOR provides practitioners with a common reference model that allows the effective communication between companies and their design chain partners. It is important that benefits and competition of a company can be improved by applying collaborative new product development and design.

Although the DCOR provides a process reference model for the practitioners, it does not systematically present the interactive process information among the design chain members. The Design Structure Matrix (DSM) is suited for converting the process information of the Level 4 in the DCOR to the interactive process information we want. By using the partition rule presented by Steward (1981), the process information is divided into three types: parallel, sequential, and coupled/interdependent processes. The DSM is able to capture the interactive processes (i.e., coupled/interdependent processes). In this paper, these coupled/ interdependent processes are applied to express the interactive process information from the Level 4 of the DCOR in the NPD stage.

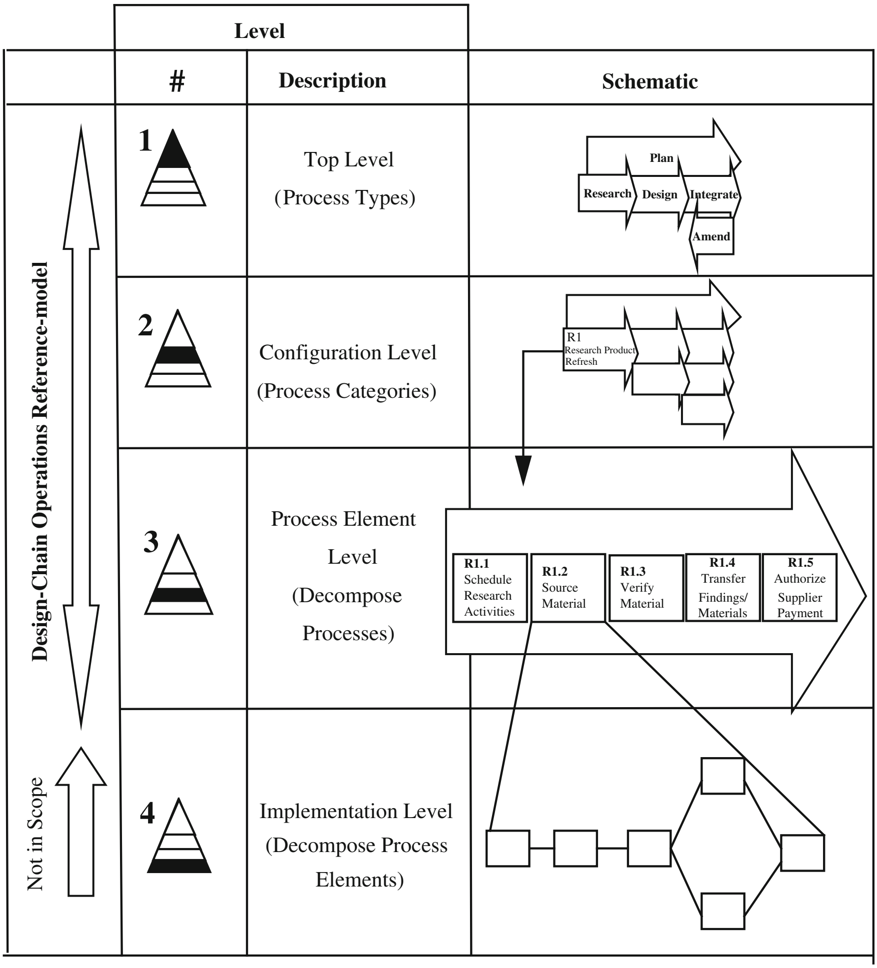


Fig. 1 Four levels of DCOR

3 The Proposed Process-Oriented Mechanism

In this section, we provide a process-oriented mechanism combining fuzzy decision analysis for solving supplier selection problem in NPD. Twelve steps of the proposed mechanism are presented as follows:

Step 1. Define the scope of supplier selection in the NPD stage for an enterprise.

Step 2. According to the requirements of the enterprise, establish D-L1-M (DCOR Level 1 Model) based on the top level of the DCOR.

Step 3. Generate D-L2-M (DCOR Level 2 Model) based on the configuration level of the DCOR.
Step 4. Form D-L3-M (DCOR Level 3 Model) based on the process element level of the DCOR.
Step 5. Build D-L4-M (DCOR Level 4 Model) based on the implementation level of the DCOR.
Step 6. Transform D-L4-M into the DSM, called the original DSM.
Step 7. Get the reordered (partitioned) DSM by applying the Steward's method (Steward 1981) to partition the original DSM.
Step 8. Construct fuzzy evaluation representation based on the DCOR metrics. The linguistic weighting variables are used to assess the importance of the metrics and the linguistic rating variables are utilized to evaluate the performance for candidate suppliers with respect to each metric. The linguistic weighting variables and the linguistic rating variables are measured by nine linguistic terms, respectively. For simplicity, but without loss of generality, these linguistic terms are assumed in this paper to be represented as triangular fuzzy number (TFN) expressed by a triple (*a*, *b*, *c*).
Step 9. Determine fuzzy weights of the metrics and fuzzy scores for candidate suppliers with ferred to TFNs. The fuzzy weight of metric *j* is denoted as $\tilde{w}_j = \left(w_{j1}, w_{j2}, w_{j3}\right)$. Hence, the fuzzy weight matrix is $\tilde{W} = \left[\tilde{w}_j\right]$ of size $1 \times n$. The fuzzy score for candidate supplier *i* with respect to metric *j* is denoted as $\tilde{x}'_{ij} = \left(x'_{ij1}, x'_{ij2}, x'_{ij3}\right)$.
Step 10. Form fuzzy decision matrix by normalizing fuzzy scores for each candidate supplier. The fuzzy decision matrix is $\tilde{X} = \left[\tilde{x}_{ij}\right]$ of size $m \times n$, where $\tilde{x}_{ij}$ denotes normalized fuzzy score of candidate supplier *i* with respect to metric *j*.
Step 11. Get fuzzy weighted composite scores for each candidate supplier ($\tilde{c}_i$) and construct the weighted composite fuzzy score matrix by $\tilde{C} = \left[\tilde{x}_{ij}\right] \cdot \left[\tilde{w}_j\right]^t,\ i = 1,\ 2, , m,\ j = 1,\ 2, , n.$
Step 12. Defuzzify the fuzzy weighted composite scores into the crisp real values. The defuzzified value corresponding $\tilde{c}_i$ is calculated by $c_i = (c_{i1} + c_{i2} + c_{i2} + c_{i3})/4$. Select the best supplier with the highest defuzzified value.

4 A Practical Application

In this section, a practical application is used to demonstrate the real-world usefulness of the proposed mechanism. The company Y, founded in 1984, is a world-class computer manufacturing company in Taiwan. To meet rapidly growing demand of the 4G LTE (Long Term Evolution) tablet personal computer (LTE-T PC) in the near future, the company Y is planning to select the best suppliers involved early in the NPD of the LTE-TPC so that it can be launched earlier than other competitors. The five main modules of the LTE-TPC are the the mainboard module (candidate suppliers are AS and GA), the LCD module (candidate suppliers are CM, HA, and AU), the Wi-LAN and Wi-WAN module (candidate suppliers are BR and IN), the Touch sensor module (candidate suppliers are TP, YF, JT, and HT), and the NFC module (candidate suppliers are NFC, WT, and BR). It is critical to select the abovementioned suppliers involved early in the NPD (Step 1). We recommend that the decision makers of the company Y adopt the proposed mechanism since it is suitable for the NPD of the LTE-TPC. The product development meeting including the project manager, key parts' engineers, procurement staffs, and related suppliers is convened, and then the D-L1-M (Step 2) is established based on the LTE-TPC schedule for time to market. The D-L2-M (Step 3), the D-L3-M (Step 4), and the D-L4-M (Step 5) are deployed in order. Due to the limit of the paper length, only the D-L1-M associated with the LCD module is presented here, as displayed in Fig. 2.

After building the D-L4-M, all the process information between the company Y and its suppliers are completely presented. To further obtain the interactive processes, the D-L4-M is transformed into the DSM (Step 6). Steward's method is adopted to partition the DSM to get the reordered DSM, as shown in Fig. 3. Then, the interdependent DSM is extracted from the reordered DSM (Step 7).

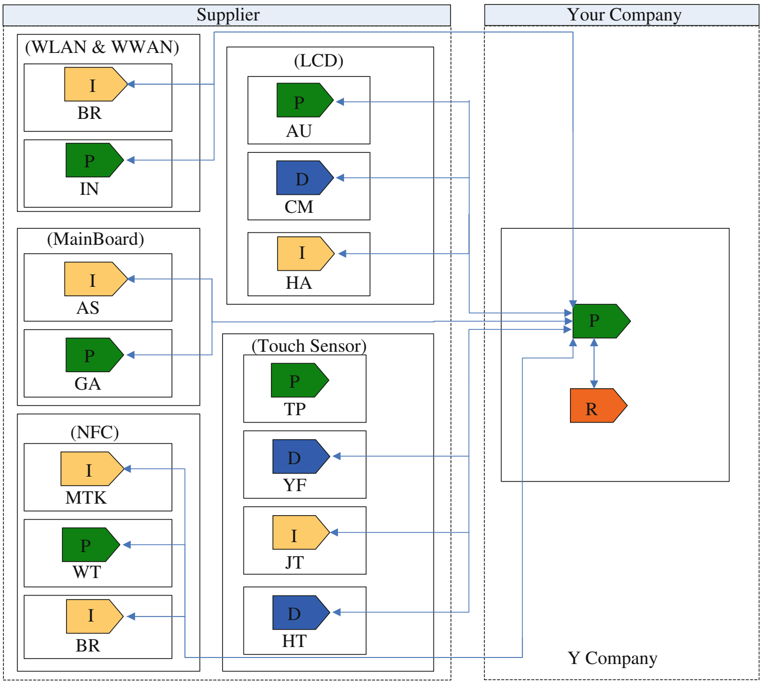


Fig. 2 D-L1-M of the LTE-TPC

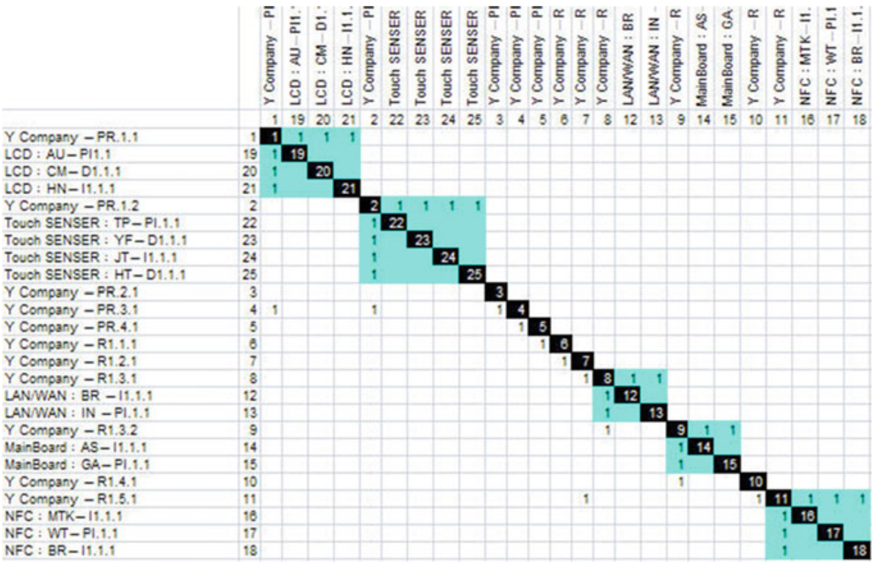


Fig. 3 Partitioned (reordered) DSM

Table 1 Linguistic variables for the weighting and rating

Linguistic weighting	Linguistic rating	TFN (a, b, c)
Definitely low (DL)	Definitely poor (DP)	(0, 0, 0.125)
Very low (VL)	Very poor (VP)	(0, 0.125, 0.25)
Low (L)	Poor (L)	(0.125, 0.25, 0.375)
Medium low (ML)	Medium poor (MP)	(0.25, 0.375, 0.5)
Medium (M)	Fair (F)	(0.375, 0.5, 0.625).
Medium high (MH)	Medium good (MG)	(0.5, 0.625, 0.75)
High (H)	Good (G)	(0.625, 0.75, 0.875)
Verv high (VH)	Very good (VG)	(0.75, 0.875, 1)
Definitely high (DH)	Definitely good(DG)	(0.875, 1, 1)

Based on the DCOR, the structure of the metrics, including five main metrics and their corresponding submetrics is proposed to evaluate the best NPD module suppliers. The linguistic weighting and rating variables are measured by nine linguistic terms, as shown in Table 1 (Step 8). The fuzzy weights of the metrics and scores of candidate suppliers for the LCD module are determined by the members participated in the LTE-TPC project team. The results are shown in Tables 2 and 3 (Step 9). From Tables 2 and 3, we can get fuzzy weight matrix and fuzzy decision matrix (Step 10).

According to Step 11, the weighted composite fuzzy score matrix can be obtained. For example, the fuzzy weighted composite fuzzy score of candidate supplier CM for the LCD module is

Table 2 The fuzzy weight of the metrics

Weighting	Expert			
	e_1	e_2	Ee_3	Mean
Reliability	H	VH	H	(0.67, 0.792, 0.917)
Responsiveness	H	MH	MH	(0.54, 0.667, 0.792)
Agility	M	MH	M	(0.42, 0.542, 0.667)
Cost	VH	VH	DH	(0.79, 0.917, 1)
Assets	VL	L	VL	(0.04, 0.167, 0.292)

Table 3 The fuzzy ratings of three candidate suppliers for the LCD module

Rating	Item	Supplier		
		CM	HA	AU
Reliability	% On-time to commit	MG	G	G
	# of design errors	VG	G	G
	Document complete	G	MG	MG
	Perfect Integration	G	MG	VG
	Mean	(0.625, 0.75, 0875)	(0.563, 0.688, 0.813)	(0.625, 0.75, 0. 875)
Responsiveness	Research cycle time	G	F	G
	Design cycle time	G	F	G
	Integrate cycle time	G	MG	G
	Mean	(0.625, 0.75, 0.875).	(0.417, 0.542, 0.667)	(0.625, 0.75, 0.875)
Agility	Pilot build time	G	MG	MG
	Amend cycle time	MG	G	F
	Re-plan frequency	MG-	F	MG
	Mean	(0.542, 0.667, 0.792)	(0.5, 0.625, 0.75)	(0.458, 0.583, 0.708)
Cost.	Plan Cost	G	G	VG
	Research Cost	G	VG	G
	Design Cost	G	G	VG
	Integrate cost	G	G	G
	Amend cost	MG	MG	MG
	Mean	(0.6, 0.725, 0.85)	(0.625, 0.75, 0.875)	(0.65, 0.775, 0.9)

$$\begin{aligned}\tilde{C}_{CM} &= [(0.625, 0.75, 0.875)(0.625, 0.75, 0.875)(0.542, 0.667, 0.792)(0.6, 0.725, 0.85)(0.475, 0.6, 0.725)]\cdot\\ &\quad [(0.67, 0.792, 0.917)(0.54, 0.66, 0.792)(0.42, 0.542, 0.667)(0.79, 0.917, 1.00)(0.04, 0.167, 0.292)]^t\\ &= (1.476, 2.219, 3.08).\end{aligned}$$

Similarly, $\tilde{C}_{HA} = (1.326, 2.04, 2.87)$, $\tilde{C}_{AU} = (1.482, 2.24, 3.09)$. Then, the defuzzified value is calculated by using Step 12. These resulting values are $C_{CM} = 2.249$, $C_{HA} = 2.069$, and $C_{AU} = 2.263$. As a result, the best supplier for the LCD module is AU since it has the highest crisp real value.

5 Conclusions

The supplier selection involved in the NPD stage is a complicated MCDM problem, in which ambiguous and linguistic decision information is usually encountered. Based on the DCOR structure, this paper have developed a process-oriented mechanism combining fuzzy arithmetic operations for supporting a company to select the best suppliers involved early in the NPD stage. The four-level deployment framework of the DCOR can clearly and completely express all NPD process information among design chain members. The DSM can adequately be used to transform the process information deployed from the DCOR into the interactive process information. Such interactive information is a critical communication media between the company and its suppliers across the design chain. The main contribution of this paper is to incorporate the NPD interactive process information into the supplier selection mechanism. Based on the practical illustration, it is concluded that the proposed mechanism can be a useful methodology for making supplier selection decision.

Acknowledgments The authors would like to thank the Ming Chi University of Technology for financially supporting this study under Contract No. 102-Academic Research Subvention-M-19.

References

Carrera DA, Mayorga RV (2008) Supply chain management: a modular fuzzy inference system approach in supplier selection for new product development. J Intell Manuf 19:1–12
De Boer L, Labro E, Morlacchi P (2001) A review of methods supporting supplier selection. Eur J Purch Supply Manag 7:75–89
Ho W, Xu X, Dey PK (2010) Multi-criteria decision making approaches for supplier evaluation and selection: a literature review. Eur J Purch Supply Manag 202:16–24
Johnsen TE (2009) Supplier involvement in new product development and innovation: taking stock and looking to the future. J Purch Supply Manag 15:187–197
Kumar M, Vrat P, Shankar R (2004) A fuzzy goal programming approach for vendor selection problem in a supply chain. Comput Ind Eng 46:69–85
Nyere J (2009) DCOR 2.0 framework update next release of the design chain operational reference-model. http://ebookbrowse.com/dcor-2009-05-13-vfinal-pdf-d287392716
Oh J, Yang J, Lee S (2012) Managing uncertainty to improve decision-making in NPD portfolio management with a fuzzy expert system. Expert Syst Appl 39:9868–9885
Steward DV (1981) The design structure system: a method for managing the design of complex systems. IEEE Trans Eng Manag 28:71–74
Tang J, Zang YE, Tu Y, Chen Y, Dong Y (2005) Synthesis, evaluation, and selection of parts design scheme in supplier involved product development. Concurr Eng 13:277–289
Zadeh LA (1965) Fuzzy sets. Inf. Control 8:338–353

Reliability-Based Performance Evaluation for a Stochastic Project Network Under Time and Budget Thresholds

Yi-Kuei Lin, Ping-Chen Chang and Shin-Ying Li

Abstract This study develops a performance indicator, named project reliability, to measure the probability that a stochastic project network (SPN) can be successfully completed under both time and budget thresholds. The SPN is represented in the form of AOA (activity-on-arc) diagram, in which each activity has several possible durations with the corresponding costs and probability distribution. From the perspective of minimal path, two algorithms are proposed to generate upper and lower limit vectors which satisfy both time and budget, respectively. Next, the project reliability is evaluated in terms of such upper and lower limit vectors. The procedure of reliability evaluation can be applied to the SPN with arbitrary probability distribution. Such an indicator is a beneficial factor of the trade-off between the time and budget in a decision scenario.

Keywords Project reliability · Stochastic project network (SPN) · Minimal path · Activity-on-arc (AOA)

1 Introduction

This paper discusses a novel performance index for a stochastic project network (SPN), called project reliability, and defines it as the probability that the project is completed within the given time and budget. A network technique is proposed to

Y.-K. Lin (✉) · P.-C. Chang · S.-Y. Li
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: yklin@mail.ntust.edu.tw

P.-C. Chang
e-mail: D9901001@mail.ntust.edu.tw

S.-Y. Li
e-mail: M10101019@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_30,

evaluate the project reliability. For the project manager, such an index is regarded as a decision factor of the trade-off between the given time and budget. Relevant literatures are reviewed as follows.

A project can be modeled as a project network (a graph with nodes and arcs) to portray the interrelationships among the activities of a project. A project network can be represented in either activity-on-arc (AOA) diagram. In AOA diagram, each activity is represented by an arc. A node is used to separate an activity from each of its immediate predecessors. Hiller and Liberman (2005) indicated AOA has fewer nodes than AON (activity-on-node) for the same project and thus most project networks are represented in AOA. A project is affected by uncertainties, and thus activity durations of the project should stochastic (Pontrandolfo 2000). Such a project is usually modeled as an SPN, in which each activity has several durations with a probability distribution. The minimal path (MP) technique is a widely used to evaluate the reliability of a network, where an MP is a sequence of arcs from a source to a sink which contains no cycle (Zuo et al. 2007; Lin 2008). It implies that an MP is a path whose proper subsets are no longer paths (Lin et al. 1995). Since MP is based on the AOA diagram, it is a practical way to evaluate reliability for the SPN in terms of MP.

2 Stochastic Project Network Model

This study proposes an MP-based procedure that firstly finds all upper and lower limit vectors for the given time and budget in terms of MP, in which the activity durations and their corresponding costs and probability distributions are proposed by the activity contractors. Subsequently we evaluate the project reliability through such vectors for an SPN.

Assumptions:

1. The duration of each a_i is an integer value: $x_{i1} < x_{i2} < x_{i3} < \ldots < x_{iw_i}$ with given probability distribution and its corresponding cost c_i takes a value: $c_{i1} > c_{i2} > c_{i3} > \ldots > c_{iw_i}$.
2. The activity durations of different a_i are s-independent.

2.1 Project Model Construction and Reliability Definition

Let $G = (\mathbf{N}, \mathbf{A})$ denote an SPN with $\mathbf{N}$ representing the set of nodes and $\mathbf{A} = \{a_i | i = 1, 2, \ldots, n\}$ representing the set of arc (activities), where n is the number of activities. The duration vector $X = (x_1, x_2, \ldots, x_n)$ is defined as the current duration state of G where x_i represents the current duration of activity a_i.

The proposed performance index, project reliability, is defined as the probability that the project completion time and cost under X does not exceed T and B, respectively. The project reliability is represented as $R_{T,B}(X) = \Pr\{X| T(X) \leq T \text{ and } B(X) \leq B\} = \Pr\{X|X \in \boldsymbol{X_{T,B}}\}$, in which $X \in \boldsymbol{X_{T,B}}$ means that X satisfies (T, B). In order to calculate such a probability, we proposed a methodology for (T, B)-UL and (T, B)-LL to depict the boundaries of $\boldsymbol{X_{T,B}}$. That is, the project reliability is equal to the probability of X between (T, B)-UL and (T, B)-LL.

2.2 Upper Limit Vector and Lower Limit Vector

Time constraint T is utilized to bound the maximal duration vectors among all $X \in \boldsymbol{X_{T,B}}$; while the budget constraint is utilized to bound the minimal duration vectors. Following are definitions for (T, B)-UL and (T, B)-LL of $\boldsymbol{X_{T,B}}$.

Definition 1 A duration vector X is a (T, B)-UL if $X \in X_{T,B}$ and $T(Y) > T$ for each duration vector Y such that $Y > X$.

Definition 2 A duration vector X is a (T, B)-LL if $X \in X_{T,B}$ and $B(Y) > B$ for each duration vector Y such that $Y < X$.

In order to generate all (T, B)-UL and (T, B)-LL, we define a pseudo duration vector $Z = (z_1, z_2, \ldots, z_n)$ and a pseudo cost vector $V = (v_1, v_2, \ldots, v_n)$, respectively. Each pseudo duration z_i satisfies $z_i \in \{x_{i1}, x_{i1} + 1, x_{i1} + 2, \ldots\}$, $i = 1, 2, \ldots, n$. Similarly, each pseudo cost v_i satisfies $v_i \in \{c_{iwi}, c_{iwi} + 1, c_{iwi} + 2, \ldots\}$, $i = 1, 2, \ldots, n$. In order to obtain all (T, B)-UL, for each mp_j, we first generate the pseudo duration vector Z satisfying $\sum_{a_i \in mp_j} z_i .= T$. Subsequently, for each Z, generate the largest X such that $B(X) \leq B$ and $X \leq Z$. Such X is regarded as a (T, B)-UL candidate. Hence we generate all pseudo cost vectors V such that $v_1 + v_2 + \ldots + v_n = B$. Subsequently, for each V, we find the largest C such that $C \leq V$. The corresponding X of such C is regarded as a (T, B)-LL candidate if it satisfies $T(X) \leq T$. Based on Lemmas 1 and 2, the following Algorithms I and II are proposed to generate all (T, B)-UL and (T, B)-LL, respectively.

Algorithm I: Generate all (T, B)-UL

Step 1. Find all pseudo duration vectors $Z = (z_1, z_2, \ldots, z_n)$ satisfying both constrains (1) and (2).

$$\sum\nolimits_{a_i \in mp_j} z_i \;= T \quad j = 1, 2, \ldots, m, \text{ and} \tag{1}$$

$$z_i \geq x_{i1} \text{ for } i = 1, 2, \ldots, n, \text{where } z_i \text{ is an integer value.} \tag{2}$$

Step 2. Utilize the following equation to find the largest duration vector X such that $X \leq Z$.

$$x_i = \begin{cases} x_{iw_i} & \text{if } x_{iw_i} \le z_i \\ x_{it} & \text{if } x_{it} \le z_i < x_{i(t+1)} \end{cases} \quad i = 1, 2, \ldots, n. \tag{3}$$

Step 3. Remove those X with B(X) > B. Then the remainder is the set of (T, B)-UL candidates.

Step 4. Find all (T, B)-UL from these candidates by using the following procedure, i.e. to remove the non-maximal ones from the candidate set.

Algorithm II: Generate all (T, B)-LL

Step 1. Find all pseudo cost vectors $V = (v_1, v_2,\ldots, v_n)$ satisfying both constrains (4) and (5).

$$v_1 + v_2 + \ldots + v_n = B, \tag{4}$$

$$v_i \ge c_{iw_i}, \quad i = 1, 2, \ldots, n, \tag{5}$$

where v_i is an integer value.

Step 2. Utilize the following equation to find the largest cost vector C for each V such that $C \le V$.

$$c_i = \begin{cases} c_{i1} & \text{if } v_i \ge c_{i1} \\ c_{it} & \text{if } c_{i(t-1)} > v_i \ge c_{it} \end{cases} \quad i = 1, 2, \ldots, n. \tag{6}$$

Step 3. Transform each C from Step 2 to the corresponding X and then remove those X with T(X) > T. Then the remainder is the set of (T, B)-LL candidates.

Step 4. Find all (T, B)-LL from these candidates by using the following procedure, i.e. to remove the non-minimal ones from the candidate set.

2.3 Evaluation of Reliability in Stochastic Project Network

We assume all (T, B)-UL from algorithm I are$X_1^u, X_2^u, \ldots, X_p^u$ and all (T, B)-LL from algorithm II are $X_1^l, X_2^l, \ldots, X_q^l$. Let $\boldsymbol{U_{T,B}} = \cup_{i=1}^{p}\{X|X \le X_i^u\}$ and $\boldsymbol{L_{T,B}} = \cup_{i=1}^{q}\{X|X \le X_i^l\}$. Since ($T$, B)-UL and (T, B)-LL are the upper limit and lower limit vectors of $\boldsymbol{X_{T,B}}$, respectively, $\boldsymbol{X_{T,B}}$ can be described as

$$\boldsymbol{X_{T,B}} = \{\boldsymbol{U_{T,B}} \backslash \boldsymbol{L_{T,B}}\} \cup \{X_1^l, X_2^l, \ldots, X_q^l\}, \tag{7}$$

where the first term $\{\boldsymbol{U_{T,B}} \backslash \boldsymbol{L_{T,B}}\}$ implies that all (T, B)-LL are deleted by subtracting $\boldsymbol{L_{T,B}}$ because $X_i^l \in \boldsymbol{L_{T,B}}$ for i = 1, 2, …, q. Note that, these (T, B)-LL

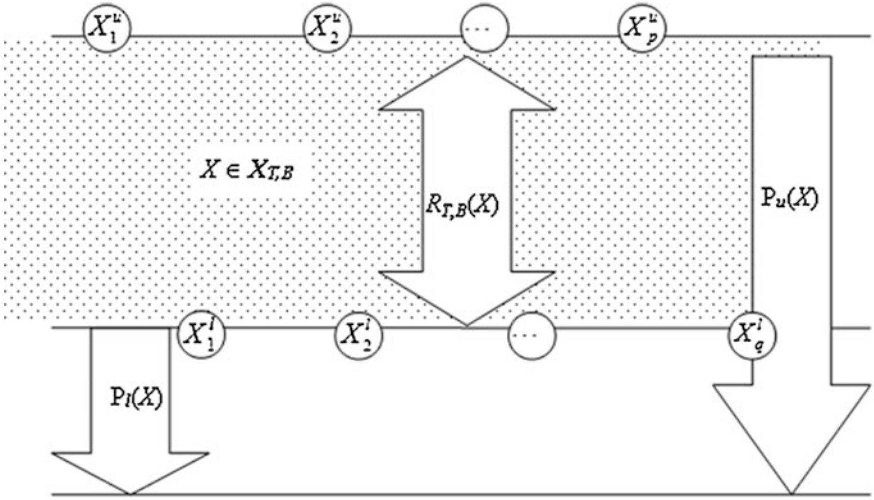


Fig. 1 Project reliability

belonging to $\boldsymbol{L_{T,B}}$ also satisfy $\boldsymbol{X_{T,B}}$, and we have to include them into $\boldsymbol{X_{T,B}}$ by adding the second term $\{X_1^l X_2^l, \ldots, X_q^l\}$. Figure 1 illustrates the project reliability, in which $\mathrm{P}_u(X) = \Pr\{\boldsymbol{U_{T,B}}\} = \Pr\{\cup_{i=1}^{p}\{X|X \leq X_i^u\}\}$ and $\mathrm{P}_l(X) = \Pr\{\boldsymbol{L_{T,B}}\} = \Pr\{\cup_{i=1}^{q}\{X|X < X_i^l\}\}$. Therefore, the project reliability is

$$
\begin{aligned}
R_{T,B}(X) &= \Pr\{X|X \in \boldsymbol{X_{T,B}}\} = \mathrm{P}_u(X) - \mathrm{P}_l(X) \\
&= \Pr\{\cup_{i=1}^{p}\{X|X \leq X_i^u\}\} \text{ - } \Pr\{\cup_{i=1}^{q}\{X|X \leq X_i^l\}\} + \sum_{i=1}^{q} \Pr(X_i^l).
\end{aligned} \tag{8}
$$

3 Illustrative Example

We utilize a simple project network composed of five activities and represented in the form of AOA diagram as shown in Fig. 2. This example demonstrates the procedure to generate the upper and lower limit vectors and to evaluate the project reliability. The activity cost and the activity duration of each activity are shown in

Fig. 2 Simple project network

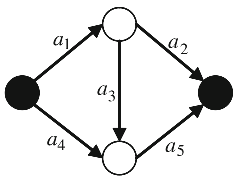


Table 1 Activity cost, activity duration and probability of each arc

a_i	Duration (weeks)	Cost (US$ 100)	Probability	a_i	Duration (weeks)	Cost (US$ 100)	Probability
1	2	8	0.3	4	2	6	0.3
	3	7	0.5		3	5	0.3
	4	6	0.2		4	4	0.4
2	3	8	0.25	5	3	8	0.35
	4	7	0.5		4	7	0.4
	5	6	0.25		5	6	0.25
3	2	7	0.2				
	3	6	0.5				
	4	5	0.3				

Table 1. The project network has three minimal paths, say $mp_1 = \{a_1, a_2\}$, $mp_2 = \{a_1, a_3, a_5\}$, and $mp_3 = \{a_4, a_5\}$. The case illustrates the method that generates the project reliability of the duration within 11 weeks and the cost within US$ 3,400.

Algorithm I: Generate all (11, 3,400)-UL

Step 1. Find all pseudo duration vectors $Z = (z_1, z_2,\ldots, z_n)$ satisfying

$$\begin{cases} z_1 + z_2 = 11 \\ z_1 + z_3 + z_5 = 11 \\ z_4 + z_5 = 11 \end{cases}, \text{ and} \tag{9}$$

$$z_1 \geq 2, z_2 \geq 3, z_3 \geq 2, z_4 \geq 2, z_5 \geq 3. \tag{10}$$

Thus, we have 15 pseudo duration vectors shown in the first column of Table 2. Steps 2 to 4. We obtain six (11, 3,400)-UL: $X_3 = (4, 5, 2, 4, 5)$, $X_7 = (3, 5, 3, 4, 5)$, $X_8 = (4, 5, 3, 4, 4)$, $X_{10} = (4, 5, 4, 4, 3)$, $X_{11} = (3, 5, 4, 4, 4)$ and $X_{12} = (2, 5, 4, 4, 5)$ by applying Algorithm I. The calculation process is summarized in Table 2.

Algorithm II: Generate all (11, 3,400)-LL

Step 1. Find all pseudo cost vectors $V = (v_1, v_2,\ldots, v_n)$ satisfying

$$v_1 + v_2 + v_3 + v_4 + v_5 = 34 \tag{11}$$

$$v_1 \geq 6, v_2 \geq 6, v_3 \geq 5, v_4 \geq 4, v_5 \geq 6 \tag{12}$$

Steps 2 to 4. We obtain 30 (11, 3,400)-LL which are summarized in Table 3. By adopting Algorithm II, Tables 2 and 3 shows the obtained (11, 3,400)-UL and (11, 3,400)-LL, respectively. The project reliability of duration within 11 weeks and cost within US$ 3,400 is $P_u(X) – P_l(X) = 0.8985 - 0.065175 = 0.833325$.

Table 2 The (11, 3,400)-UL

Step 1	Step 2	Step 3	Step 4
$Z_1 = (2, 9, 2, 4, 7)$	$X_1 = (2, 5, 2, 4, 5)$	$B(X_1) = 3{,}100$	No, $X_3 > X_1$
$Z_2 = (2, 9, 3, 5, 6)$	$X_2 = (2, 5, 3, 4, 5)$	$B(X_2) = 3{,}000$	No, $X_3 > X_2$
$Z_3 = (2, 9, 4, 6, 5)$	$X_3 = (2, 5, 4, 4, 5)$	$B(X_3) = 2{,}900$	Yes, X_3 is a (11, 3,400)-UL.
$Z_4 = (2, 9, 5, 7, 4)$	$X_4 = (2, 5, 4, 4, 4)$	$B(X_4) = 3{,}000$	No, $X_3 > X_4$
$Z_5 = (2, 9, 6, 8, 3)$	$X_5 = (2, 5, 4, 4, 3)$	$B(X_5) = 3{,}100$	No, $X_3 > X_5$
$Z_6 = (3, 8, 2, 5, 6)$	$X_6 = (3, 5, 2, 4, 5)$	$B(X_6) = 3{,}000$	No, $X_7 > X_6$
$Z_7 = (3, 8, 3, 6, 5)$	$X_7 = (3, 5, 3, 4, 5)$	$B(X_7) = 2{,}900$	Yes, X_7 is a (11, 3,400)-UL.
$Z_8 = (3, 8, 4, 7, 4)$	$X_8 = (3, 5, 4, 4, 4)$	$B(X_8) = 2{,}900$	Yes, X_8 is a (11, 3,400)-UL.
$Z_9 = (3, 8, 5, 8, 3)$	$X_9 = (3, 5, 4, 4, 3)$	$B(X_9) = 3{,}000$	No, $X_8 > X_9$
$Z_{10} = (4, 7, 2, 6, 5)$	$X_{10} = (4, 5, 2, 4, 5)$	$B(X_{10}) = 2{,}900$	Yes, X_{10} is a (11, 3,400)-UL.
$Z_{11} = (4, 7, 3, 7, 4)$	$X_{11} = (4, 5, 3, 4, 4)$	$B(X_{11}) = 2{,}900$	Yes, X_{11} is a (11, 3,400)-UL.
$Z_{12} = (4, 7, 4, 8, 3)$	$X_{12} = (4, 5, 4, 4, 3)$	$B(X_{12}) = 2{,}900$	Yes, X_{12} is a (11, 3,400)-UL.
$Z_{13} = (5, 6, 2, 7, 4)$	$X_{13} = (4, 5, 2, 4, 4)$	$B(X_{13}) = 3{,}000$	No, $X_{12} > X_{13}$
$Z_{14} = (5, 6, 3, 8, 3)$	$X_{14} = (4, 5, 3, 4, 3)$	$B(X_{14}) = 3{,}000$	No, $X_{12} > X_{14}$
$Z_{15} = (6, 5, 2, 8, 3)$	$X_{15} = (4, 5, 2, 4, 3)$	$B(X_{15}) = 3{,}100$	No, $X_{12} > X_{15}$

Table 3 The (11, 3,400)-LL

Step 1	Step 2	Step 3		Step 4
$V_1 = (6, 6, 5, 4, 13)$	$C_1 = (6, 6, 5, 4, 8)$	$X_1 = (4, 5, 4, 4, 3)$	$T(X_1) = 11$	30 (11, 3,400)-LL: $X_{52} = (4, 4, 2, 2, 3)$,
$V_2 = (6, 6, 5, 5, 12)$	$C_2 = (6, 6, 5, 5, 8)$	$X_2 = (4, 5, 4, 3, 3)$	$T(X_2) = 11$	$X_{73} = (4, 3, 3, 2, 3)$, $X_{77} = (4, 3, 2, 3, 3)$,
$V_3 = (6, 6, 5, 6, 11)$	$C_3 = (6, 6, 5, 6, 8)$	$X_3 = (4, 5, 4, 2, 3)$	$T(X_3) = 11$	$X_{78} = (4, 3, 2, 2, 4)$, $X_{136} = (3, 5, 2, 2, 3)$,
$V_4 = (6, 6, 5, 7, 10)$	$C_4 = (6, 6, 5, 6, 8)$	$X_4 = (4, 5, 4, 2, 3)$	$T(X_4) = 11$	$X_{157} = (3, 4, 3, 2, 3)$, $X_{161} = (3, 4, 2, 3, 3)$,
$V_5 = (6, 6, 5, 8, 9)$	$C_5 = (6, 6, 5, 6, 8)$	$X_5 = (4, 5, 4, 2, 3)$	$T(X_5) = 11$	$X_{162} = (3, 4, 2, 2, 4)$, $X_{172} = (3, 3, 4, 2, 3)$,
$V_6 = (6, 6, 5, 9, 8)$	$C_6 = (6, 6, 5, 6, 8)$	$X_6 = (4, 5, 4, 2, 3)$	$T(X_6) = 11$	$X_{176} = (3, 3, 3, 3, 3)$, $X_{177} = (3, 3, 3, 2, 4)$,
⋮	⋮	⋮	⋮	⋮
$V_{329} = (12, 7, 5, 4, 6)$	$C_{329} = (8, 7, 5, 4, 6)$	$X_{329} = (2, 4, 4, 4, 5)$	$T(X_{329}) = 11$	$X_{245} = (2, 3, 3, 4, 3)$, $X_{246} = (2, 3, 3, 3, 4)$, $X_{247} = (2, 3, 3, 2, 5)$,
$V_{330} = (13, 6, 5, 4, 6)$	$C_{330} = (8, 6, 5, 4, 6)$	$X_{330} = (2, 5, 4, 4, 5)$	$T(X_{330}) = 11$	$X_{248} = (2, 3, 2, 4, 4)$, and $X_{249} = (2, 3, 2, 3, 5)$.

4 Conclusions and Future Research

This study proposes the project reliability to be a performance index which is utilized to measure whether the project can be completed under the given time and budget or not. A procedure integrating two algorithms is developed to evaluate the project reliability and is illustrated through a simple project network. In particular, the proposed procedure can be applied to the SPN with arbitrary probability distribution. Activity duration and its corresponding cost are affected by the employed resources, such as the system engineers, system analysts, and consultants in the DR project. Based on this paper, future research may take the resources allocation into consideration for the project reliability maximization. Moreover, it is an important issue to consider the trade-off among the time, budget and project reliability, and it can be solved by using multi-objective optimization approaches.

References

Hiller FS, Liberman GJ (2005) Introduction to operations research, 8/e. McGraw-Hill, New York

Lin YK (2008) Project management for arbitrary random durations and cost attributes by applying network approaches. Comput Math Appl 56:2650–2655

Lin JS, Jane CC, Yuan J (1995) On reliability evaluation of a capacitated-flow network in terms of minimal pathsets. Networks 25:131–138

Pontrandolfo P (2000) Project duration in stochastic networks by the PERT-path technique. Int J Proj Manage 18:215–222

Zuo MJ, Tian Z, Huang HZ (2007) An efficient method for reliability evaluation of multistate networks given all minimal path vectors. IIE Trans 39:811–817

System Reliability and Decision Making for a Production System with Intersectional Lines

Yi-Kuei Lin, Ping-Chen Chang and Kai-Jen Hsueh

Abstract A three-phase procedure is proposed to measure the performance of a production system with intersectional lines by taking reworking actions into account. In particular, for a production system with intersectional lines, common station shares its capacity to all lines when processing. Hence, it is important to analyze the capacity of the common station while performance evaluation. This study addresses the system reliability as a key performance indicator to evaluate the probability of demand satisfaction. First, the production system is constructed as a production network (PN) by the graphical transformation and decomposition. Second, capacity analysis of all stations is implemented to determine the input flow of each station based on the constructed PN. Third, a simple algorithm is proposed to generate all minimal capacity vectors that stations should provide to satisfy the given demand. We evaluate the system reliability in terms of such minimal capacity vectors. A further decision making issue is discussed to decide a reliable production policy.

Keywords Production system · Intersectional lines · System reliability · Decision making · Production policy

Y.-K. Lin (✉) · P.-C. Chang · K.-J. Hsueh
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: yklin@mail.ntust.edu.tw

P.-C. Chang
e-mail: D9901001@mail.ntust.edu.tw

K.-J. Hsueh
e-mail: M10101018@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_31,

1 Introduction

This utilizes an AOA (activity-on-arrow) network diagram approach to construct the manufacturing system. In particular, each station in the production system has stochastic capacity levels (i.e., multi-state) due to machine failure, partial failure, and maintenance (Lin 2009; Lin and Chang 2011). Therefore, the manufacturing system is also multi-state and we can treat it as the so-called stochastic-flow network (Aven 1985; Hudson and Kapur 1985; Xue 1985; Zuo et al. 2007). Considering reworking actions, an effective methodology is proposed to evaluate the system reliability for such a production system. We propose a graphical methodology to model the production system as a stochastic-flow network, named production network (PN) herein. In particular, intersectional lines are considered. That is, different lines share the capacity of common station. Based on the PN, we derive the minimal capacity vectors that should be provided to satisfy the demand. In terms of such vectors, the production manager can calculate the system reliability and determine a reliable production strategy.

2 Methodology

2.1 Assumptions

1. The capacity of each station is a random variable according to a given probability distribution.
2. The capacities of different stations are statistically independent.
3. Each inspection point is perfectly reliable.

2.2 A Three-Phase Evaluation Procedure

Phase I: An AOA diagram is adopted to form a production system. Each arrow is regarded as a station of workers and each node denotes an inspection point following the station. We utilize a graphical transformation and decomposition to construct the production system as a PN.

Phase II: We determine the input amount of raw materials to satisfy the given demand d. A subsequent calculation for the maximum output of each line is assist to decide the demand assignment. Once all possible demand assignments are obtained, the input flow of each station is also derived.

Phase III: According to the results of capability analysis, a simple algorithm is developed to generate all minimal capacity vectors that satisfy demand d. In terms of such vectors, the system reliability can be derived by several existed methods easily. Moreover, the production manager can determine a reliable strategy to assign the output for each line in terms of every single minimal capacity vector.

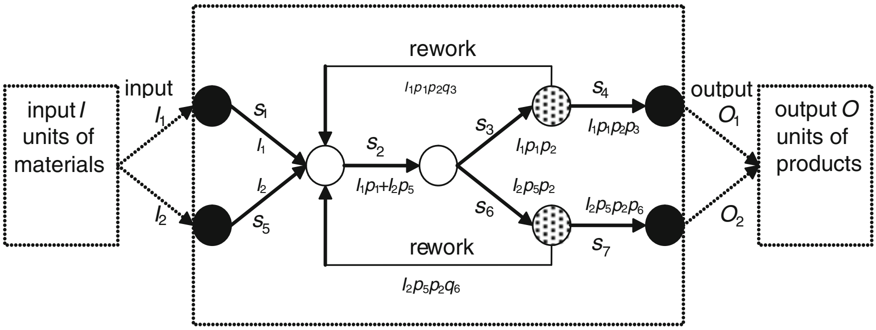


Fig. 1 Two lines in a manufacturing system

3 Network Model Construction (Phase I)

3.1 Transformation and Decomposition

Let (**N**, **S**) be a PN with two lines, where **N** represents the set of nodes and $\mathbf{S} = \{s_i|i = 1, 2, \ldots, n_1 + n_2\}$ represents the set of arrows with n_1 (resp. n_2) is the number of stations in L_1 (resp. L_2). Each station s_i possesses a distinct success rate p_i (i.e., the failure rate $q_i = 1-p_i$). Two lines, say L_1 (consisting of s_1, s_2, s_3, and s_4; $n_1 = 4$) and L_2 (consisting of s_5, s_6, and s_7; $n_2 = 3$), are layout in the production system. The common station s_2 has to process WIP from both s_1 and s_5 and thus $L_2 = \{s_5, s_2, s_6, s_7\}$ as shown in Fig. 1. The input amount of each station is shown under each arrow, where I_1 (resp. I_2) is the input amount of raw materials and O_1 (resp. O_2) is units of output product for L_1 (resp. L_2). To distinguish the input flows from the regular process or the reworking process, we transform the production system into a PN as Fig. 2, in which a dummy-station s_i' is set to denote the station s_i doing the reworking action. Note that since s_2 serves as a common station, it appears in both lines.

To analyze the PN in terms of paths, we decompose each line L_j into two paths, named the general manufacturing path $L_j^{(G)}$ and the reworking path $L_j^{(\mathrm{R}|r,r-k)}$, where r and k are the indices to denote that defective WIP output from the rth sequenced station are reworked starting from previous k stations. Take Fig. 2 for instance, the set $L_1^{(\mathrm{G})} = \{s_1, s_2, s_3, s_4\}$ in line L_1 would be a general manufacturing path. On the other side, the path with reworking action is $L_1^{(\mathrm{R}|3,3-1)} = \{s_1, \ s_2, s_3, s_2', s_3', s_4'\}$ where (R|3,3–1) denotes that defective WIP output from the third sequenced ($r = 3$) station s_3 in the line L_1 is reworked starting from previous one ($k = 1$) station (i.e., starting from s_2). For the special case that k is set to be zero, it implies that the defective WIP is reworked at the same station (rth sequenced station).

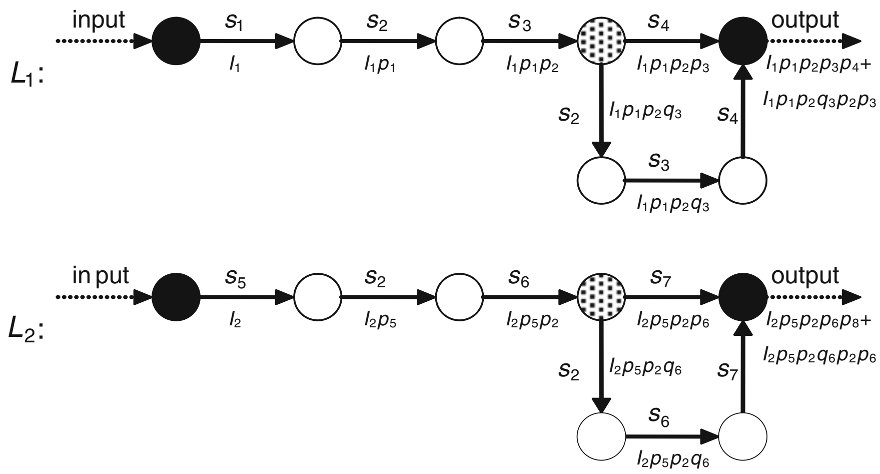


Fig. 2 The transformed manufacturing network for Fig. 2

4 Capability Analysis (Phase II)

For each line L_j, suppose that I_j units of raw materials are able to produce O_j units of product; we intend to obtain the relationship between I_j and O_j fulfilling $O_j \geq d_j$ and $\sum_{j=1}^{2} d_j = d$, where d_j is the assigned demand for line L_j. Two sets, say Ψ_i^{prior} and Ψ_i^{post}, are defined to record the stations prior to and posterior to the station s_i, respectively. The following equation guarantees the PN can produce exact sufficient output O_j that satisfies demand d_j.

$$I_j = d_j / \left\{ \left(\prod\nolimits_{t:s_t \in L_j^{(\mathrm{G})}} p_t \right) + \delta_j \left(\prod\nolimits_{t:s_t \in L_j^{(\mathrm{R}|r,r-k)}} p_t \right) \right\},\ j = 1,\ 2. \tag{1}$$

The maximum output of each line is determined by the bottleneck station in that line. Thus, we assume the input WIP entering each station s_i exact equals the maximal capacity M_i. Then derive the potential output amount of s_i, say φ_i, in terms of its success rates p_i and success rates of its follow-up stations (i.e., $\left(\prod_{t:\,s_t \in \Psi_i^{\text{post}}} p_t\right)$). By comparing the potential output amount of all stations, the minimum one is the bottleneck of the line. The determination of maximum output is shown as following equation:

$$\begin{aligned} \varphi_i = M_i p_i \Bigg\{ & \left(\prod\nolimits_{t:\,s_t \in \Psi_i^{\text{post}}} p_t \right) + \alpha_i \left(\prod\nolimits_{t:\,s_t \in \Psi_i^{\text{post}} \cap \Psi_{\gamma_j}^{\text{prior}}} p_t \right) \\ & (1 - p_{\gamma_j}) \left(\prod\nolimits_{t:s_t \in L_j^{(\mathrm{R}|r,r-k)}} p_t \right) \Bigg\}, \end{aligned} \tag{2}$$

where the index α_i equals 1 for s_i not on the reworking path; otherwise α_i equals 0.

To determine the input flow of each station, we utilize $f_{j,i}^{(\mathrm{G})}$ and $f_{j,i}^{(\mathrm{R}|r,r-k)}$ to represent the input amount of the ith station in the jth line for $L_j^{(\mathrm{G})}$ and $L_j^{(\mathrm{R}|r,r-k)}$, respectively. The input raw materials/WIP processed by the ith station s_i should satisfy the following constraint,

$$\sum\nolimits_{j=1}^{2}\left(f_{j,i}^{(\mathrm{G})}+f_{j,i}^{(\mathrm{R}|r,r-k)}\right)\leq M_i,\ i = 1,2,\ \ldots,\ n_1 + n_2. \tag{3}$$

Constraint (3) ensures that the total amount of input flow entering station s_i does not exceed the maximal capacity M_i. The term $\sum\nolimits_{j=1}^{2}\left(f_{j,i}^{(\mathrm{G})}+f_{j,i}^{(\mathrm{R}|r,r-k)}\right)$ is further defined as the loading of each station, say w_i.

Let x_i denote the capacity of each station s_i. The capacity x_i of each station s_i is a random variable and thus the PN is stochastic, where x_i takes possible values $0 = x_{i1} < x_{i2} < \ldots < x_{ic_i} = M_i$ for $i = 1, 2, \ldots, n_1 + n_2$ with c_i denoting number of possible capacities of s_i. Under the state $X = (x_1, x_2, \ldots, x_{n_1+n_2})$, it is necessary that $x_i \geq w_i$ to guarantee that s_i can process the input raw materials/WIP.

5 Performance Evaluation and Decision Making (Phase III)

Given the demand d, the system reliability R_d is the probability that the output product from the PN is not less than d. Thus, the system reliability is $\Pr\{X|V(X) \geq d\}$, where $V(X)$ is defined as the maximum output under X. Any minimal vector Y in the set $\{X|V(X) \geq d\}$ is claimed to be the minimal capacity vectors for d. That is, Y is a minimal capacity vector for d if and only if (1) $V(Y) \geq d$ and (2) $V(Y') < d$ for any capacity vectors Y' such that $Y' < Y$. Given Y_1, Y_2, …, Y_h, the set of minimal capacity vectors satisfying demand d, the system reliability R_d is $R_d = \Pr\left\{\bigcup_{v=1}^{h} B_v\right\}$, where $B_v = \{X|X \geq Y_v\}$.

Given two intersectional lines with a common station s_c installed in L_1, we have $L_1 = \{s_1, s_2, \ldots, s_c, \ldots, s_{n_1}\}$ and $L_2 = \{s_{n_1+1}s_{n_1+2}, \ldots, s_c, \ldots, s_{n_1+n_2}\}$. The minimal capacity vectors for d can be derived by the following steps.

Step 1 Find the maximum output for each path.

$$O_{1,\max} = \min\{\varphi_i | i : s_i \in L_1\} \text{ and } O_{2,\max} = \min\{\varphi_i | i : s_i \in L_2\}. \tag{4}$$

Step 2 Find the maximum output of the common station s_c.

$$O_{c,\max} = \max\{(\varphi_c | s_c \in L_1),\ (\varphi_c | s_c \in L_2)\}. \tag{5}$$

Step 3 Find the demand assignment (d_1, d_2) satisfying $d_1 + d_2 = d$ under constraints $d_1 \leq O_{1,\max}$ and $d_2 \leq O_{2,\max}$.

Step 4 For each demand pair (d_1, d_2), do the following steps.

4.1. Determine the amount of input materials for each line by

$$I_1 = d_1/\left\{\left(\prod_{t:s_t \in L_1^{(G)}} p_t\right) + \delta_1 \left(\prod_{t:s_t \in L_1^{(R|r,r-k)}} p_t\right)\right\} \text{ and } I_2 = d_2/\left\{\left(\prod_{t:s_t \in L_2^{(G)}} p_t\right) + \delta_2 \left(\prod_{t:s_t \in L_2^{(R|r,r-k)}} p_t\right)\right\}. \quad (6)$$

4.2. Determine the input flows for each station s_i.

$$f_{j,i}^{(G)} = I_j \prod_{t:\, s_t \in \Psi_i^{\text{prior}}} p_t \text{ for } i \text{ such that } s_i \in L_j^{(G)} \text{ and}$$
$$f_{j,i}^{(R|r,r-k)} = I_j \delta_j \prod_{t:\, s_t \in \Psi_i^{\text{prior}}} p_t \text{ for } i \text{ such that } s_i \in L_j^{(R|r,r-k)}. \quad (7)$$

4.3. Transform input flows into stations' loading vector $W = (w_1, w_2, \ldots, w_c, \ldots, w_{n_1+n_2})$ via

$$w_i = \sum_{j=1}^{2} \left(f_{j,i}^{(G)} + f_{j,i}^{(R|r,r-k)}\right). \quad (8)$$

4.4. For each station, find the smallest possible capacity x_{ic} such that $x_{ic} \geq w_i > x_{i(c-1)}$. Then $Y = (y_1, y_2, \ldots, y_c, \ldots, y_{n_1+n_2})$ is a minimal capacity vector for d where $y_i = x_{ic}$ for all i.

Step 5 Apply RSDP algorithm to derive the system reliability (Zuo et al. 2007).

6 Example

Given a production system with a common station in the form of AOA diagram (see Fig. 3). Two intersectional lines, say $L_1 = \{s_1, s_2, s_3, s_4, s_5, s_6, s_7\}$ and $L_2 = \{s_8, s_2, s_9, s_{10}, s_{11}, s_{12}, s_{13}\}$, are producing products through seven stations. The success rate and capacity data of each station is given in Table 1. We consider the PN that has to satisfy the demand $d = 240$ products per hour, in which output products are packaged into a box in terms of 24 units. By the proposed algorithm, three minimal capacity vectors for $d = 240$ are derived. The derived minimal capacity vectors are shown in Table 2. In terms of these vectors, we obtain the system reliability $R_{240} = 0.91324$ by the RSDP algorithm.

The production manager could further evaluate the satisfaction probability for each demand pair in terms of its corresponding minimal capacity vector. This probability is denoted as R_{d_1,d_2} for each demand pair $D = (d_1, d_2)$. Table 2 shows

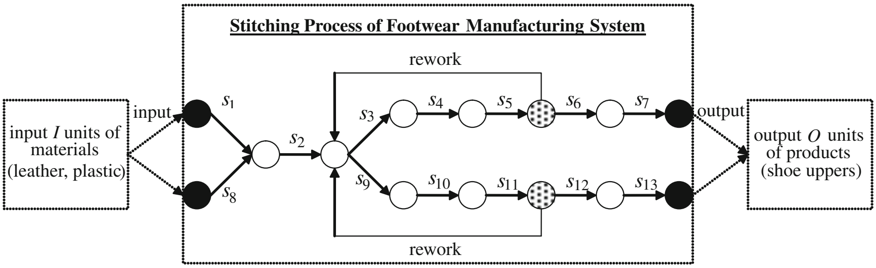


Fig. 3 A production system with common station

Table 1 Success rate and capacity probability distribution of stations

Station	Success rate	Capacity	Probability	Station	Success rate	Capacity	Probability
s_1	0.954	0	0.001	s_8	0.961	0	0.002
		60	0.002			60	0.003
		120	0.003			120	0.005
		180	0.006			180	0.013
		240	0.988			240	0.977
s_2^b	0.971	0	0.002				
		180	0.005				
		360	0.993				
s_3	0.983	0	0.001	s_9	0.978	0	0.001
		30	0.001			30	0.001
		60	0.001			60	0.001
		90	0.003			90	0.004
		120	0.003			120	0.005
		150	0.003			150	0.010
		180	0.988			180	0.978
s_4	0.965	0	0.002	s_{10}	0.972	0	0.003
		80	0.012			80	0.015
		160	0.986			160	0.982
s_5	0.975	0	0.003	s_{11}	0.975	0	0.001
		120	0.005			120	0.002
		240	0.992			240	0.997
s_6	0.986	0	0.003	s_{12}	0.989	0	0.002
		60	0.003			60	0.002
		120	0.005			120	0.008
		180	0.008			180	0.015
		240	0.981			240	0.973
s_7	0.991	0	0.001	s_{13}	0.993	0	0.002
		36	0.001			36	0.003
		72	0.003			72	0.005
		108	0.005			108	0.007
		144	0.010			144	0.010
		180	0.012			180	0.010
		216	0.968			216	0.963

Table 2 Demand pair and corresponding satisfaction probability

Demand pair (strategy)	Minimal capacity vector	Satisfaction probability
$D_1 = (96, 144)$	$Y_1 = (120, 360, 120, 160, 120, 120, 108, 180, 180, 160, 240, 180, 180)$	$R_{96,144} = 0.87189$
$D_2 = (120, 120)$	$Y_2 = (180, 360, 150, 160, 240, 180, 144, 180, 150, 160, 240, 180, 144)$	$R_{120,120} = 0.87124$
$D_3 = (144, 96)$	$Y_3 = (180, 360, 180, 160, 240, 180, 180, 120, 120, 160, 120, 120, 108)$	$R_{144,96} = 0.88358$

R_{d_1,d_2} for different demand pairs. The results indicate that $D_3 = (144, 96)$ with $R_{144,96} = 0.88358$ would be a better strategy to produce products since it has higher satisfaction probability. Thus, the production manger may decide to produce 144 pairs of shoe uppers per hour by L_1 and 96 pairs of shoe uppers per hour by L_2.

7 Conclusion

This paper presents a three-phase procedure to construct and evaluate the performance of production system. We evaluate the probability of demand satisfaction for the production system, where the probability is referred to as the system reliability. Such a quantitative performance indicator is scientific from the management perspective. In addition, different demand assignments may result different satisfaction probabilities. A reliable decision making for production strategy relies on the overall capability analysis.

References

Aven T (1985) Reliability evaluation of multistate systems with multistate components. IEEE Trans Reliab 34:473–479

Hudson JC, Kapur KC (1985) Reliability bounds for multistate systems with multistate components. Oper Res 33:153–160

Lin YK (2009) Two-commodity reliability evaluation of a stochastic-flow network with varying capacity weight in terms of minimal paths. Comput Oper Res 36:1050–1063

Lin YK, Chang PC (2011) Reliability evaluation of a manufacturing network with reworking action. Int J Reliab Qual Saf Eng 18:445–461

Xue J (1985) On Multistate System Analysis. IEEE Trans Reliab 34:329–337

Zuo MJ, Tian Z, Huang HZ (2007) An efficient method for reliability evaluation of multistate networks given all minimal path vectors. IIE Trans 39:811–817

Customer Perceptions of Bowing with Different Trunk Flexions

Yi-Lang Chen, Chiao-Ying Yu, Lan-Shin Huang, Ling-Wei Peng and Liang-Jie Shi

Abstract Bowing has traditionally been used to signify politeness and respect. A chain of restaurants in Taiwan has recently required servers to bow at a 90° angle to increase the customers' sense of being honored. Whether bowing at 90° is accepted by most consumers remains to be determined. This study analyzed 100 valid responses by questionnaire to determine consumer feelings regarding different degrees of trunk flexion when receiving bows. Results show that respondents typically believe that bowing at 30° was the most satisfactory, followed by 45°. Bowing at 45° or 60° causes customers to feel honored, and bowing at 90° induces the feelings of surprise and novelty but produces the lowest proportions of agreement to the at ease, necessary, and appropriate items. Previous studies had well validated that, when trunk is flexed to 90°, the posture is harmful because of the higher spinal loading. The finding of this study can be provided to the restaurant industry as a reference for service design from the perspective of server's health.

Keywords 90° bowing · Consumer perception · Trunk flexion

Y.-L. Chen (✉) · C.-Y. Yu · L.-S. Huang · L.-W. Peng · L.-J. Shi
Department of Industrial Engineering and Management, Ming Chi University of Technology, 84 Gungjuan Rd, Taishan, New Taipei 24301, Taiwan
e-mail: ylchen@mail.mcut.edu.tw

C.-Y. Yu
e-mail: M01258007@mail.mcut.edu.tw

L.-S. Huang
e-mail: U98217017@mail.mcut.edu.tw

L.-W. Peng
e-mail: U98217029@mail.mcut.edu.tw

L.-J. Shi
e-mail: U98217013@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_32,

1 Introduction

Traditional service industries place heavy emphasis on service encounters to raise customer satisfaction (Bitner et al. 1994). Because small service-based businesses (e.g., restaurants) have low entry requirements and engage in fierce competition, operators are constantly considering how to surprise and delight customers. In Eastern cultures, particularly in China and Japan, a greater angle of trunk flexion while bowing represents greater politeness and respect. A chain of restaurants in Taiwan has recently required servers to bow at a 90° angle when arriving at and leaving a table to increase the customers' sense of being honored, which has been established as a unique service feature. However, the servers in these restaurants bow at a 90° angle approximately 500 times a day, frequently using a cervical spine extension posture to maintain eye contact with customers. The bowing with trunk flexion 90°, undoubtedly, has been well-recognized as an awkward and harmful posture to the individual (DeLitto and Rose 1992; Holmes et al. 1992; Chen 1999).

Bowing has traditionally been used to signify politeness and respect. Lai (2009) indicated that bowing to a greater angle of trunk flexion produces better customer perceptions (of care and respect), and also indirectly improves service effects. However, whether bowing at 90° is accepted by most consumers remains to be determined.

This study therefore used a consumer perception survey to determine the perceptions and feelings of consumers regarding to provide opinions on the optimal angle of trunk flexion during bows, and also performed a bowing experiment to examine the differences in spinal curves and trunk muscle activities under five trunk positions (from upright to 90°).

2 Methods

2.1 The Consumer Perception Survey

This study distributed 122 questionnaires to determine consumer perceptions regarding different degrees of trunk flexion while bowing. Excluding unreturned and ineffective questionnaires, 100 valid responses were retrieved for an effective recovery rate of 82 %. The questionnaire comprised two sections. The first section surveyed the basic information of the respondents, including gender, age, occupation, salary level, and education level. The second section used different semantic feeling questions, asking respondents to select the bowing angle, with which they most agreed from among five angles (0, 30, 45, 60, and 90°). The content validity of the survey was confirmed using a pilot study and comments obtained from three marketing experts. In addition, to increase survey validity, photographs of five types of bows were provided along with the survey during implementation (Fig. 1).

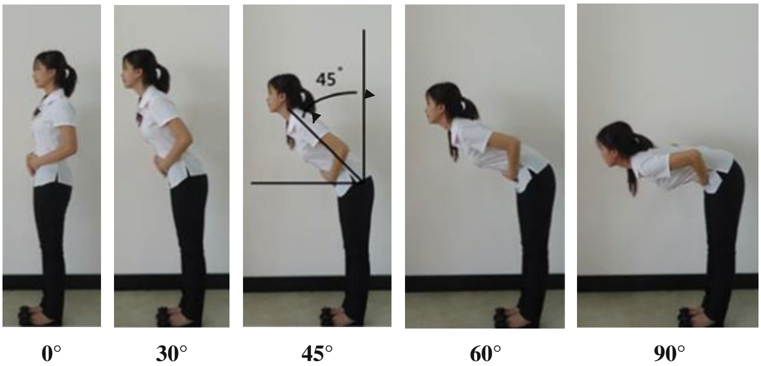


Fig. 1 Depictions of five bowing angles provided in the questionnaire

2.2 Survey Reliability

The second portion of this study consisted of an analysis of the reliability of the consumer questionnaire regarding bowing, as shown in Table 1. Typically, Cronbach α values less than 0.35 indicate low reliability and require rejection, whereas α values greater than 0.7 indicate high reliability. The reliability values of the questions in our survey were all greater than 0.8 (Table 1), indicating high validity, and showing that agreement among respondents on consumer feelings of different bowing angles exhibited high internal consistency.

2.3 Survey Criterion-Related Validity

The survey questionnaire used overall satisfaction as a criterion (Question 7) for performing validity analysis. The Chi-square test indicated that, aside from Question 6 (novelty), which showed no significant correlation with the criterion ($p > 0.05$), the other questions exhibited high correlation with the criterion ($p < 0.001$). These results show that, aside from Question 6, all of the questions could directly explain overall satisfaction.

Table 1 Internal consistency of survey questions in the questionnaire

Questions	Cronbach's α
1. Bowing at this angle makes me feel at ease	0.835
2. I feel that bowing at this angle is necessary	0.828
3. I feel that bowing at this angle is a pleasant surprise	0.837
4. Bowing at this angle makes me feel honored	0.848
5. I feel that bowing at this angle is appropriate	0.826
6. I feel that bowing at this angle is novel	0.862
7. Overall, I am satisfied when receiving a bow at this angle	0.816

3 Results and Discussion

3.1 Basic Sample Information of Survey

Of the 100 respondents in this study, men and women each constituted approximately half. 58 % of respondents were single. 27 % of the respondents ranged between 21 and 25 years of age, and 20 % ranged between 26 and 30 years of age. Half (50 %) of the respondents had an undergraduate degree. Approximately one-third were employed in manufacturing industry, and 27 % were students. 31 % of respondents had monthly incomes of ranged between NT$ 30,000 and 40,000.

3.2 Consumer Feelings Regarding Different Bowing Angles

Respondents were asked to select the angle with which they most agreed from five bowing angles to determine consumer feelings toward different bowing angles; the results are shown in Table 2. Most of the respondents considered that bowing at 90° gave them feelings of pleasant surprise and novelty (55 and 79 %). However, 45 and 60° achieved the effect of making consumers feel honored (60 %), which is twice the proportion of the 90° bows (30 %). In summary, although 90° bows are most capable causing people to feel pleasant surprise and novelty, 65 % of the respondents were most satisfied with bowing angles of 30 and 45°, significantly greater than the 20 % that most preferred 90°. In particular, respondents considered that bowing at 30° caused consumers to feel at ease (49 %), and were necessary (63 %) and appropriate (47 %). If the frequencies for bowing at 45° were added, then the proportions for the at ease, necessary, and appropriate items would subsequently be 67, 70, and 72 %, respectively, presenting an overall satisfaction of 75 %. In contrast, for the at ease, necessary, and appropriate items, bowing at 90° received the lowest proportion of agreement, with only 5, 1, and 3 %, respectively. The famous insurance saleswoman Shibata Kazuko, who was ranked

Table 2 Frequency distribution for consumers expressing agree the most for different bowing angles

Questions	Agree the most				
	0°	30°	45°	60°	90°
1. Bowing at this angle makes me feel at ease	4	49	18	24	5
2. I feel that bowing at this angle is necessary	0	63	17	19	1
3. I feel that bowing at this angle is a pleasant surprise	0	8	14	23	55
4. Bowing at this angle makes me feel honored	0	10	21	39	30
5. I feel that bowing at this angle is appropriate	0	47	25	25	3
6. I feel that bowing at this angle is novel	0	3	6	12	79
7. Overall, I am satisfied when receiving a bow at this angle	0	35	30	15	20

first in the Japanese insurance industry for 30 straight years, insisted on bowing no more than 45° even in Japan, a society renowned for expressing politeness through 90° bows to maintain a feeling of appropriateness between both parties (Lai and Lin 2012); this is consistent with the results of our study.

3.3 Cross-Analysis of Respondent Traits and Bowing Angles

To determine whether respondents' traits influenced their views of different bowing angles, we used the Chi-square test to analyze the agree the most questions. The results showed that gender did not influence respondents' feelings of different bowing angles ($p > 0.05$). Marital status and age had significant influences on the at ease, necessary, appropriate, and overall satisfied items (all $p < 0.05$). In general, married respondents were more satisfied with bowing angles of 60°, and unmarried respondents preferred 30°. Respondents over the age of 31 mostly preferred 60 and 90° bowing angles, and those under 30 mostly preferred 30°. The results for marital status may imply age factors. The level of education influenced at ease, appropriate, and overall satisfaction (all $p < 0.05$). Respondents with a junior high school education or lower were more satisfied with 60°, and those with a higher level of education preferred 30°. The pleasant surprise, honor, and novelty items were not influenced by respondent traits. Most respondents selected 60° and 90° for these items, demonstrating that restaurant operators who use standardized 90° bowing angles as a form of marketing can achieve the effects of attracting customers, and creating an atmosphere of surprise and amazement. However, whether or not this bowing design satisfies customers remains to be discussed. In summary, whether male or female, the well-educated unmarried younger group tended to be more accepting of smaller bowing angles (e.g., 30°); respondents in other groups tended to prefer greater bowing angles (e.g., 60 or 90°).

The posture bowing at 90° would cause the lumbar spine to bend to its limitation and this 'bow-out' posture of the back would increase the stretch on the posterior elements of the lumbar spine and thereby raise the stress on these structures (Lee and Chen 2000). That is, the lower back ES muscles become silent or inactive and the forward bending moment is counteracted by the passive tension of the muscles as well as the shorter lever arms between the discs and the posterior spinal ligaments (DeLitto and Rose 1992; Holmes et al. 1992). This posture undoubtedly would result in higher lower back loading.

4 Conclusion

If service industry operators endeavor to provide customers with a sense of honored, bowing at 45 or 60° angles yields optimal effects. In contrast, bowing at 90° has the greatest capacity to evoke pleasant surprise and novelty. Respondents were most satisfied with a bowing angle of 30°, followed by 45°. Results show that bowing at 90° received the smallest proportion of agreement for the at ease, necessary, and appropriate items. Moreover, this harmful and awkward posture would injure server's spine, especially when daily repetitive bowings. The results of this study can provide a trade-off consideration for service operators in designing service encounters.

References

Bitner MJ, Booms BH, Mohr LA (1994) Critical service encounters: the employee's viewpoint. J Mark 58:95–106

Chen YL (1999) Geometric measurements of the lumbar spine in Chinese men during trunk flexion. Spine 24:666–669

Delitto RS, Rose SJ (1992) An electromyography analysis of two techniques for squat lifting and lowering. Phys Ther 71:438–448

Lai YX (2009) A study of job standardization on service encounter in resort hotel, Master's thesis, Graduate Institute of Recreation, Tourism, and Hospitality Management. National Chiayi University

Lai CH, Lin CS (2012) Insurance queen, bowing no more than 90 degrees. Bus Wkly 1281:144

Lee YH, Chen YL (2000) Regressionally determined vertebral inclination angles of lumbar spine in static lifts. Clin Biomech 15:678–683

Holmes JA, Damaser MS, Lehman SL (1992) Erector spinae activation and movement dynamics about the lumbar spine in lordotic and kyphotic squat-lifting. Spine 17:327–334

A Pilot Study Determining Optimal Protruding Node Length of Bicycle Seats Using Subjective Ratings

Yi-Lang Chen, Yi-Nan Liu and Che-Feng Cheng

Abstract This study preliminarily investigated the subjective discomfort and riding stability by requiring ten participants to ride straight-handles bicycles equipped with five seat-protruding node lengths (PNLs, 0–12 cm, in increments of 3 cm) of seats for 20 min. Results indicated that seat PNL caused differences in the participants' subjective discomfort and stability scores. The various PNLs had significantly positive (r = 0.910, $p < 0.01$) and negative (r = −0.904, $p < 0.05$) correlations to the subjective discomfort rating for the perineum and ischial tuberosity, respectively. However, various PNLs did not affect riding stability during cycling. The findings of this study suggest that a 6 cm PNL is the optimal reference for bicycle seat designs.

Keywords Protruding node lengths (PNL) · Posture analysis · Subjective ratings

1 Introduction

Previous studies have primarily focused on riding efficiency, bicycle types, and frame size. In recent years, the focus of bicycle-related research has gradually shifted to seat (or saddle) design (Groenendijk et al. 1992; Bressel et al. 2009). During cycling, the contact between the seat and the buttocks is the critical cause

Y.-L. Chen (✉) · Y.-N. Liu · C.-F. Cheng
Department of Industrial Engineering and Management, Ming Chi University of Technology, 84 Gungjuan Rd, Taishan, New Taipei 24301, Taiwan
e-mail: ylchen@mail.mcut.edu.tw

Y.-N. Liu
e-mail: i770314@hotmail.com

C.-F. Cheng
e-mail: m01258004@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_33,

of discomfort and pain. Groenendijk et al. (1992) showed that the pressure distribution on the seat demands that pads support the pelvic bones. Richmond (1994) noted that handlebars that are set too low can also induce compression neuropathy and certain overuse symptoms. Nakamura et al. (1995) examined four long-period and long-distance bicycle-commuting Japanese male students and found that a nodule had developed near each of their coccygeal regions and the shape corresponded to the saddle of the bicycle.

Previous studies on bicycle seats mainly focused on analyzing traditional seats with a protruding node length (PNL; Bressel and Cronin 2005; Bressel et al. 2007) or analyzed seat pressure distribution for various commercial seats (Bressel et al. 2009). In summary, the most obvious difference in bicycle seats is whether they feature protruding nodes. Whether a bicycle seat has a protruding node significantly influences the rider's comfort when cycling. Traditional seats with a longer protruding node provide riding stability (Bressel et al. 2009). However, they increase the pressure on the perineal/groin regions. Non-protruding node seats can minimize pressure to the anterior perineum (Lowe et al. 2004), but they may also increase the risk of falling injuries if stability is compromised. Therefore, an appropriate PNL design is critical.

In this study, we hypothesized that an optimal PNL may exist between the traditional and non-PNL seats and can properly maintain a degree of body stability, reduce discomfort in the perineal region. We collected data on the riders' subjective discomfort ratings and riding stability after the participants had ridden a straight-handles bicycle for 20 min under five PNL conditions to identify the optimal PNL.

2 Methods

2.1 Participants

Ten male university students participated in this study. Their mean (SD) age was 22.8 (1.7) years, and the ages ranged from 21 to 26 years. Their mean (SD) height and weight were 171.6 (8.3) cm and 65.5 (6.3) kg, respectively. None of the participants had any history of musculoskeletal injury or pain and maintained good exercise habits, physical stamina, and bicycling habits. The participants were informed of the test procedures and were paid for their participation.

2.2 Experimental Bicycle Seats and Handles

Five of the bicycle seat types used in this study were made by a bicycle manufacturer (original type no: 6091010, Giant, Taichung, Taiwan). Except for PNL, all

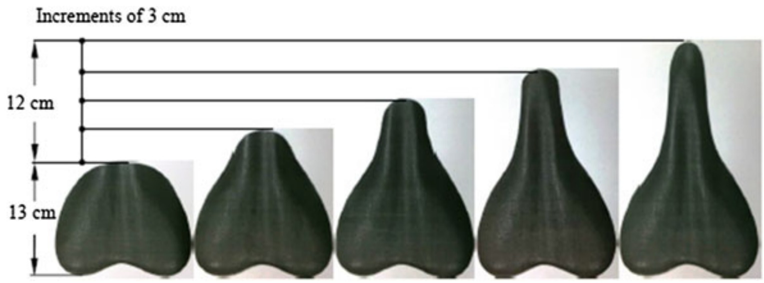


Fig. 1 Schematic diagram of the five types of PNL seat cushions used in this study

other seat design factors remained unchanged (e.g., shape, material, and structure). The width of the seats was the commercially adopted 16 cm (Bressel and Cronin 2005), and the length of the seat-protruding nose ranged from 0 to 12 cm, and each 3 cm interval was established as a level, as shown in Fig. 1. We referenced the study of Chen and Yu (2012) and selected the straight-handles as the handle design, which was the most frequently used in Chen and Yu's survey in Taiwan.

2.3 Subjective Discomfort and Stability Rating

This study modified the scale by Bressel et al. (2009) for the subjective discomfort of various body parts and cycling stability ratings. The subjective assessments were performed using a continuous visual analogue scale (Bressel et al. 2009). The scale was 10 cm in length and was modeled after comfort scales modified by this study form Mundermann et al. (2002). The left end of the scale was labeled no discomfort at all and the right end was labeled extreme discomfort. The levels of discomfort experienced in each cyclist's wrist, neck, lower back, perineum, and ischial tuberosity was rated. Regarding cycling stability, the scale correspondingly ranged from not unstable at all to most unstable seat imaginable. After the participants rode a bicycle for 20 min, they were immediately asked to rate the discomfort and stability scores.

2.4 Experimental Design and Procedure

The 10 participants simulated cycling for 20 min under 5 seat PNLs [0, 3, 6, 9, and 12 cm]). During the final minute, their cycling posture was randomly recorded. At the end of each ride, the subjective discomfort for various body parts and stability rating scores were immediately self-reported by the participants. The order of implementation for the various bicycle setup combinations was random.

The participants were required to wear cycling shirts. Prior to the experiment, the participants had to warm up for 5 min to acclimate to the 120-W impedance setting and the 15 ± 5 km/h pedaling speed. Each participant adjusted the seat to the most comfortable height and the seat height was set at 100 % of the trochanteric leg length. To prevent effects from fatigue, the participants had a maximum of two tests per day with a minimum of 2 h intervals between each test.

2.5 Statistical Analysis

This study used SPSS 17.0 statistical software for the statistical analyses. The statistical significance level was set at 0.05, and each participant was considered a block. One-way analysis of variance (ANOVA) was performed to clarify the effects of the PNL variable on subjective discomfort rating and stability scores, and Duncan's Multiple-range test (Duncan's MRT) was conducted for post hoc comparisons. In addition, a Pearson product-moment correlation was used to explore the PNL and subjective discomfort rating values.

3 Results

Results of one-way ANOVA show that the PNL significantly influenced only the subjective discomfort scores of the perineum ($p < 0.01$) and the ischial tuberosity ($p < 0.05$), and did not affect the other body parts, as shown in Table 1. The shorter PNL that was used indicated a lower score of discomfort for the perineum, but a higher score of discomfort for the ischial tuberosity. The results also showed that the PNL had significantly positive and negative correlations to the discomfort scores of the perineum ($r = 0.910$, $p < 0.01$) and ischial tuberosity ($r = 0.904$, $p < 0.05$), respectively. Regarding riding stability, the participants felt no difference existing among these 5 PNL conditions ($p > 0.05$, as shown in Table 1).

4 Discussion

Previous studies have not conducted systematic research on the PNLs of bicycle seats. This study collected the subjective rating values for various PNL conditions to determine the optimal PNL. Varied PNLs affected the trade-off discomfort between the perineum and ischial tuberosity regions. Because the riding stability was not significantly affected by PNL variable, we recommend that the 6 cm PNL be referenced as the optimal seat design.

The results indicated that various PNLs significantly influenced the discomfort level for the perineum and ischial tuberosity, but had no effect on the other body

Table 1 ANOVA and Duncan MRT for the PNL's effect on subjective discomfort and stability

Variables	N	DF	F	*p* value	PNL (cm)[b]	Mean (SD)[a]	Duncan groups
Discomfort on							
Neck/shoulders	50	4	1.2	0.446	–	–	–
Wrist	50	4	1.0	0.430	–	–	–
Lower back	50	4	0.8	0.538	–	–	–
Perineum	50	4	3.1	$p < 0.05$	0	3.93 (2.02)	A
					3	4.04 (2.17)	A
					6	4.17 (1.97)	A
					9	4.70 (2.33)	B
					12	4.97 (2.18)	B
Ischial tuberosity	50	4	3.6	$p < 0.01$	0	5.12 (2.01)	A
					3	4.60 (1.86)	B
					6	4.33 (1.94)	B
					9	4.10 (1.90)	B
					12	3.69 (1.77)	C
Stability	50	4	3.6	0.284	0	3.50 (2.04)	A
					3	3.32 (1.96)	A
					6	3.18 (1.84)	A
					9	2.89 (1.90)	A
					12	2.93 (1.77)	A

[a] subjective scores
[b] protruding node length

parts (as shown in Table 1). Figure 2 shows that the discomfort scores for the perineum and ischial tuberosity had positive ($r = 0.910$, $p < 0.01$) and negative ($r = -0.904$, $p < 0.05$) correlations with the PNL, respectively. In other words, the traditional seat (PNL = 12 cm) and non-PNL seat may generate greater

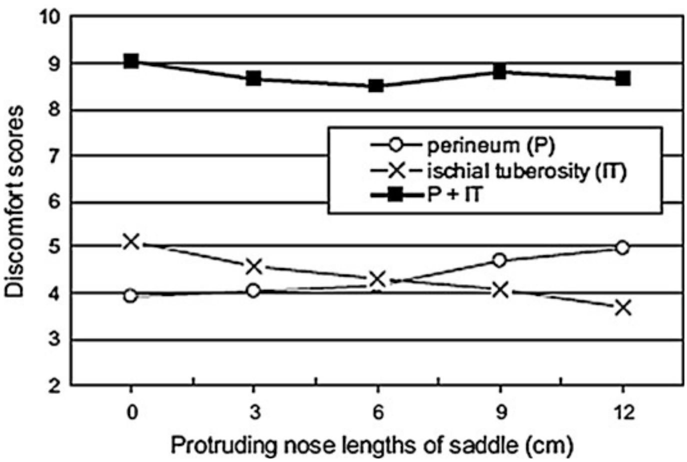


Fig. 2 Perineum and ischial tuberosity discomfort ratings when applying various PNLs

discomfort in the perineum and ischial tuberosity, respectively. When PNL is equal to 6 cm, the cyclists may subjectively perceive the less discomforts of both the perineum and ischial tuberosity regions. Figure 2 also shows that the sums of the discomfort scores for these two body regions remained nearly unchangeable. How discomfort can be appropriately distributed between the perineum and ischial tuberosity regions may depend on the PNL.

In the analysis, the participants felt no difference in riding stability. This may be the bicycling with straight-handles that used in this study. Chen and Yu (2012) found that the handles height would influence the trunk flexion during cycling. In other words, lower handles would lead more trunk forward flexion. Chen and Yu found a difference of 30° when cycling with straight-handles compared to that with drop-handles. Whether a more inclined trunk position would cause the cycling more unstably merits further clarification.

Considering both discomfort on the perineum/ischial tuberosity and perceived stability, this study suggests that 6 cm PNLs should be used as a reference for bicycle seat designs, especially for straight-handles bike. However, this PNL seat should be further validated in actual road cycling and evaluated by pressure distribution on the seat.

5 Conclusion

No previous study has systematically examined the effects of PNL on body discomfort and cycling stability. This study collected data on the subjective rating values at various PNL conditions. The results showed that, when PNL = 6 cm, the discomfort between the perineum and ischial tuberosity regions achieved a more favorable distribution, subsequently providing a sufficient degree of stability for the rider. The finding can be served as a reference for bicycle seat design.

References

Bressel E, Bliss S, Cronin J (2009) A field-based approach for examining bicycle seat design effects on seat pressure and perceived stability. Appl Ergon 40:472–476

Bressel E, Cronin J (2005) Bicycle seat interface pressure: reliability, validity, and influence of hand position and workload. J Biomech 38:1325–1331

Bressel E, Reeve T, Parker D, Cronin J (2007) Influence of bicycle seat pressure on compression of the perineum: a MRI analysis. J Biomech 40:198–202

Chen YL, Yu ML (2012) A preliminary field study of optimal trunk flexion by subjective discomfort in recreational cyclists. J Chinese Inst Ind Eng 29:526–533

Groenendijk MC, Christiaans HCM, Van Hulten CMJ (1992) Sitting comfort on bicycles. In: Megaw ED (ed) Contemporary ergonomics. Taylor and Francis, London, pp 551–557

Lowe BD, Schrader SM, Breitenstein MJ (2004) Effect of bicycle saddle designs on the pressure to the perineum of the bicyclist. Med Sci Sports Exerc 36:1055–1062

Mundermann A, Nigg BM, Stefanyshyn DJ, Humble RNR (2002) Development of a reliable method to assess footwear comfort during running. Gait Posture 16:38–45
Nakamura A, Inoue Y, Ishihara T, Matsunaga W, Ono T (1995) Acquired coccygeal nodule due to repeated stimulation by a bicycle saddle. J Dermatol 22:365–369
Richmond DR (1994) Handlebar problems in bicycling. Clin Sports Med 13:165–173

Variable Neighborhood Search with Path-Relinking for the Capacitated Location Routing Problem

Meilinda F. N. Maghfiroh, A. A. N. Perwira Redi and Vincent F. Yu

Abstract The Location Routing Problem (LRP) integrates strategic decisions (facility location) and tactical decisions (vehicle routing) aimed at minimizing the total cost associated with location opening cost and routing cost. It belongs to the class of NP-hard problems. In this study, we present a variable neighborhood search with path-relinking (VNSPR) for solving the CLRP. The path-relinking procedure is integrated into the variable neighborhood search (VNS) framework. We tested our heuristic approach on three well-know CLRP data sets and the results were compared with those reported in the literature. Computational results indicate that the proposed VNSPR heuristic is competitive with existing approaches for the CLRP.

Keywords Location routing problem · Variable neighborhood search · Path-relinking

1 Introduction

The Location Routing Problem (LRP) integrates strategic decisions (facility location), and tactical decisions (vehicle routing). This problem involves finding the optimal number and locations of the depots and simultaneously allocating customers to the depot and determining the routes to visit all customers. This

M. F. N. Maghfiroh (✉) · A. A. N. Perwira Redi · V. F. Yu
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: meilinda.maghfiroh@gmail.com

A. A. N. Perwira Redi
e-mail: wira.redi@gmail.com

V. F. Yu
e-mail: vincent@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_34,

problem belongs to the class of NP-hard problems since it combines two difficult sub-problems: the facility location problem (FLP) and the vehicle routing problem (VRP), where both are shown to be NP-hard (Lenstra and Kan 1981). In recent years, the attention given to the location routing problem has increased due to the interdependency of facility location problem and vehicle routing problem.

The LRP with capacity constraints on both depots and routes is called capacitated LRP (CLRP). This study focuses on solving the CLRP to minimize the total cost associated with depot opening cost, vehicle fixed cost and total travelling cost. The CLRP can be stated as follows. Given a graph $G = (V, E)$ where V and E represent the set of vertices and the set of edges of the graph, respectively. V consists of a subset I of m potential depot sites and a subset $J = V \backslash I$ of n customers. E contains edges connecting each pair of nodes in V. Associated with each edge $(i, j) \in E$ is a travelling cost c_{ij}. Each depot site $i \in I$ has a capacity W_i and opening cost O_i. Each customer $j \in J$ has a demand d_j which must be fulfilled by a single vehicle. A set K of vehicles with capacity Q is available. Each vehicle used by depot i incurs a depot dependent fixed cost F_i and performs a single route.

Many researchers have tried to solve CLRP using various solution methods in order to solve them. Laporte and Nobert (1981) proposed an exact algorithm for a single facility fixed fleet size LRP without tour length restrictions. They formulated the problem as an integer linear program and solved it by first relaxing integrality constraints and using a branch and bound technique to achieve integrality. Tuzun and Burke (1999) developed a two-phase tabu search (TS) for the LRP with capacitated routes and uncapacitated depots. The two phases of their TS algorithm are dedicated to vehicle routing problem and depot location decision. The algorithm iteratively adds a depot to the current solution until the solution degrades.

Prins et al. (2006) solved the CLRP with capacitated depots and routes by combining greedy randomized adaptive search procedure (GRASP) with a learning process and a path-relinking mechanism. Furthermore, Barreto et al. (2007) developed a class of three-phase heuristics based on clustering techniques. Clusters of customers fitting vehicle capacity are formed in the first phase. A travelling salesman problem (TSP) is solved for each cluster in the second phase. Finally in the third phase, the depots to be opened were determined by solving a facility location problem, where the TSP cycles were combined to form super nodes.

Yu et al. (2010) proposed an SALRP heuristic for the CLRP based on the popular simulated annealing heuristic. The proposed SALRP heuristic is tested on three sets of well-known benchmark instances and the results are compared with other heuristics in the literature. The computational study indicates that the SALRP heuristic is competitive with other well-known algorithms.

Escobar et al. (2013) proposed a two phase hybrid heuristic algorithm for the CLRP. The two phases are a construction phase and an improvement phase using a modified granular tabu search. Most recently, Ting and Chen (2013) developed a multiple ant colony optimization algorithm (MACO) for the CLRP. They decomposed the problem into a facility location problem and a multiple depot vehicle routing problem (MDVRP) where the second problem is treated as a sub-problem within the first problem.

Following the idea of variable neighborhood search (VNS) by systematically changing search neighborhood, this study proposed a variable neighborhood search with path-relinking (VNSPR) which combines with VNS path-relinking (PR) as a post optimization procedure after performing VNS algorithm. The proposed method was tested on a large number of instances and the results were compared with those reported in the literature. The rest of this study is organized as follows. Section 2 presents details of the proposed VNSPR. Section 3 discusses the computational results. Finally, Sect. 4 draws conclusions.

2 VNSPR Framework

In this section, the detail proposed VNSPR will be discussed. To avoid or at least alleviate the solution being trapped in the first local optimum found, the variable neighborhood search heuristic changes neighbourhood during the search process. Starting from an incumbent solution the VNS searches within a finite sequence of neighborhoods where the successive neighborhoods are explored using a local search algorithm. To enhance the performance of the VNS, our hybrid meta-heuristic includes VND as the local search component and uses PR as diversification strategy. Figure 1 illustrates the components and the general structure of the proposed VNSPR.

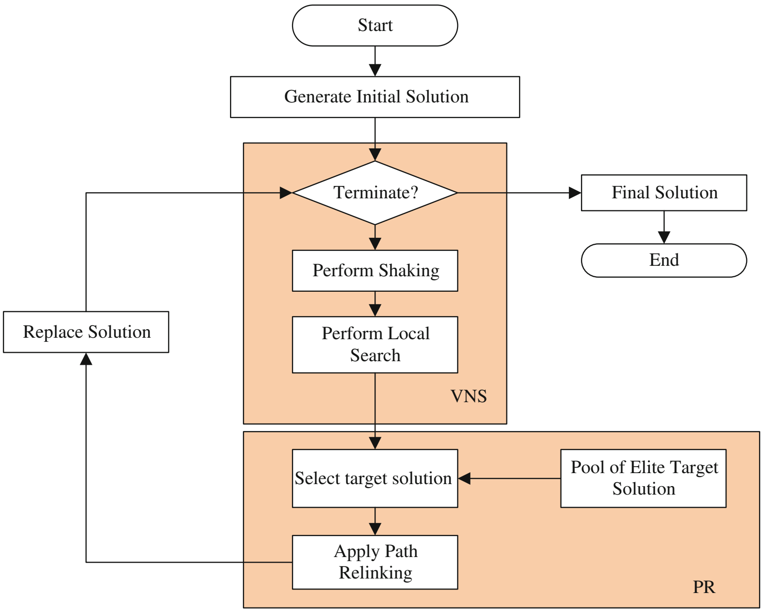


Fig. 1 VNSPR framework

The proposed VNSPR uses five parameters k_{max}, $N_{non\text{-}improving}$, m, EX, and I_{iter}. I_{iter} denotes the maximum number of iterations for the search procedure. k_{max} is the maximum number of pre-selected neighborhood structures, while m is the selected modulus number. The number of elite solutions to be put in the pool as target solutions is equal to EX. Finally, $N_{non\text{-}improving}$ is the maximum allowable number of iterations during which the best objective function value is not improved.

The current solution and objective value are set to be X and obj(X) respectively. Set the k value to be 1. The neighborhood will change depending on the value of k. At each iteration the next solution Y is obtained after the shaking phase. Then, Y' will be generated based on the local search result. The objective function is then evaluated. If obj(Y') < obj(X), then the current solution X will be replaced by Y' and the value of k remains the same. Otherwise, set $k = k + 1$ and the neighborhood will be changed based on the neighborhood sequence. This procedure is repeated until $k = k_{max}$. X_{best} will record the best solution found so far. To avoid being trapped at a local optimum, the current solution will be replaced with the best solution if k modulus m is equal to zero.

Further, the PR explores the path between a local optimum X obtained by VNS and an elite solution X' randomly chosen from EX. The PR uses a forward strategy to transform the initial solution X into the guiding solution X' by repairing from left to right the broken pairs in X, resulting in a path with non-increasing distance from X to $X'.X'$. The procedure looks for a node i with different positions in X and X'. Then node i exchanges positions with the node at the same position in X' to repair the difference. The best solution chosen will be a solution with $\arg\min_{X \in EX} obj(X)$among the EX.

2.1 Initial Solution and Solution Representation

For solving the LRP problem, the initial solution is constructed randomly. The first position of the solution is the first selected open depot followed by the customers on the first route, customer on the second route and so forth. When all customers already assigned to the first depot, then the second depot will be selected and added into the solution representation. This whole process in continued until all customers are assigned in a depot. Finally, the closed depot is appended to the solution.

2.2 Neighborhood Structures

The proposed VNSPR algorithm incorporates five neighborhood structures to explore different possibilities of depot locations and to improve customer assignments to each depot. The detail of the neighborhoods used in this algorithm is present in Table 1. The two neighborhoods N_1 and N_2 correspond to insertion

Table 1 Neighborhood structures

N	k	Neighborhood
N_1	1–4	Random insertion
N_2	5–8	Random swap
N_3	9–12	2-opt
N_4	13–16	CROSS-exchange
N_5	17–20	iCROSS-exchange

and swap moves respectively. The classical 2-opt operator used in standard routing problem is a special case of our neighborhood N_3. The 2-opt procedure is done by replacing two node disjoint arcs by two other arcs. Another two neighborhoods applied are based on Taillard et al. (1997) whose proposed a neighborhood called CROSS-exchange. The main idea of this exchange is to take two segments of different routes and exchange them. The extension of CROSS-exchange called iCROSS-exchange is introduced by Braysy (2003). In this neighborhood, the sequences of the segment get inverted (Fig. 2).

The insertion (N_1) and swap (N_2) operations have several possibilities.

1. If i and j is both a customers, the customer i is reassigned to the depot that serves customer j. For swap operation, this possibility is worked in vice versa.
2. In the insertion operation, if the i and j is both a depots, the depot i will be closed and its customers will be assigned to the depot before depot i.
3. For swap operation, the depot i will be closed if depot j is closed before and depot i will be servicing depot j's customers and vice versa. This neighborhood will reassign the route from one to another depot. Thus, it can help to evaluate the savings occurred from the depot capacity, travel route and fixed cost.

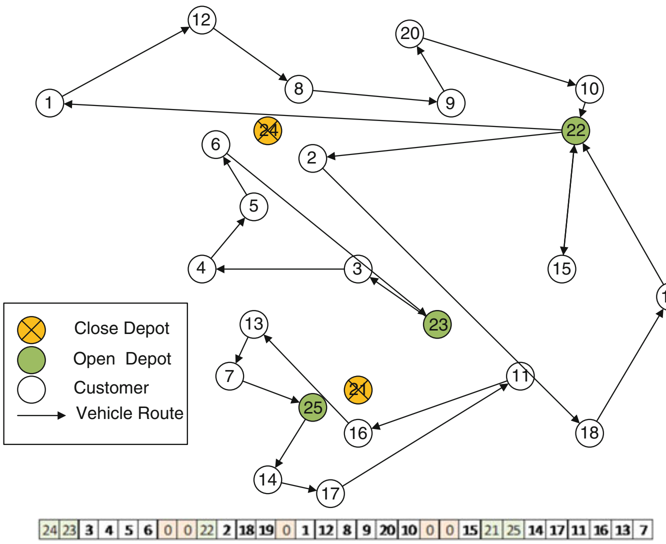


Fig. 2 An illustration of solution representation

2.3 Local Search

We choose neighborhoods by implementing the sequential deterministic order of neighborhoods within VND method. We call it sequential because the neighborhood structures are explored one by one in the given order. The algorithm goes to a neighborhood N_{k+1} unless it falls on a local optimum with respect to the neighborhood N_k. Otherwise, it is returned to the first one N_1. The effectiveness of VND is related to the order of neighborhoods considered and the order the solutions in each neighborhood are explored. To maintain the solution and computational time, the neighborhoods used for VND are limited to insertion (N_1) and swap (N_2) operation.

2.4 Post Optimization: Path Relinking

In order to intensification and divers the solution, path relinking (PR) algorithm is adopted. VNS with PR will maintains a pool of elite solutions *EX* generated using VNS. Each solution produce after local search is checked for inclusion in *EX*. This *EX* will be used as the initiating or guiding solutions. In this hybrid method the PR operator explores the paths between a local optimum obtained by VNS and a solution randomly chosen from *EX*.

The path from X to X' is then guided by the Hamming distance Δ, equal to the number of differences between the nodes at the same position in X and X', i.e., $\Delta(X, X') = \sum_{i=1,|X|} X_i \neq X'_i$.

3 Computational Result

In this section, we present the results of our computational experiments with the VNSPR described in previous section. The proposed VNSPR algorithm is coded in C++ Visual Studio 2008 and runs on a PC with a Dual Core (1.83 Ghz) processor and 2 GB RAM, under the Windows XP operating system. For the purpose of verification, VNSPR is applied to the benchmark instances used were designed by Barreto (2004). The proposed algorithm has been compared with three latest heuristic proposed to solve CLRP: SALRP (Yu et al. 2010), Modified Ant Colony Algorithm (MACO) (Ting and Chen 2013), and Two Phase Hybrid Heuristic (HH) (Escobar et al. 2013) (see Table 2).

Compared with the best know solutions, from 19 instances of this data set, the proposed VNSPR obtains 13 best solutions. The gap between the solution is vary from 0.00 to 1.60 % with average gap is 0.33 %. Compared with others algorithm, the result of VNSPR is competitive enough. The relative average gap of VNSPR is better than SALRP (0.43 %) and HH (0.78 %). In term of total number of BKS obtained, VNSPR result is outperforms MACO (12 BKS) and HH (7 BKS).

Table 2 Solutions cost for Prins et al.'s instances

Prob. ID	*n*	*m*	BKS	SALRP		MACO		HH		VNSPR	
				Cost	*Gap (%)*	*Cost*	*Gap (%)*	*Cost*	*Gap (%)*	*Cost*	*Gap (%)*
B1	21	5	424.9	424.9	**0.00**	424.9	**0.00**	424.9	**0.00**	424.9	**0.00**
B2	22	5	585.1	585.1	**0.00**	585.1	**0.00**	585.1	**0.00**	585.1	**0.00**
B3	29	5	512.1	512.1	**0.00**	512.1	**0.00**	512.1	**0.00**	512.1	**0.00**
B4	32	5	562.2	562.2	**0.00**	562.22	**0.00**	562.2	**0.00**	562.2	**0.00**
B5	32	5	504.3	504.3	**0.00**	504.3	**0.00**	504.3	**0.00**	504.3	**0.00**
B6	36	5	460.4	460.4	**0.00**	460.4	**0.00**	460.4	**0.00**	460.4	**0.00**
B7	50	5	565.6	565.6	**0.00**	565.6	**0.00**	580.4	2.62	565.6	**0.00**
B8	75	10	844.4	848	0.43	844.88	0.06	848.9	0.53	844.4	**0.00**
B9	100	10	833.4	838.3	0.59	836.75	0.40	838.6	0.62	833.43	**0.00**
B10	12	2	204	204	**0.00**	204	**0.00**	–	–	204	**0.00**
B11	55	15	1112.1	1112.8	0.06	1112.58	0.04	–	–	1112.1	**0.00**
B12	85	7	1622.5	1622.5	**0.00**	1623.14	0.04	–	–	1632.7	0.63
B13	318	4	557275	563493	1.12	560210.8	0.53	–	–	559224	0.35
B14	318	4	670119	684164	2.10	670118.5	**0.00**	–	–	678689	1.28
B15	27	5	3062	3062	**0.00**	3062	**0.00**	3062	**0.00**	3062	**0.00**
B16	134	8	5709	5709	**0.00**	5709	**0.00**	5890.6	3.18	5775.9	1.17
B17	88	8	355.8	355.8	**0.00**	355.8	**0.00**	362	1.74	355.8	**0.00**
B18	150	10	43919.9	45109.4	2.71	44131.02	0.48	44579	1.50	44314	0.90
B19	117	14	12290.3	12434.5	1.17	12355.91	0.53	–	–	12536	2.00
Average					*0.43*		*0.11*		*0.78*		*0.33*

4 Conclusions

In this study, both the location decision and routing problem in the LRP are tackled together. We propose a hybrid method, called variable neighborhood search with path-relinking, for the CLRP. The algorithm was tested on Barreto's instances to verify its performance. Computational results indicate the effectiveness and efficiency of the proposed algorithm. The proposed VNSPR is competitive with existing state-of-the-art algorithms in solving CLRP. Moreover, the relative percentage gap between best known solutions and the solutions obtained by the proposed VNSPR is relatively small, which shows the robustness of the algorithm.

References

Barreto SS (2004) Análise e Modelização de Problemas de localização-distribuição [Analysis and modelling of location-routing problems]. University of Aveiro, Portugal

Barreto S, Ferreira C, Paixão J, Santos BS (2007) Using clustering analysis in a capacitated location-routing problem. Eur J Oper Res 179(3):968–977

Braysy O (2003) A reactive variable neighborhood search for the vehicle-routing problem with time windows. INFORMS J Comput 15(4):347–368

Escobar JW, Linfati R, Toth P (2013) A two-phase hybrid heuristic algorithm for the capacitated location-routing problem. Comput Oper Res 40(1):70–79

Laporte G, Nobert Y (1981) An exact algorithm for minimizing routing and operating costs in depot location. Eur J Oper Res 6(2):224–226

Lenstra JK, Kan AHGR (1981) Complexity of vehicle routing and scheduling problems. Networks 11(2):221–227

Prins C, Prodhon C, Calvo R (2006) Solving the capacitated location-routing problem by a GRASP complemented by a learning process and a path relinking. 4OR 4(3):221–238

Taillard É, Badeau P, Gendreau M, Guertin F, Potvin JY (1997) A Tabu search heuristic for the vehicle routing problem with soft time windows. Transp Sci 31(2):170–186

Ting C-J, Chen C-H (2013) A multiple ant colony optimization algorithm for the capacitated location routing problem. Int J Prod Econ 141(1):34–44

Tuzun D, Burke LI (1999) A two-phase tabu search approach to the location routing problem. Eur J Oper Res 116(1):87–99

Yu VF, Lin S-W, Lee W, Ting C-J (2010) A simulated annealing heuristic for the capacitated location routing problem. Comput Ind Eng 58(2):288–299

Improving Optimization of Tool Path Planning in 5-Axis Flank Milling by Integrating Statistical Techniques

Chih-Hsing Chu and Chi-Lung Kuo

Abstract Optimization of the tool path planning in 5-axis flank milling of ruled surfaces involves search in an extremely high-dimensional solution space. The solutions obtained in previous studies suffer from lengthy computational time and suboptimal results. This paper proposes an optimization scheme by integrating statistical techniques to overcome these problems. The scheme first identified significant factors in the tool path planning that influence the machining error of a machined surface by a first sampling plan. We then conducted a series of simulation experiments designed by the two-level fractional factorial method to generate experimental data with various settings. A regression model was constructed with Response Surface Methodology (RSM) that approximates the machining error in terms of those identified factors. This simplified model accelerates estimation of the objective function, computed as a black-box function in previous studies, with less computation. Test results show that the proposed scheme outperforms PSO in both the computational efficiency and the solution quality.

Keywords 5-axis machining · Response surface methodology · Optimization

1 Introduction

With two rotational degrees of freedom in tool motion, 5-axis machining provides higher productivity and better shaping capability compared to traditional 3-axis machining. The 5-axis machining operation is categorized into two types: end

C.-H. Chu (✉) · C.-L. Kuo
Department of Industrial Engineering and Engineering Management,
National Tsing Hua University, Section 2, Kuang-Fu Road, Hsinchu, Taiwan
e-mail: chchu@ie.nthu.edu.tw

C.-L. Kuo
e-mail: u920827@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_35,

milling and flank milling. Tool path planning is a critical task in both milling operations, with avoidance of tool collision and machining error control as two major concerns (Rehsteiner 1993). To produce a machined surface exactly the same as its design specifications using a cylindrical cutter is highly difficult in 5-axis flank milling. The cutter cannot make a contact with a surface ruling without inducing overcut or undercut around the ruling due to local non-developability of a ruled surface (Chu and Chen 2006), except simple geometries like cylindrical and conical surfaces. A common method used in industry is to let the cutter follow the surface rulings, although extensive machining errors often occur on twisted surfaces (Tsay and Her 2001).

Previous studies (Chu et al. 2011; Hsieh and Chu 2011) have shown that the machining error can be effectively reduced through optimization of tool path planning in a global manner. Such an optimization approach works as a systematic mechanism for precise control of machining error. Wu and Chu (2008) transformed tool path planning in 5-axis flank milling into a curve matching problem and applied dynamic programming to solve for an optimal matching with the error of the machined surface as an objective function in the optimization. They solved the similar curve matching problem with Ant Colony Systems algorithm to reduce the lengthy time required by the dynamic programming approach. They allowed the cutter to freely make contact with the surface to be machined, rather than moving among pre-defined surface points in previous works. However, the PSO based search in the previous works (Hsieh and Chu 2011; Hsieh et al. 2013) suffers from unsatisfactory quality of sub-optimal solutions due to excessive nonlinearity inherited in the machining error estimation and high-dimensional solution space. The solutions obtained by PSO easily get trapped in local optima and are thus very far from global optima. The computational time in these works was lengthy, reducing the practicality of industrial applications. This study attempts to overcome these problems with an approximate optimization scheme that integrates various statistical techniques in the tool path planning. The scheme first identified significant factors that influence the machining error of a machined surface. We then conducted a series of simulation experiments designed by the two-level fractional factorial method to generate experimental data with various settings. A regression model was constructed with Response Surface Methodology (RSM) that approximates the machining error in terms of those identified factors. This simplified model accelerates estimation of the objective function with fewer computations compared to previous studies. Test results show that the proposed scheme outperforms PSO in both computational efficiency and solution quality.

2 Preliminaries

There are numerous variables in the tool path planning for 5-axis flank milling of a ruled surface. As illustrated in Table 1, some variables determine the precision of CNC machines and the others control the tool position at a cutter location.

Table 1 Possible factors in tool path planning for 5-axis flank milling

Factor	Notation
Number of error measuring points in the *u* direction	U^N
Number of error measuring points in the *v* direction	V^N
Tool radius	T^R
Tool cutting length	T^L
Number of cutter locations in a tool path	N^{CL}
Number of linear interpolation between two cutter locations	T^{IN}
Distance along the tangent direction on the first boundary curve	N^U
Distance along the normal direction on the first boundary curve	T^U
Distance along the bi-normal direction on the first boundary curve	B^U
Distance along the tangent direction on the second boundary curve	N^L
Distance along the normal direction on the second boundary curve	T^L
Distance along the bi-normal direction on the second boundary curve	B^L

The moving tri-hedron of the surface on two boundary curves is used to position a cylindrical cutter. Three parameters along the directions of the tangent, surface normal, and bi-normal specify the center point of each cutter end (see Fig. 1). We then categorize the parameters listed in Table 1 into two groups: normal factors and block factors. For example, users need to specify $U^N, V^N, T^R, T^L, N^{CL}, T^{IN}, T^U$ in a CNC machining operation and thus they are not variables to be optimized. We only need to consider $T^U, N^U, B^U, T^L, N^L, B^L$ in determining a cutter location.

The objective function used in optimization of tool path planning is the geometric error on the machined shape with respect to the design surface. Exact estimation of the machined geometry has no close-form solutions and involves highly non-linear equations. Most CNC tool path planning methods perform the error estimation approximately estimated with the z-buffer method. The estimation procedure consists of four steps as shown in Fig. 2. The design surface is sampled in a discrete manner. At each sampling point, two straight lines are extended along the positive and negative normal directions with a distance of the cutter radius. The lengths of these lines will get updated after the cutter sweeps across them along a given tool path. We approximate the tool swept surface by generating a finite

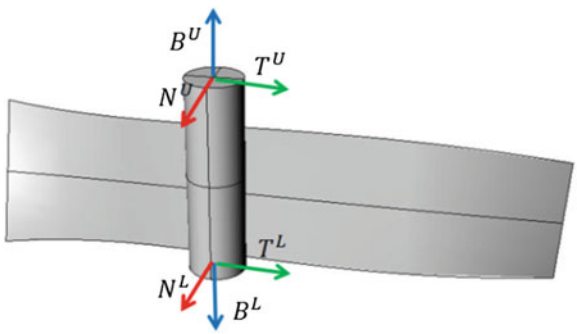


Fig. 1 Positioning a tool with the moving tri-hedron at a cutter location

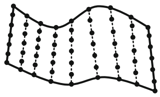
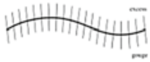
Step	Illustration
Sample points from the design surface	
Create straight lines on each point	
Intersect the lines with the cutter	
Calculatethe machining error	

Fig. 2 Approximate estimation of the machining error (Chu et al. 2011)

number of tool positions interpolated by two consecutive cutter locations. The next step is to intersect the lines with the peripheral surface of the cutter. The machining error is calculated as the sum of the lengths of the trimmed straight lines.

Previous studies (Hsieh and Chu 2011; Hsieh et al. 2013) reduced the machining error through optimization of the tool path planning based on PSO. Greedy approaches can only find sub-optimal solutions in the optimization, as interactions exist between cutter locations, i.e. cutter locations with minimized errors at an early stage may induce larger errors at later cutter locations. For machining complex geometries, a tool path normally consists of hundreds of cutter locations. Each cutter location contains 6 parameters to be specified when the moving tri-hedron is used for positioning the tool axis. PSO-based search suffers from several difficulties. Estimation of the machining error involves highly non-linear computation and has no closed-form solutions. This results in lengthy computational time in the optimization. The PSO-based search can quickly converge in local sub-optimal solutions in a high-dimensional solution space and thus produces unsatisfactory solution quality. This study proposes to solve the above mentioned difficulties by integrating statistical techniques.

3 Optimization Scheme

Optimization of tool path planning for 5-axis flank milling with the machining error as an objective function can be written as:

$$\begin{aligned} &\text{Min} \sum_{i=0}^{N^{CL}-1} E_i \\ &E_i = e\left(T_i^U, T_{i-1}^U, N_i^U, N_{i-1}^U, B_i^U, B_{i-1}^U\right) \quad i = 0, 1, \ldots, N^{CL} - 1 \end{aligned} \tag{1}$$

The machining error is the summation of the errors produced by each tool motion between two consecutive cutter locations. We then examined whether the 6 normal factors in Eq. (1) are significant ones using ANOVA techniques. A 2^{9-4} sampling plan was carried out to identify significant factors. In this plan, 2 means the number of levels of each factor investigated, 9 is the total number of factors, and 4 describes the size of the fraction of the full factorial used. This sampling design was chosen mainly because it has the minimum number of experiments in a resolution IV design. Based on the effect hierarchy principle, lower-order effects are more likely to be important than higher-order effects. A lower-resolution design has defining words of short length, which imply aliasing of low-order effects. Resolution R implies that no effect involving I factors is aliased with effects involving less than R-I factors (Wu and Hamada 2009). The p-values the 2^{9-4} sampling imply that $T^U, N^U, B^U, T^L, N^L, B^L$ are all significant factors. RSM is a strategy to achieve this goal that involves experimentation, modeling, data analysis, and optimization (Box and Wilson 1951). RSM-based optimization normally consists of two steps: response surface design and optimization. The response surface design constructs approximate functions for the independent variables and the response variable by systematically exploring the relationships between these two variables. RSM usually employs low-order polynomial approximation such as first-order regression models. Second-order or even higher-order polynomials can be used when the relationships to be investigated show the existence of a curvature. We applied least squares estimation to fit an approximate model and examined significance of the independent variables by regression analysis. The approximate model of the objective function is expressed as:

$$\sum_{i=0}^{N^{CL}-1}|E_i| \approx \beta_0 + \sum_{j=1}^{N^{CL}-1}\sum_{k=1}^{r}\beta_{jk}X_{jk} + (\mathrm{n}-1)\sum_{j=1}^{N^{CL}-1}\sum_{k=1}^{r}\beta_{jk}X_{jk}^2 + (n-1)\sum_{i<k}\sum_{k=1}^{r}\sum_{j=1}^{N^{CL}-1}\beta_{ijk}X_{ik}X_{jk} + \varepsilon \qquad (2)$$

where X_i, X_j are significant factors, β_j are constants to be determined by RSM, and k is the number of significant factors. A second sampling plan was conducted to construct the above model based on RSM. The plan was designed by 5^{6-1} experiments. The upper- and lower-bounds of each factor were determined based on our previous study (Hsieh et al. 2013). A dicotomic search was applied to adjust individual parameter setting within the range. The final parameter settings are shown in Table 2. Constructing the RSM-model is equivalent to determining the β_i values from the experimental data generated from the 5^{6-1} sampling. Once the model had been constructed, the Steepest Descent method was applied to find its optimal solutions. The similar approximate model can be used as a greedy

Table 2 Parameter setting in constructing the RSM-based model

Factor	Upper bound	Lower bound
N^U	0.105	−0.105
T^U	0.5	−0.5
B^U	0.5	−0.5
N^L	0.105	−0.105
T^L	0.5	−0.5
B^L	0.5	−0.5

approach, i.e. the original problem is subdivided into ($N^{CL}-1$) regions, each corresponding to two consecutive cutter locations. The optimal solution of each region is computed sequentially and adds up to the final solution as:

$$\mathrm{y} \approx \sum_{j=1}^{N^{CL}-1}\left(\beta_0 + \sum_{k=1}^{r}\beta_{jk}X_{jk} + (\mathrm{n}-1)\sum_{k=1}^{r}\beta_{jk}X_{jk}^2 + (n-1)\sum_{k=1}^{r}\beta_{ijk}X_{ik}X_{jk} + \varepsilon\right). \tag{3}$$

4 Experimental Results

A ruled surface shown in Fig. 3 was used as test geometry to demonstrate the effectiveness of the proposed scheme. This surface has substantial twist near both ends, which induce excessive machining errors when a cylindrical cutter is used. We compare the computational efficiency by counting the total number of error estimations for a tool path. For the PSO-based search, the number is equal to the particle number (N) multiplying by the iteration number (G). The proposed scheme consists of two major steps: sampling and model construction. The total number of estimations conducted by the sampling step depends on the number of factors F, the level number $\mathrm{L_F}$, and the fraction number $\mathrm{P_F}$ as ${\mathrm{L}_F}^{F-P_F}$. The model construction requires the error estimation for ${\mathrm{L}_G}^{G-P_G}$ times. Thus the scheme totally computes the machining error for $({\mathrm{L}_F}^{F-P_F} + {\mathrm{L}_G}^{G-P_G})$ times.

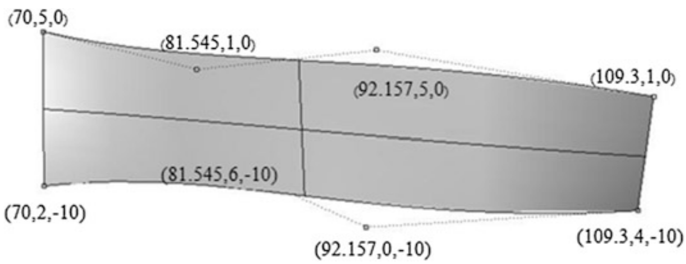


Fig. 3 Test ruled surface and its control points

Table 3 Comparison between the solutions obtained by this work and PSO

Method	Machining error (mm)
RSM (global)	7.71
RSM (greedy)	9.15
PSO	11.55

Table 4 Parameter setting in PSO-based search

Parameter	Value
W	0.5
C1	0.5
C2	0.5
Iteration number	100
Particle number	100
Tool radius	2 mm
Tool length	30 mm
Number of cutter location	40

Table 5 Comparison of computational efficiency

Method	Number of error estimations
PSO (global)	10,000
RSM	3,157

As shown in Table 3, the tool path generated by the proposed scheme produces a smaller machining error than that of the PSO-based tool path planning. The parameter setting in the PSO is listed in Table 4. Both global search and greedy approaches outperform the previous work. The computational efficiency of the proposed scheme was also compared with the PSO-based tool path planning, as shown in Table 5. The comparison is based on the total number of error estimations for a given tool path. The error estimation conducted by the greedy RSM method is within two cutter locations rather than a complete tool path and thus not included in the comparison. The total number of computations required by our method is only one-third of the previous work. The proposed scheme not only produces better solution quality, it also requires fewer computations than the previous work.

5 Conclusions

This study described a new optimization scheme for the tool path planning in 5-axis flank milling of ruled surfaces. This scheme improves the solution quality and computation efficiency of previous PSO-based methods. It adopted various statistical techniques to approximate the total error on the machined surface. A first sampling plan was conducted to identify significant factors in the tool path planning. We carried out a series of simulation experiments designed by the two-level fractional factorial method to generate experimental data with systematic settings. The experimental data results in a second-order regression model constructed with the response surface methodology. This simplified model approximates the objective function in terms of those identified factors and enables quick estimation of the function. The test results on a ruled surface with excessive twist demonstrated the advantages of the proposed scheme. It enhanced the solution quality by reducing 33 % of the machining error produced by the PSO-based tool path planning with the number of computations required 31 % fewer. This work improves the practicality for optimization-based tool path planning in 5-axis flank milling.

References

Box GEP, Wilson KB (1951) On the experimental attainment of optimum conditions. J Royal Stat Soc B 13:1–45

Chu CH, Chen JT (2006) Automatic tool path generation for 5-axis flank milling based on developable surface approximation. Int J Adv Manuf Technol 29(7–8):707–713

Chu CH, Tien KW, Lee CT, Ting CJ (2011) Efficient tool path planning in 5-axis milling of ruled surfaces using ant colony system algorithms. Int J Prod Res 49(6):1557–1574

Hsieh ST, Chu CH (2011) PSO-based path planning for 5-axis flank milling accelerated by GPU. Int J Comput Integr Manuf 24(7):676–687

Hsieh ST, Tsai YC, Chu CH (2013) Multi-pass progressive tool path planning in five-axis flank milling by particle swarm optimization. Int J Comput Integr Manuf (in press)

Rehsteiner F (1993) Collision-free five-axis milling of twisted ruled surfaces. CIRP Ann 42(1):457–461

Tsay DM, Her MJ (2001) Accurate 5-axis machining of twisted ruled surfaces. ASME J Manuf Sci Eng 123:731–738

Wu CF, Hamada MS (2009) Experiments: planning, analysis and optimization. Wiley, New York

Wu PH, Li YW, Chu CH (2008) Tool path planning for 5-axis flank milling based on dynamic programming techniques. Int J Mach Tools Manuf 50:1224–1233

A Multiple Objectives Based DEA Model to Explore the Efficiency of Airports in Asia–Pacific

James J. H. Liou, Hsin-Yi Lee and Wen-Chein Yeh

Abstract Airport efficiency is an important issue for each country. The classical DEA models use different input and output weights in each decision making unit (DMU) that seems not reasonable. We present a multiple objectives based Data Envelopment Analysis (DEA) model which can be used to improve discriminating power of DEA method and generate a more reasonable input and out weights. The traditional DEA model is first replaced by a multiple objective linear program (MOLP) that a set of Pareto optimal solutions is obtained by genetic algorithm. We then choose a set of common weights for inputs and outputs within the Pareto solutions. A gap analysis is included in this study that can help airports understand their gaps of performances to aspiration levels. For this new proposed model based on MOLP it is observed that the number of efficient DUMs is reduced, improving the discrimination power. Numerical example from real-world airport data is provided to show some advantages of our method over the previous methods.

Keywords DEA · Airport · Multiple-criteria decision-making (MCDM) · Genetic algorithm

1 Introduction

Airport efficiency has been a central issue in cost control owing to reasons such as airport monopoly power, changing ownership structure, increasing competitive pressure from airlines and competing airports and government aspirations to

J. J. H. Liou (✉) · H.-Y. Lee
Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei, Taiwan
e-mail: jhliou@ntust.edu.tw

W.-C. Yeh
Department of Air Transportation, Kainan University, Luzhu Township, Taoyuan County, Taiwan

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_36,

develop their nations as air hub or logistics center (Lam et al. 2009). This paper examines the performance of major airports in Asia–Pacific region. The potential air transportation demand in the Asia–Pacific region is enormous due to the region's high population density, strong economic growth and the widespread adoption of open-skies policies. This region has been ranked the second largest air freight market, following only that of North America. The report by Airports Council International (ACI) indicated that if the current trend continues, the Asia–Pacific region will replace North America as the region with largest passenger volume. To meet the growing demands, airports in this region face a more severe demand for efficient and better service quality. Therefore, the accurate assessment of productive efficiencies has thus been one of the most pertinent issues in the unending quest towards global competitiveness within the international airline industry.

This paper contributes to the existing airport efficiency literature by presenting a new data envelopment analysis (DEA) model, which incorporates multiple objective linear programming (MOLP) and increases discriminating power. DEA has become a popular method often used in the literature to study the relative efficiencies of firms and it is a non-parametric, no statistical hypotheses and tests are required. DEA has been used to compare performance of airports within national boundaries, including the U.S. (Gillen and Lall 1997; Sarkis 2000), UK (Parker 1999), Spain (Martin and Roman 2001), Japan (Yoshida and Fujimoto 2004), Taiwan (Yu 2010), Italia (Gitto and Mancuso 2012), Portugal (Barros and Sampaio 2004) as well as airports around the world (Yang 2010; Adler and Berechman 2001). However, traditional DEA has been criticized by its weak discriminating power and unrealistic weight distribution (Li and Reeves 1999). To remedy the above shortcomings, Golany (1988) first integrated the DEA and MOLP by taking account the preference of the decision maker (DM). But the prior information could be biased or hard to obtain due to the complexity of problems. Another popular method, the cross-efficiency matrix, has been a widely used for improve discriminating power. However, the cross-efficiency matrix only provides cross and self-efficiency scores; it does not provide the new input and output weights corresponding to those new efficiency scores (Li and Reeves 1999). Our proposed MOLP based DEA model improves prior models in three ways. First, the proposed model is non-radial. All of the inputs and outputs will be projected on to the same efficient frontier. Thus, the weight distribution is more reasonable than traditional methods. Second, instead of solving n mathematical programming problems, it is required to solve only one. Finally, the efficiency measurement is based on aspiration levels, not relatively good DUMs from the existing DMUs. With the new concept, the decision maker sets an aspiration level as the benchmark, a DMU which might not exist in the current basket of apples, but decision-makers will understand the gaps between each DUM and the aspiration levels. Decision-makers can therefore devise and implement a strategy to reduce the gaps to aspiration levels. This paper improves prior studies and determines the most preferred solution and more reasonable weight distribution for decision makers.

2 The Multiple Objectives Based DEA Method

The classical DEA analysis considers individual DMUs separately and calculates a set of weights which brings maximal relative efficiency to each group. But this approach tends to obtain most of the DMUs are efficient, thus, hard to discriminate them. Current approach sets target values as the aspiration levels for inputs and outputs and calculates the multiple objectives programming to find a set of common based weights. We then compute the efficiency ratio of all DMUs and analyze their gaps to aspiration levels.

2.1 Classical Efficiency Measure

If the *a*th DMU uses *m*-dimension input variables x_{ia} $(i = 1, \ldots, m)$ to produce *s*-dimension output variables y_{ra} $(r = 1, \ldots, s)$, the efficiency of DMU h_a can be found from the following model:

$$\text{Max } h_a = \frac{\sum_{r=1}^{S} u_r y_{ra}}{\sum_{i=1}^{m} v_i x_{ia}} \tag{1}$$

Subject to:

$$\frac{\sum_{r=1}^{S} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \le 1, \quad k = 1, \ldots, n$$
$$0 < \varepsilon \le u_r, 0 < \varepsilon \le v_i, \quad i = 1, \ldots, m; \; r = 1, \ldots, s$$

where

x_{ik} Stands for the *i*th input of the *k*th DMU,
y_{rk} Stands for the *r*th output of *k*th DMU,
u_r, v_i Stand for the weight of the *r*th output and *i*th input respectively,
h_a Relative efficiency value.

2.2 Fuzzy Multiple Objective Programming

Based on Tsai et al. (2006), the Eq. (1) can be transformed as a MOLP problem. Multiple objective programming can be employed to find a set of common weight combinations so that the optimized efficiency value can be calculated for each

DMU in overall relative efficiency achievement. That means each DMU is analyzed on a same baseline rather than on different efficient frontiers. This above goal can be formulated in Eq. (2).

$$\text{Max}\, h_1 = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_i x_{i1}} \tag{2}$$

$$\text{Max}\, h_2 = \frac{\sum_{r=1}^{s} u_r y_{r2}}{\sum_{i=1}^{m} v_i x_{i2}}$$

$$\vdots$$

$$\text{Max}\, h_n = \frac{\sum_{r=1}^{s} u_r y_{rn}}{\sum_{i=1}^{m} v_i x_{in}}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \leq 1, \quad k = 1, 2, \ldots, n$$

$$u_r \geq \varepsilon > 0, \quad r = 1, 2, \ldots, s$$

$$v_i \geq \varepsilon > 0, \quad i = 1, 2, \ldots, m$$

2.3 Apply Genetic Algorithm NSGA-II to Obtain the Pareto Solutions

The presence of multiple objectives in a problem, in principle, gives rise to a set of optimal solutions (largely known as Pareto-optimal solutions), instead of a single optimal solution. Classical optimization methods suggest converting the MOLP to a single-objective optimization problem by emphasizing one particular Pareto-optimal solution at a time. Tsai et al. (2006) solves the MOLP by using the compromise solution as the optimal solution. But the compromise solution does not guarantee the solution is a Pareto solution. Furthermore, the obtained weight distribution from compromise solution sometimes produces extreme value in some inputs/outputs and zero values in some inputs/outputs that cannot reflect the real situation. We apply genetic algorithm NSGA II to solve Eq. (2) and to attain the Pareto solutions. Based on derived Pareto solutions, we select the solution according to airport managers' opinions. The common weights are then substituted into Eq. (1) to calculate the efficiency of each DMU.

3 The Data and Variables for Empirical Case

To measure productive efficiency using DEA, one must first identify outputs that an airport produces and inputs it uses in producing those outputs. Based on prior studies (Parker 1999; Sarkis 2000; Martin and Roman 2001; Abbott and Wu 2002; Assaf et al. 2012), the characteristics of the selected DEA input/out variables are summarized in Table 1. On the input side, we consider employees, runways, terminal size and gates as the input variables. The most important inputs at airports are labor and capital. The easiest measure of the former is the number of employees. The size of the terminal and number of gates determine the airport's ability to load passengers and cargo into aircrafts and hence play a crucial role in airport operation activity. The number of runways decides the aircraft movements. An airport's primary function is to provide an interface between aircraft and passengers or freight. From this perspective, the selected outputs in our efficiency are the passengers, cargo and aircraft movements.

The selection of variables in DEA must be isotonic, i.e., the value of output variable cannot decrease when input variables are increase. This was tested with Pearson analysis for input and output variables. The results indicate the selected variables are positively correlated with significant p values. The data source for the input and output variables come from Airport Benchmarking Report (2010).

4 Results and Discussions of Empirical Case

The classical DEA model exist some problems, such as weak discriminating power and unrealistic weight distribution for inputs and outputs. The classical DEA solves n linear programming problems and uses different weights for inputs and outputs in each DMU calculation. These results imply the efficiency analysis is not on the same baseline. The unrealistic weight distribution refers to the situation where some DMUs can be treated as efficient by classical DEA model simply because they have extremely large weights in a single output and extremely small weights in a single input while these extreme weights are practically unreasonable.

Table 1 Characteristics of DEA input and output variables

	Variable	Definition
Input	Employee (persons)	Sum of employees
	Runway	Number of runways
	Terminal size (square meter)	Total area of passenger and cargo terminals
Output	Gate	Number of gates
	Passenger volume (persons)	Passenger throughput of the airport
	Cargo volume (tons)	Cargo throughput of the airport
	Aircraft movement	Number of flights at the airport

Table 2 The weights for inputs and outputs

	Input				Output		
	Employee	Runway	Terminal size	Gate	Passenger	Cargo	Aircraft movement
Weight	203.74	120.39	321.48	229.65	232.26	119.22	104.24

The reason is because the classical DEA model tends to pursue a favorable weight distribution when each DMU is evaluated. Another noted point is that the relative efficiency might not fit on today's competitive environment in the air transport markets. Enterprise should not pursue a relatively good firm as the benchmark but an aspired level to fulfill customers' needs. To remedy the above shortcomings, we introduce aspired levels for the inputs/outputs as the benchmark that is decided by airport managers based on their aspiration. After adding the aspired levels as a virtual DMU, we follow the procedures as described in Sect. 3 to formulate the problem as a MOLP model. The MOLP problem is then solved by genetic algorithm to find non-dominated solutions. Since the non-dominated solutions are not unique, we can select a most preferred one according to decision maker's opinions to reflect the real-world situation. In this study, we select the non-dominated solution based on the managers' input. Table 2 shows the relative weights in our analysis that is obtained from the MOLP problem solved by genetic algorithm. The results show there is no extreme weight distribution for input and output variables. It is evidence that the uneven weight distribution is fixed by our proposed method.

Using the obtained weight distribution (Table 2), we can derive the efficiencies for each DMU (Table 3). The results are clear and significant that no airport presents prefect efficiency except the aspired airport. The discrimination power has been significant improved by using the proposed model which efficient DUMs have reduced from 12 DMUs to only 1 DMU (the virtual UM). The leading airports are Hong Kong, followed by Tokyo Haneda and Sydney, respectively. Based on the obtained weight distribution for inputs and outputs, we further calculate the gaps to aspired levels for each airport. The gaps are analyzed by assuming that the under the current inputs of each airport, what are the gaps to reach the aspiration levels if the airports want to achieve perfect score. The gap numbers provide very useful information for airport management. The decision makers will not only know their relative position with their peers but also the gaps to the aspiration levels. Thus, airport managers can further set strategies to improve the volumes with respect to passengers, cargo and aircraft movements. Conversely, our model not only helps airports apprehend the gaps between current performance and aspiration levels but also provides them with a chance to surpass their leading competitors.

Table 3 Analysis results of 22 airports in Asia–Pacific

No.	DUM	CCR	Tzeng's method	Proposed method	Gap to aspired levels		
					Passengers	Cargo (tons)	Aircraft movements
1	Auckland	1.000 (1)	1.000 (1)	0.533 (10)	34,158,403	1,164,722	1,079,839
2	Brisbane	0.962 (12)	0.767 (7)	0.548 (9)	35,604,473	328,236	824,535
3	Perth	1.000 (1)	0.527 (19)	0.421 (19)	28,526,491	416,003	593,230
4	Sydney	1.000 (1)	0.811 (6)	0.699 (3)	48,109,785	2,132,314	1,155,868
5	Guangzhou	1.000 (1)	1.000 (1)	0.662 (4)	63,582,220	3,793,511	1,447,186
6	Beijing	1.000 (1)	0.610 (12)	0.639 (5)	111,611,982	5,738,180	2,242,731
7	Hong Kong	0.926 (14)	1.000 (1)	0.926 (1)	54,204,438	10,815,252	986,354
8	Shanghai	0.750 (18)	0.556 (15)	0.458 (15)	133,322,384	18,691,234	2,461,311
9	Shenzhen	1.000 (1)	0.848 (5)	0.52 (12)	59,952,294	3,221,306	1,262,088
10	Xiamen	0.729(20)	0.661 (10)	0.436 (17)	36,909,224	1,253,180	789,816
11	Tokyo Haneda	1.000 (1)	0.742 (8)	0.878 (2)	42,302,792	1,607,590	954,948
12	Tokyo Narita	0.761 (16)	0.545 (16)	0.476 (14)	93,599,554	12,372,425	1,466,893
13	Kansai	0.726 (21)	0.542 (17)	0.456 (16)	46,405,109	4,642,605	1,091,671
14	Kuala Lumpur	0.751 (17)	0.589 (13)	0.422 (18)	93,871,998	3,798,086	1,658,757
15	Penang	1.000 (1)	0.527 (18)	0.415 (20)	14,599,629	1,071,098	346,418
16	Jakarta	1.000 (1)	0.978 (4)	0.636 (6)	59,539,996	1,543,514	1,151,265
17	New Delhi	0.606 (23)	0.435 (21)	0.377 (22)	100,637,825	3,728,368	1,998,137
18	Dubai	0.938 (13)	0.410 (22)	0.38 (21)	169,486,919	15,311,634	2,724,419
19	Incheon	0.738 (19)	0.615 (11)	0.586 (8)	77,089,326	12,568,962	1,264,853
20	Bangkok	0.837 (15)	0.665 (9)	0.527 (11)	84,039,895	4,695,710	1,363,302
21	Singapore	0.608 (22)	0.453 (20)	0.494 (13)	105,057,301	9,711,656	1,638,635
22	Taipei	1.000 (1)	0.588 (14)	0.607 (7)	49,333,100	6,483,728	781,319

5 Conclusion

This paper contributes to the existing literature by presenting a model to improve prior models in several ways. First, discriminating power has been improved with only aspired airport with perfect score and efficiencies of other airports are all less than 1. Second, the results can be solved by one MOLP model instead of n linear programming models. The obtained weight distribution is more reasonable than classical DEA models and other MOLP methods. Third, we introduce the concept of gaps to aspired levels that can help decision makers understanding of how airport can improve their performance to reach absolutely good levels, not a relatively good one. This gap analysis might be more suitable for today's competitive environment. Finally, little literature discusses the airport performance of Asia–Pacific region; we contribute to the existing research of airport efficiency. Our empirical example shows the effectiveness and usefulness of the proposed model. The results indicate Hong Kong is the leading airport in the Asia–Pacific region, followed by Tokyo Haneda and Sydney, respectively.

References

Abbott M, Wu S (2002) Total factor productivity and efficiency of Australian airports. Aust Econ Rev 35:244–260

Adler N, Berechman J (2001) Measuring airport quality from the airlines viewpoint: an application of data envelopment analysis. Transp Policy 8:171–181

Airport Benchmarking Report (2010) http://www.atrsworld.org/airportawards.html

Assaf AG, Gillen D, Barros C (2012) Performance assessment of UK airports: evidence from a Bayesian dynamic frontier model. Transp Res Part E: logistics Transp Rev 48:603–615

Barros CP, Sampaio A (2004) Technical and allocative efficiency of airports. Int J Transport Econ 31:355–377

Gillen D, Lall A (1997) Developing measures of airport productivity and performance: an application of data envelopment analysis. Transp Res E 33:261–273

Gitto S, Mancuso P (2012) Bootstrapping the Malmquist indexes for Italian airports. Int J Prod Econ 135:403–411

Golany B (1988) An interactive MOLP procedure for the extension of DEA to effectiveness analysis. J Oper Res Soc 39:725–734

Lam SW, Low JMW, Tang LC (2009) Operational efficiencies across Asia Pacific airports. Transp Res Part E 45:654–665

Li XB, Reeves GR (1999) A multiple criteria approach to data envelopment anaylsis. Eur J Oper Res 115:507–517

Martin JC, Roman C (2001) An application of DEA to measure the efficiency of Spanish airports prior to privatization. JAir Transp Manag 7:149–157

Parker D (1999) The performance of the BAA before and after privatization. J Transp Econ Policy 33:133–146

Sarkis J (2000) An analysis of the operational efficiency of major airports in the United States. J Oper Manag 18:335–351

Tsai HC, Chen CM, Tzeng GH (2006) The comparative productivity efficiency for global telecoms. Int J Prod Econ 103:509–526

Yang HH (2010) Measuring the efficiencies of Asia-Pacific international airports-Parametric and non-parametric evidence. Comput Ind Eng 59:697–702

Yoshida Y, Fujimoto H (2004) Japanese-airport benchmarking with the DEA and endogenous-weight TFP methods: testing the criticism of overinvestment in Japanese regional airports. Transp Res Part E 40:533–546

Yu MM (2010) Assessment of airport performance using the SBM-NDEA model. Omega 38:440–452

A Distributed Constraint Satisfaction Approach for Supply Chain Capable-to-Promise Coordination

Yeh-Chun Juan and Jyun-Rong Syu

Abstract Order promising starts with the available-to-promise (ATP) quantities. The short is then promised by capable-to-promise (CTP) quantities. Supply chain CTP coordination can be viewed as a distributed constraint satisfaction problem (DCSP) composed of a series of constraints about slack capacity, materials and orders distributed among supply chain members. To solve this problem, supply chain members should consider and resolve their intra- and inter-constraints via supply chain coordination. This research has proposed a DCSP approach for supply chain CTP coordination. With this approach, supply chain members can collaboratively determine a feasible integral supply chain CTP production plan.

Keywords Order promising · Capable-to-promise · Available-to-promise · Supply chain coordination · Distributed constraint satisfaction problem

1 Introduction

Order promising is a critical not only for the individual manufacturing companies but also for the entire supply chains (Min and Zhou 2002; Kim 2006). It starts with the available-to-promise (ATP) quantities, the short is then promised on the basis of capable-to-promise (CTP) quantities. CTP extends ATP by taking into account the slack capacity and the available materials (Stadtler 2005).

Y.-C. Juan (✉)
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: ycjuan@mail.mcut.edu.tw

J.-R. Syu
Department of Industrial Engineering and Management Information, Huafan University, New Taipei, Taiwan
e-mail: zone1230@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_37,

In supply chain environment, CTP is viewed as a constraint satisfaction problem (CSP) composed of a series of constraints about the order (quantity and due date) and the availability of capacity and materials distributed among supply chain members (Lin and Chen 2005). Most of the existing related studies assumed that the supply chain is in a shared environment and all knowledge can be gathered from supply chain members to the leading company, so the CTP quantity are always calculated with a centralized CSP approach, e.g. the advanced planning and scheduling (APS), operation research (OR) and other optimization approaches.

However, considering the cost or security/privacy for individual supply chain members, collecting information from supply chain members and calculating CTP quantity with a centralized CSP approach may become infeasible for a distributed supply chain. In such case, the supply chain CTP planning becomes a distributed CSP (DCSP). To solve this problem, supply chain members should first consider and resolve their own (intra-) CTP constraints and then communicate with their upstream and downstream supply chain members to resolve their inter-CTP constraints with a distributed supply chain CTP coordination approach. This research has proposed a DCSP approach to support supply chain CTP coordination. With this approach, supply chain members can determine whether they can satisfy a new order with the coordinated supply chain CTP quantity.

2 Distributed Constraint Satisfaction Problem

A CSP is composed of n variables, $x_1, x_2, \ldots,$ and x_n which have their own finite and discrete domain, $D_1, D_2, \ldots,$ and D_n, and a set of constraints ($p_1, p_2, \ldots, p_k$). A variable x_i should take its value from its own domain D_i. A constraint is defined by a predicate $p_k(x_{k1}, \ldots, x_{kj})$ which is defined on the Cartesian product $D_{k1} \times \ldots \times D_{kj}$. The predicate is true if and only if the values assigned to the variables satisfy the constraint (Yokoo and Hirayama 2000). Solving a CSP is to find the values assigned to all variables such that all constraints can be satisfied.

A DCSP is a CSP in which variables and constraints are distributed among multiple companies. Yokoo and Hirayama (2000) classified the existing DCSP algorithms according to the algorithm type (backtracking, iterative improvement, and hybrid) and the number of variables that must be solved in an agent (DCSPs with a single local variable, multiple local variables, and distributed partial CSPs).

The asynchronous backtracking (ABT) is an algorithm for agents with single local variable (Yokoo et al. 1992; Yokoo et al. 1998). It statically determines the priority order of variables/agents. Each agent communicates its current value to neighboring agents via *ok?* messages. The low-priority agents will change their value to fit high-priority agents. If high-priority agents select a bad value, low-priority agents need to perform an exhaustive search to their domain and communicate a new constraint to high-priority agents via *nogood* messages.

The asynchronous weak-commitment search (AWS) algorithm developed for agents with single local variable is similar to the ABT one. It dynamically changes the priority of variables/agents so that an exhaustive search can be avoided (Yokoo 1995; Yokoo et al. 1998). Besides, agents change their value and increase its priority value by using a min-conflict heuristic approach.

The distributed breakout (DB), an algorithm for single local variable, defines a weight for each constraint and uses the summation of weights of constraint violating pairs as an evaluation value (Yokoo and Hirayama 1996). To guarantee the evaluation value is improved, neighboring agents exchange the values of possible improvements by using *ok?* and *improve* messages, and only the agent that can maximally improve the evaluation value is given the right to change its value.

The agent-ordering AWS algorithm is based on AWS algorithm and introduces the prioritization among agents to handle multiple local variables (Yokoo and Hirayama 1998). Each agent first tries to find a local solution to fit the local solution of high-priority agents. If there is no such local solution, backtracking or modifying the agent priority by using various heuristics occurs.

The variable-ordering AWS is also an algorithm extending from AWS algorithm for handling multiple local variables (Yokoo and Hirayama 1998). Each agent creates multiple virtual agents, each of which corresponds to a local variable. An agent selects a variable with the highest priority from its local variables violating the constraints with high-priority variables and modifies its value so that the constraints can be satisfied. If there is no value can fit the value of high-priority agents, similar to AWS, the agent will increase its priority value.

For an over-constrained DCSP, i.e. a distributed partial CSP, most of the existing algorithms are to find a solution with a minimal number of violated constraints. The iterative DB algorithm modifies the DB one so that an agent can detect that the number of violated constraints is less than the current target number and propagate the new target number using *improve* messages. Agents continue this iteration until the target number becomes zero (Hirayama and Yokoo 1997). The asynchronous incremental relaxation (IR) algorithm applies the ABT one to solve the distributed partial CSPs (Yokoo 1993). Agents first try to solve an original DCSP by using ABT. If the problem is found to be over-constrained, agents give up constraints that are less important than a certain threshold. Next, agents apply ABT to find a solution to the relaxed DCSP.

3 The Proposed Approach

This section illustrates the DCSP model formulation and the proposed DCSP algorithm for supply chain CTP coordination.

Figure 1 is the formulated DCSP model for supply chain CTP coordination. The supply chain members are viewed as an agent and represented by a set of identifiers, x_1, x_2, …, x_n, from downstream to upstream. Here, assume the supply chain has four members, including the end customer (x_1), assembler (x_2), manufacturer (x_3), and supplier (x_4).

The formulated model is a common variables/constraints model for DCSPs. Each agent x_i has four sets of variables.

1. $ATPQty_{x_i}$ and $ATPFD_{x_i}$ are the quantity and finish date of the scheduled ATP that x_i can immediately respond to customer order enquires. Their domains are $D\_ATPQty_{x_i}$ and $D\_ATPFD_{x_i}$ which can be derived by calculating ATP = MPS—(the sum of the actual orders) for each time period.
2. $SCap_{x_i}$ is x_i's slack capacity used to produce x_i's finished products for supply chain CTP production plan. Its domain $(D\_SCap_{x_i})$ is x_i's own capacity and x_i's subcontract capacity.
3. $MatQty_{x_i}$ and $MatDD_{x_i}$ are the quantity and due date of materials required for producing x_i's finished products for supply chain CTP production plan. Their domains are $D\_MatQty_{x_i}$ and $D\_MatDD_{x_i}$ which are determined by the CTP production plan of x_i's suppliers.
4. The *quantity* $(CTPQty_{x_i})$ and *due date* $(CTPFD_{x_i})$ are the quantity and finish date of the planned CTP that x_i can promise the customer order enquires. Their domains are $D\_CTPQty_{x_i}$ and $D\_CTPFD_{x_i}$ which can be calculated and planned by x_i's APS system.

Based on these variables, the intra- and inter-constraints for supply chain CTP coordination can be defined as follows.

1. Each agent x_i has two sets of intra-constraints, $p_{Capacity}$ and $p_{Material}$.
   (a) $p_{Capacity}(SCap_{x_i}, CTPQty_{x_i}, CTPFD_{x_i})$ is a slack capacity constraint in which $SCap_{x_i}$ must be sufficient to fulfill $CTPQty_{x_i}$ and $CTPFD_{x_i}$.
   (b) $p_{Material}(MatQty_{x_i}, MatDD_{x_i}, CTPQty_{x_i}, CTPFD_{x_i})$ is a material constraint in which the planned $MatQty_{x_i}$ and $MatDD_{x_i}$ must support the fulfillment of $CTPQty_{x_i}$ and $CTPFD_{x_i}$.

2. For agent x_i (supplier) and its downstream agent x_{i-1} (customer), there is a constraint p_{Order} between x_i and x_{i-1}
   (a) $p_{Order}(ATPQty_{x_i}, ATPFD_{x_i}, CTPQty_{x_i}, CTPFD_{x_i}, MatQty_{x_{i-1}}, MatDD_{x_{i-1}})$ is an order constraint in which $ATPQty_{x_i}$and $CTPQty_{x_i}$ must satisfy $MatQty_{x_{i-1}}$, i.e. $MatQty_{x_i} \leqq ATPQty_{x_i} + CTPQty_{x_i}$, and $ATPFD_{x_i}$ and $CTPFD_{x_i}$ must satisfy $MatDD_{x_i}$, i.e. $MatDD_{x_{i-1}} \geqq APSFD_{x_i}$ and $CTPFD_{x_i}$.

From Fig. 1, the proposed DCSP algorithm for supply chain CTP coordination must be capable of handling multiple local variables and related constraints relaxation for slack capacity, materials and order. Since APS techniques and systems can solve the constraints of operation sequences, lead times and due dates to generate a feasible production plan (Chen and Ji 2007), this research use APS systems to solve the intra-constraints ($p_{Capacity}$ and $p_{Material}$). Besides, this research will modify and integrate the concepts of agent-ordering AWS algorithm and asynchronous IR algorithm to propose a coordination algorithm shown in Fig. 2 for solving the inter-constraints p_{Order}.

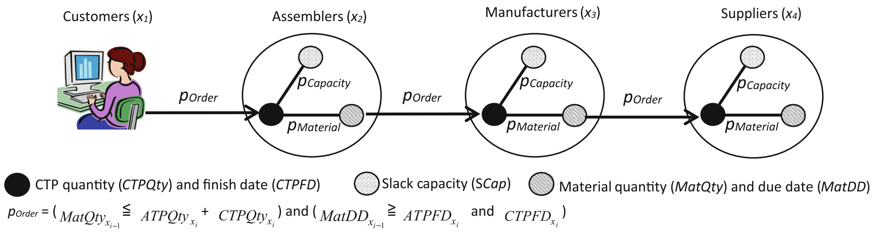


Fig. 1 DCSP model for supply chain CTP coordination

In the algorithm, agents can only communicate with their neighboring agents via *ok?* and *nogood* messages. The *ok?* message is formatted as (**ok?**, (x_i, (*Mat*, *MatQty*, *MatDD*)) which means agent x_i (customer) wishes its supplier to provide the quantity *MatQty* of product *Mat* by due date *MatDD*. The *nogood* message is formatted as (**nogood**, (x_i, (*order, relax_DD, relax_Qty*))) which means the agent x_i (supplier) cannot satisfy the original x_{i-1}'s (customer) order requirements and propose two constraint relaxation suggestions, a due-date constraint relaxation *relax_DD* and a quantity constraint relaxation *relax_Qty*. The procedures of the proposed algorithm are shown in Fig. 2 and explained as follows.

- In the initiation, the agent x_1 (end customer) proposes its demand by sending *ok?* message to agent x_2 (x_1's supplier) (Fig. 2a).
- When agent x_i receives an *ok?* message from downstream agent x_{i-1} (Fig. 2b), the order constraint p_{Order} among agent x_i and x_{i-1} is formed. If agent x_i can satisfy p_{Order} with scheduled ATP quantities, the integral CTP production plan is achieved and the CTP coordination process is terminated. Otherwise, the necessary CTP quantities are then calculated as ($MatQty_{x_{i-1}} - ATPQty_{x_i}$) and planned by APS system (Fig. 2d). APS system makes a local CTP production plan *CTP_PP* according to x_i's resources constraints ($p_{Capacity}$ and $p_{Material}$) to satisfy the *ctp* requirements for x_{i-1}'s order. If p_{Order} is satisfied and x_i has suppliers, agent x_i will propose its required material demand to agent x_{i+1} by sending *ok?* message. The order constraint p_{Order} is, therefore, further propagated upstream from agent x_i to agent x_{i+1}. If x_i doesn't have suppliers, the integral CTP production plan is achieved and the CTP coordination process is terminated. If x_i does not have enough resources for *ctp* requirements, the procedure **backtrack** is called.
- In **backtrack** procedure (Fig. 2e), APS system is called to provide two constraint relaxation suggestions, *relax_DD* and *relax_Qty*, via its simulation function. The *relax_DD* suggests to relax the originally requested due date ($MatDD_{x_{i-1}}$) to a possible earliest finish date ($CTPFD_{x_i}$) for the originally requested quantity ($MatQty_{x_{i-1}}$). The *relax_Qty* suggests to relax the originally requested quantity ($MatQty_{x_{i-1}}$) to a possible maximal finish quantity ($ATPQty_{x_i}$+ $CTPQty_{x_i}$) before the originally requested due date ($MatDD_{x_{i-1}}$). Then, agent x_i sends a *nogood* message to inform agent x_{i-1} about constraint violations and relaxation suggestions.

when initialized do -------------------- **(a)**
send (**ok?**, (x_1, (Mat_{x_1} , $MatQty_{x_1}$, $MatDD_{x_1}$))) to x_2;
end do;

when received (**ok?**, (x_{i-1}, ($Mat_{x_{i-1}}$, $MatQty_{x_{i-1}}$, $MatDD_{x_{i-1}}$)) **do** -------------- **(b)**
order ← (x_{i-1}, ($Mat_{x_{i-1}}$, $MatQty_{x_{i-1}}$, $MatDD_{x_{i-1}}$)
if ($MatQty_{x_{-1}} \leqq ATPQty_{x_i}$) and ($MatDD_{x_{i-1}} \geqq ATPFD_{x_i}$) **then**
broadcast to other agents that the integral CTP production plan has been achieved;
terminate this CTP coordination process;
end if;
ctp ← (x_{i-1}, ($Mat_{x_{i-1}}$, $MatQty_{x_{i-1}} - ATPQty_{x_i}$, $MatDD_{x_{i-1}}$);
$CTP\_PP \cdot (SCap_{x_i}, MatQty_{x_i}, MatDD_{x_i}, CTPQty_{x_i}, CTPFD_{x_i})$ ← **APS_planning** (*ctp*);
if ($MatQty_{x_{i-1}} \leqq ATPQty_{x_i} + CTP\_PP.CTPQty_{x_i}$) and ($MatDD_{x_{i-1}} \geqq ATPFD_{x_i}$ and $CTP\_PP.CTPFD_{x_i}$)
then
if x_i has supplier **then**
send (**ok?**, (x_i, (Mat_{x_i} , $CTP\_PP.MatQty_{x_i}$, $CTP\_PP.MatDD_{x_i}$))) to x_{i+1};
else
broadcast to other agents that the integral CTP production plan has been achieved;
terminate this CTP coordination process;
end if;
else
backtrack;
end if;
end do;

when received (**nogood**, (x_{i+1}, (*order, relax_DD, relax_Qty*))) **do** --------- **(c)**
add (**ok?**, (x_i, (Mat_{x_i} , $CTP\_PP.MatQty_{x_i}$, $CTP\_PP.MatDD_{x_i}$))) to *nogood_list*;
$CTP\_PP \cdot (SCap_{x_i}, MatQty_{x_i}, MatDD_{x_i}, CTPQty_{x_i}, CTPFD_{x_i})$ ← **APS_planning** (*relaxDD*);
if ($MatQty_{x_{i-1}} \leqq ATPQty_{x_i} + CTP\_PP.CTPQty_{x_i}$) and ($MatDD_{x_{i-1}} \geqq ATPFD_{x_i}$ and $CTP\_PP.CTPFD_{x_i}$)
then
send (**ok?**, (x_i, (Mat_{x_i} , $CTP\_PP.MatQty_{x_i}$, $CTP\_PP.MatDD_{x_i}$))) to x_{i+1};
else
$CTP\_PP \cdot (SCap_{x_i}, MatQty_{x_i}, MatDD_{x_i}, CTPQty_{x}, CTPFD_{x_i})$ ← **APS_planning** (*relaxQty*);
if ($MatQty_{x_{i-1}} \leqq ATPQty_{x_i} + CTP\_PP.CTPQty_{x_i}$) and ($MatDD_{x_{i-1}} \geqq ATPFD_{x_i}$ and $CTP\_PP.CTPFD_{x_i}$)
then
send (**ok?**, (x_i, (Mat_{x_i} , $CTP\_PP.MatQty_{x_i}$, $CTP\_PP.MatDD_{x_i}$))) to x_{i+1};
else
if x_i has customer then
backtrack;
else
broadcast to other agents that there is no solution for the integral CTP production plan;
terminate this CTP coordination process;
end if;
end if;
end if;
end do;

procedure **APS_planning** ------------------ **(d)**
Infinite Capacity Planning;
Finite Capacity Planning;
Detailed Scheduling;

Fig. 2 DCSP algorithm for supply chain CTP coordination procedure **backtrack** ------------------- **(e)**

($SCap_{x_i}$, $MatQty_{x_i}$, $MatDD_{x_i}$, $CTPQty_{x_i} = MatQty_{x_{i-1}}$, $CTPFD_{x_i}$ =earliest($MatDD_{x_{i-1}}$))← **APS_planning** (*ctp*);

relax_DD ← copy *order* and replace $MatDD_{x_{i-1}}$ with $CTPFD_{x_i}$;

($SCap_{x_i}$, $MatQty_{x_i}$, $MatDD_{x_i}$, $CTPQty_{x_i}$ =max($MatQty_{x_{i-1}} - ATPQty_{x_i}$), $CTPFD_{x_i} = MatDD_{x_{i-1}}$)← **APS_planning** (*ctp*);

relax_Qty ← copy *order* and replace $MatQty_{x_{i-1}}$ with $ATPQty_{x_i} + CTPQty_{x_i}$;

if *order* ∉ *nogood_sent* **then**
  send (**nogood**, (x_i, (*order, relax_DD, relax_Qty*))) to x_{i-1};
  add *order* to *nogood_sent*;
end if;

Fig. 2 continued

- When agent x_i receives a *nogood* message from its supplier (Fig. 2c), the original requirements become a new constraint and are recorded in a list *nogood_list* to avoid re-proposing. Besides, agent x_i uses APS system to evaluate the received two constraint relaxation suggestions. It first calls APS system to make a local CTP production plan according to the first relaxation suggestion *relax_DD*. If the planned quantity and finish date can satisfy x_i's customer requirements, agent x_i will accept the *relax_DD* suggestion and re-propose its material demand to agent x_{i+1}. Otherwise, it calls APS system to make a local production plan according to the second relaxation suggestion *relax_Qty*. If the planned quantity and finish date can satisfy x_i's customer requirements, agent x_i will accept the *relax_Qty* suggestion and send *ok?* message to agent x_{i+1} to re-propose the material demand. If both of *relax_DD* and *relax_Qty* are not accepted and x_i has customers, it will call procedure **backtrack** to send a *nogood* message to its customer. The *nogood* constraint is, therefore, propagated from upstream to downstream. If x_i is the end customer (x_1), it will broadcast to other agents that there is no solution for the integral CTP production plan and terminate the CTP coordination process.

4 The Completeness Analysis of the Proposed Algorithm

In the proposed algorithm, the constraint relaxation is suggested and backtracked to customer if a new p_{Order} constraint violation is found. Since the number of possible p_{Order} constraint violation is finite, the relaxation and backtracking cannot be done infinitely. Therefore, after a certain time point, the constraint violation will be diminished. Consequently, the completeness of the proposed coordination algorithm for solving the formulated DCSP is guaranteed.

5 Conclusions

Under the consideration of global manufacturing, we has formalized the supply chain CTP problem as a DCSP and proposed a coordination algorithm to solve it. The completeness of the proposed CTP coordination algorithm is also analyzed.

Acknowledgments The authors gratefully acknowledge the funding support by National Science Council, ROC through project No. NSC 99-2221-E-131-025.

References

Chen K, Ji P (2007) A mixed integer programming model for advanced planning and scheduling (APS). Eur J Oper Res 181:515–522

Hirayama K, Yokoo M (1997) Distributed partial constraint satisfaction problem. In: Proceedings of 3rd international conference on principles and practice of constraint programming, pp 222–336

Kim DS (2006) Process chain: a new paradigm of collaborative commerce and synchronized supply chain. Bus Horizons 49:359–367

Lin JT, Chen JH (2005) Enhance order promising with ATP allocation planning considering material and capacity constraints. J Chin Inst Ind Eng 22:282–292

Min H, Zhou G (2002) Supply chain modeling: past, present and future. Comput Ind Eng 43:231–249

Stadtler H (2005) Supply chain management and advanced planning: basics, overview and challenges. Eur J Oper Res 163:575–588

Yokoo M (1993) Constraint relaxation in distributed constraint satisfaction problem. In: Proceedings of 5th international conference on tools with artificial intelligence, pp 56–63

Yokoo M (1995) Asynchronous weak-commitment search for solving distributed constraint satisfaction problems. In: Proceedings of 1st international conference on principles and practice of constraint programming, pp 88–102

Yokoo M, Hirayama K (1996) Distributed breakout algorithm for solving distributed constraint satisfaction problems. In: Proceedings of 2nd international conference on Multiagent systems, pp 401–408

Yokoo M, Hirayama K (1998) Distributed constraint satisfaction algorithm for complex local problems. In: Proceedings of 3rd international conference on Multiagent systems, pp 372–379

Yokoo M, Hirayama K (2000) Algorithms for distributed constraint satisfaction: a review. Auton Agent Multi-Ag 3:185–207

Yokoo M, Durfee EH, Ishida T, Kuwabara K (1992) Distributed constraint satisfaction for formalizing distributed problem solving. In: Proceedings of 12th IEEE international conference on distributed computing systems, pp 614–621

Yokoo M, Durfee EH, Ishida T, Kuwabara K (1998) The distributed constraint satisfaction problem: formalization and algorithms. IEEE T Knowl Data En 10:673–685

Design and Selection of Plant Layout by Mean of Analytic Hierarchy Process: A Case Study of Medical Device Producer

Arthit Chaklang, Arnon Srisom and Chirakiat Saithong

Abstract The objectives of this research are to design the alternatives of plant layout and to select the most appropriate layout in which many criteria, both qualitative and quantitative criteria, are taken into account by mean of Analytic Hierarchy Process. Proximity requirements between each pair of facilities are determined by taking density of flow, harmful effect to nearby facilities and appropriateness into consideration. Furthermore, simulation approach is employed in order to evaluate the performance of quantitative criteria such as number of work in process and time in system of each alternative. The result of this research provides guideline to facility planner in order to select the most appropriate layout subject to a set of decision criteria.

Keywords Plant layout design · Plant layout selection · Analytic hierarchy process · Simulation

1 Introduction

In term of design problems, the unique answer for a given problem does not generally exist since an individual makes decision, which is selective, cumulative, and tentative, and this is contradictory to optimization problem (Simon 1975). In solving optimization problems, the derived answers are well defined and they are optimized to chosen criteria (Heragu 1997). Regarding to the characteristic of plant layout problem, plant layout problem should not be considered as neither pure design problem nor pure optimization problem (Heragu 1997). This is because there are many factors involved both qualitative factors and quantitative

A. Chaklang (✉) · A. Srisom · C. Saithong
Department of Industrial Engineering, Faculty of Engineering at Si Racha, Kasetsart University Si Racha Campus, Chon Buri 20230, Thailand
e-mail: sfengcrs@src.ku.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_38,

factors. Optimizing quantitative factors may sacrifice some quantitative factors whereas considering only qualitative factors may lead to poor efficiency of the plant (Heragu 1997). For illustration, a facility planner arranges the machines by their size; large, medium, and small machines, regardless to other factors. This causes highly flexible on allocating resources and it looks nice and tidy. However, this design would result in high cost of material handling especially in the case of high production volume (Tompkins et al 2010). It should be noted that material handling issue is considered as an integral part of plant layout design because it uses a number of working operators, utilizes more than half of floor space, and consumes majority of production time (Frazelle 1986). On the other hand, if the facility planner considers only minimizing material handling cost, the obtained design may be impractical because some important factors, which are not easy to be captured, are omitted (Heragu 1997). As a result, design of plant layout should regard not only quantitative factors but also qualitative factors as well.

In order to select the most appropriate plant layout, there are many factors involved with and the most appropriate one is selected subject to a set of decision criteria as well as the nature of business. For example, in Reconfigurable Manufacturing Systems (RMSs), quickly changing of market, not only in term of variety but also volume, results in requirement of flexibility of plant design in order to manipulate flow of material, material handling system, and other related issues as well. Thus, reconfigurable layout is a crucial factor of selection criteria. In addition, proximity requirement among facilities is also an important factor since a number of product families pass through facilities in accordance with their routing sequences (Abdi 2005). Furthermore, the other factors such as quality effect, maintainability, configuration cost, and productivity should be regarded as well (Abdi 2005; Azadeh and Izadbakhsh 2008; Ngampak and Phruksaphanrat 2011; Yang and Kuo 2003; Yanga and Shia 2002). Multi-criteria Decision Making (MCDM) should be taken employed in order to deal with the selection of plant layout process. Analytic Hierarchy Process (AHP) is a systematic approach dedicated to MCDM. It is based on pair-wise comparison and the relative scores represent how much an attribute dominate (is dominated) over attributes (Saaty 2008). Since this research considers multi-criteria in order to make decision, AHP is applied in order to select the most appropriate layout subject to potential criteria.

Regarding to the evaluation of quantitative factors, those factors must be evaluated according to the area of factors' type. Aguilar et al. (2009) considers for economic performance and net present value is used as evaluations' criteria. Yang and Kuo (2003) interests in flow density which is evaluated by the product between rectilinear distance and associated volume. Ngampak and Phruksaphanrat (2011) takes the distance moved between stations into account, however, they do not show the improved efficiency from adopting the selected layout.

In this research, a medical device producer is used as the case study to design and select plant layout. The problem is that the factory has insufficient production capacity due to the increase in demand. Thus, management decides to expand production capacity by establishing a new factory. At the existing factory, the factory arranges the machines according to the similarity of processing. This is because, according to the nature of business, there are various types of product with low in their volume. As a result, for type of layout in the new factory, the process layout should be continually employed and the following factors should be take into account; flexibility for reconfiguration, work in process, cycle time, traveled distance, and personal judgment on appropriateness.

2 Research Methodology

The following methodology, as can be seen in Fig. 1, is used in this research.

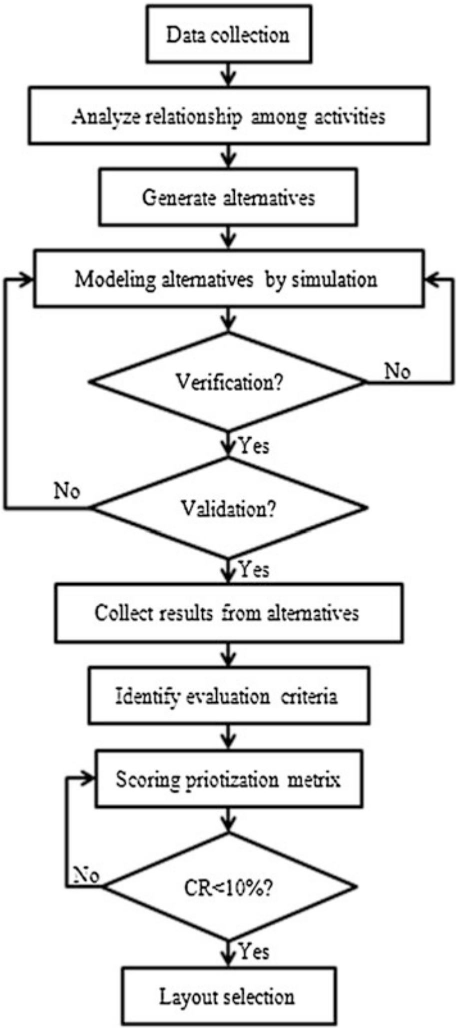


Fig. 1 Methodology for this research

3 Analyze Activity Relationships and Construct Alternatives

After finishing data collection, the next step is to determine proximity requirement among facilities. All combinations of relationships are represented by using relationship chart, as can be seen in Fig. 2. The numerical values inside parenthesis and behind departments' name are the specified required space.

A number of alternatives are generated in accordance with activity relationship chart in Fig. 2. Then, the block diagrams of alternatives are constructed. After that, for each of block diagram, detail layout is designed. The arrangements of machines within department along with pickup and delivery point are specified. There are 15 alternatives generated from A1-A5, B1-B5, and C1-C5 and some examples of alternatives are shown in Fig. 3.

4 Modeling Alternatives by Simulation

Because of this research also considers for quantitative criteria, simulation approach is employed in order to evaluate performance quantitatively. However, there is some limitation about checking validation of the models. There lacks some

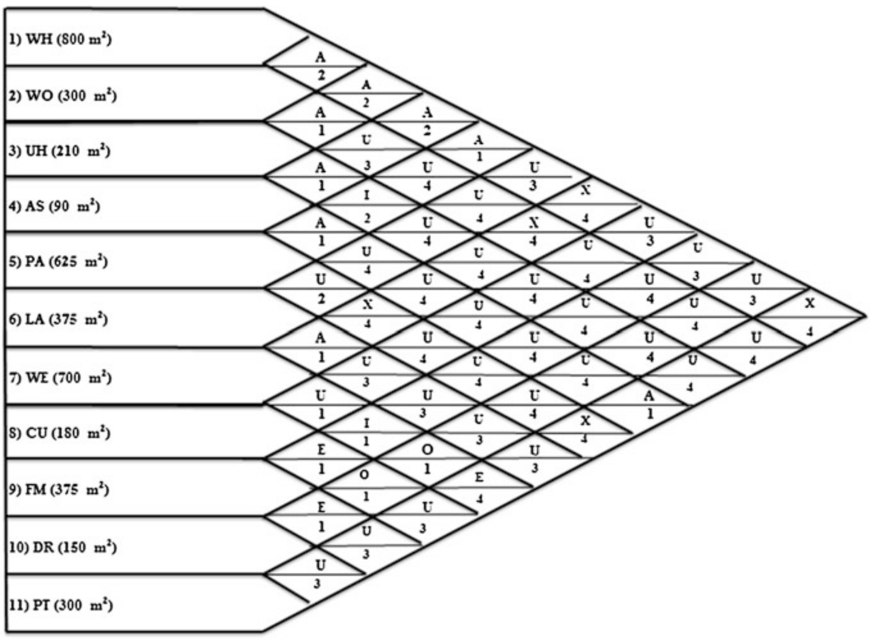


Fig. 2 Activity relationship chart

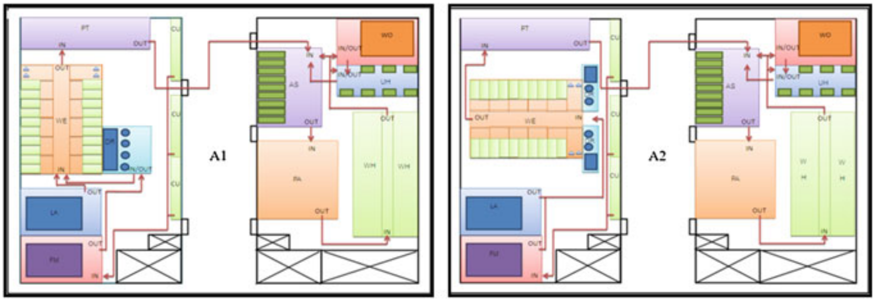


Fig. 3 Alternative layouts

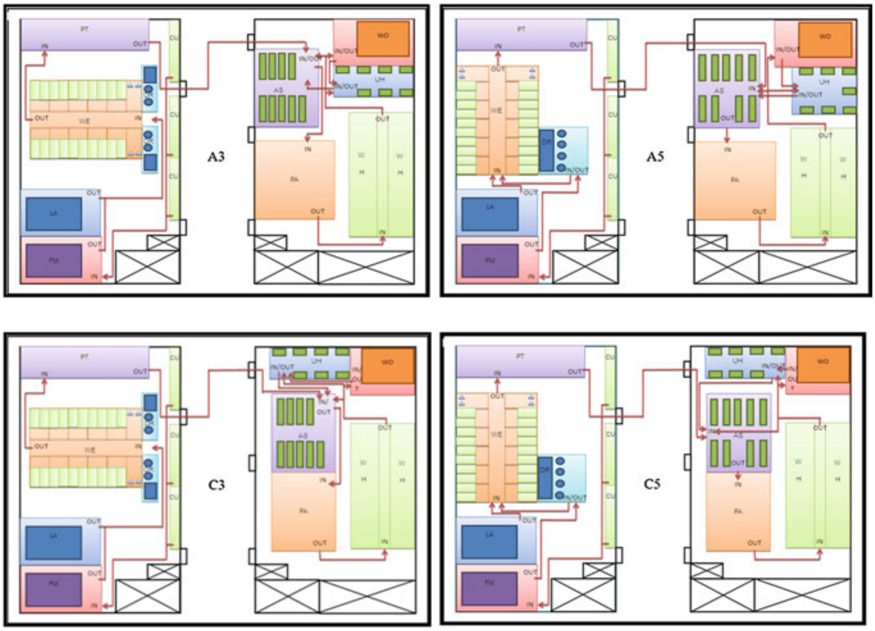


Fig. 3 continued

of important data in order to check validation of the models carefully because it deals with design a new factory. Thus, the number of produced products is used to check validation of the models only and the result shows that the error percentage is less than 3 % for all alternative models. Furthermore, the percentage of defective products from departments is assumed to be equal to the old factory. Figure 4 shows simulation model used in this research.

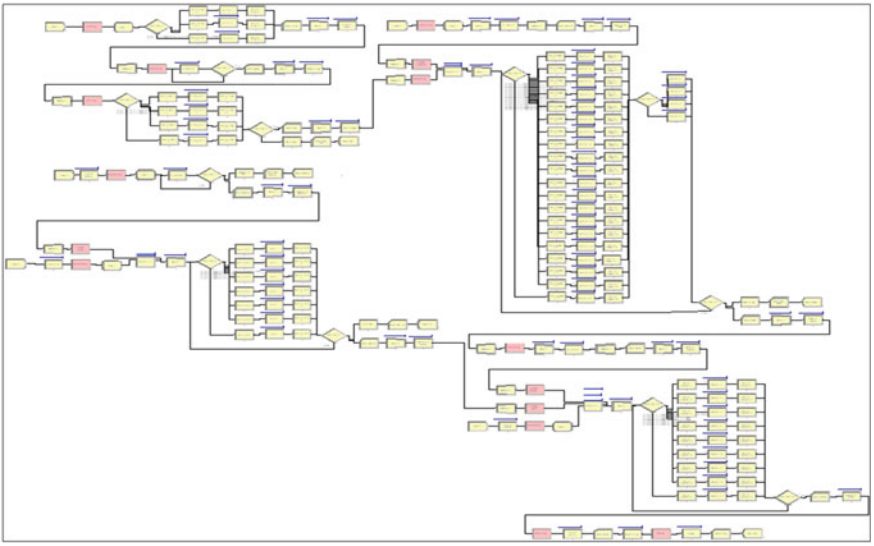


Fig. 4 Simulation model

Fig. 5 Comparison matrix

$$S_k = \begin{pmatrix} a_{11k} & a_{12k} & \dots & a_{1jk} \\ \dots & \dots & a_{ijk} & \dots \\ a_{i1k} & a_{i2k} & \dots & a_{NPk} \end{pmatrix}$$

5 Analytic Hierarchy Process

After deriving performance of quantitative criteria from simulation, the next step is to evaluate total performance in which both quantitative and qualitative criteria are taken into account by mean of Analytic Hierarchy Process (AHP). AHP is based on pair wise comparison in which an attribute is compared to other attributes as can be seen in Fig. 5. The hierarchical structure of this problem is depicted in Fig. 6.

Where: a_{ijk} represents the relative important of attribute ith over attribute jth of individual kth.

The next step is to construct prioritization matrix, to calculate eigenvectors as well as consistency ratio (CR). The eigenvectors imply importance of attributes while CR values determine accuracy of the matrix evaluated. An example is illustrated in Fig. 7. After that, the most appropriate layout can be selected from ranking of layouts by considering all criteria as illustrated in Fig. 8.

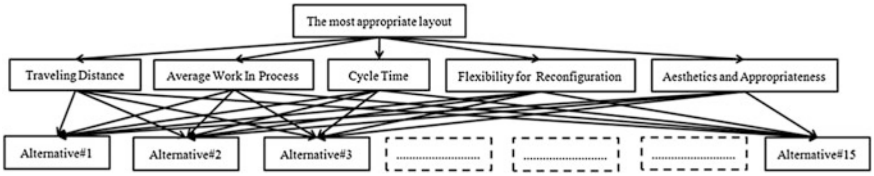


Fig. 6 Hierarchical structure

	Traveling Distance															Eigenvector
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	
A1	1	1	5	1	1	5	5	5	5	10	1	1	5	1	5	0.1215
A2	1	1	1	1	1	1	5	5	1	5	1	1	5	1	5	0.0875
A3	1/5	1	1	1/5	1	1	5	5	1	5	1/5	1/5	5	1	5	0.0655
A4	1	1	5	1	1	5	5	5	5	10	1	1	5	1	5	0.1215
A5	1	1	1	1	1	5	5	5	5	5	1	1	5	1	5	0.1025
B1	1/5	1	1	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1/5	1	0.0293
B2	1/5	1/5	1/5	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1/5	1	0.0222
B3	1/5	1/5	1/5	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1/5	1	0.0222
B4	1/5	1	1	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1/5	1	0.0293
B5	1/10	1/5	1/5	1/10	1/5	1/5	1/5	1/5	1/5	1	1/10	1/10	1/5	1/10	1/5	0.0088
C1	1	1	5	1	1	5	5	5	5	10	1	1	5	1	5	0.1215
C2	1	1	5	1	1	5	5	5	5	10	1	1	5	1	5	0.1215
C3	1/5	1/5	1/5	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1/5	1	0.0222
C4	1	1	1	1	1	5	5	5	5	10	1	1	5	1	1	0.0976
C5	1/5	1/5	1/5	1/5	1/5	1	1	1	1	5	1/5	1/5	1	1	1	0.0269
CR=6% Acceptable																

Fig. 7 An example of prioritization matrix, Eigenvector and CR value

	Criteria					Total weight	Ranking
	Distance	Ave. WIP	Cycle Time	Flexibility	Appropriateness		
A5	0.0287	0.0834	0.0043	0.0039	0.0149	0.1352	1
C4	0.0274	0.0149	0.0019	0.0131	0.0569	0.1142	2
A1	0.0341	0.0071	0.0012	0.0133	0.0536	0.1092	3
C2	0.0341	0.0440	0.0033	0.0030	0.0149	0.0993	4
C1	0.0341	0.0440	0.0021	0.0033	0.0146	0.0980	5
C3	0.0062	0.0584	0.0074	0.0030	0.0149	0.0899	6
A4	0.0341	0.0186	0.0022	0.0029	0.0149	0.0727	7
A2	0.0245	0.0054	0.0004	0.0031	0.0149	0.0483	8
C5	0.0075	0.0049	0.0004	0.0065	0.0282	0.0476	9
A3	0.0184	0.0054	0.0012	0.0030	0.0137	0.0417	10
B1	0.0082	0.0247	0.0007	0.0013	0.0053	0.0403	11
B4	0.0082	0.0149	0.0007	0.0027	0.0123	0.0389	12
B5	0.0025	0.0040	0.0002	0.0030	0.0149	0.0245	13
B3	0.0062	0.0095	0.0012	0.0010	0.0032	0.0211	14
B2	0.0062	0.0084	0.0003	0.0010	0.0032	0.0191	15

Fig. 8 Evaluation result

6 Conclusion and Recommendation

This research provides guideline to planner in order to design and select the most appropriate plant layout subject to both quantitative and qualitative criteria. Simulation approach is employed in order to assess quantitative criteria. Then, all of criteria are aggregated and the most appropriate layout is selected by mean of Analytic Hierarchy Process. In this case study, the alternative A5 is the most interesting layout. For recommendation, this research is conducted when some decisions are already made, e.g., facilities, structure, and required space. Thus, the alternatives generated are quite limited in order to explore more potential efficient designs.

Acknowledgments The authors would like to express their sincere appreciation to Faculty of Engineering at Si Racha, Kasetsart University Si Racha Campus for financial support. Lastly, this research cannot be carried out without greatly support from the case study company.

References

Abdi MR (2005) Selection of a layout configuration for reconfigurable manufacturing systems using the AHP. Paper presented at International Symposium on the Analytic Hierarchy Process 2005, Honolulu, Hawaii, 8–10 July 2005

Aguilar AA, Bautista MA, Ponsich A, Gonzalez MA (2009) An AHP-based decision-making tool for the solution of multiproduct batch plant design problem under imprecise demand. Comput Oper Res 36:711–736

Azadeh A, Izadbakhsh HR (2008) A multi-variate/multi-attribute approach for plant layout design. Int J Ind Eng 15:143–154

Frazelle EH (1986) Material handling: a technology for industrial competitiveness. Material handling research center technical report, Georgia Institute of Technology, Atlanta, Apr 1986

Ngampak N, Phruksaphanrat B (2011) cellular manufacturing layout design and selection: a case study of electronic manufacturing service plant. In: Proceedings of international multi conference of engineers and computer scientists 2011, Hong Kong, 16–18 Mar 2011

Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1:83–98

Simon HA (1975) Style in design. In: CM Eastman (ed) Spatial synthesis in computer-aid building design, Wiley, New York

Tompkins JA et al (2010) Facilities planning. Wiley, USA

Yang T, Kuo C (2003) A hierarchical AHP/DEA methodology for the facilities layout design problem. Eur J Oper Res 147:128–136

Yanga J, Shia P (2002) Applying analytic hierarchy process in firm's overall performance evaluation: a case study in China. Int J Bus 7:29–46

Using Taguchi Method for Coffee Cup Sleeve Design

Yiyo Kuo, Hsin-Yu Lin, Ying Chen Wu, Po-Hsi Kuo, Zhi-He Liang and Si Yong Wen

Abstract The present study aims to design the coffee cup sleeve which can detect the temperature of coffee and notify the consumers. When consumers find that the coffee is going to become cool, then they can drink the coffee quickly before it become sour. Due to the limitation of cost, thermal label is adopted to cohere on the coffee cup sleeve for detecting and notifying the important temperature. However, the temperature of coffee and the coffee cup sleeve are different which have to be taken into consideration by the thermal label. Different thermal labels are suitable for different temperature detection. Taguchi method is used for optimizing the selection of thermal labels for the importation temperature. Finally the surface of coffee cup sleeve with thermal labels on it is well designed to be a real product.

Y. Kuo (✉) · H.-Y. Lin
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: yiyo@mail.mcut.edu.tw

H.-Y. Lin
e-mail: y801018@yahoo.com.tw

Y. C. Wu
Department of Visual Communication Design, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: Bohaha0725@yahoo.com.tw

P.-H. Kuo
Department of Industrial Design, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: kevin8132@gmail.com

Z.-H. Liang · S. Y. Wen
Department of Business and Management, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: ktv8591@gmail.com

S. Y. Wen
e-mail: cool710186@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_39,

Keywords Taguchi method · Coffee cup sleeve · Product design · Thermal label

1 Introduction

Drinking coffee has become a routine behavior of many people in Taiwan. Usually consumers buy a cup of coffee on the way to office or school and then enjoy the coffee while they are working or studying. This life style can be view as enjoyment or fashion. However, after buying a cup of coffee, sometimes it is possible that consumer forget to drink the coffee due to they keep their mine on working or study. Then the coffee becomes cooler and cooler. Finally the coffee would be sour and hard to be drunk. Therefore, it would be a good ideal, if there is something that can remind consumers of the temperature of the coffee. Thus, the consumers can know the best timing to drink the coffee.

The coffee cup is the only thing that contacts the coffee. Therefore, coffee cup is the best choice for detecting the temperature of coffee. According to the survey for current product, one kind of cup made by ceramics can change the color when it detects different level of temperature. However, cup made by paper whose color can change while it detecting different level of temperature is not found. If a coffee bar sales coffee with paper cups which can remind the temperature of coffee. It would attract more consumers. However, sometimes coffee bars also provide coffee cup sleeve to keep consumers from scalding their hand. And the coffee cup sleeves would cover most part of the cup. Therefore, the present study aims to design a coffee cup sleeve which can remind the temperature of the coffee without affecting the total cost too much.

In this study, thermal labels are adopted to cohere on the coffee cup sleeve for detecting and notifying the important temperature. The thermal labels are designed for detecting certain level of temperature. There are two kind of thermal label, one is irreversible temperature indicators thermometer and the other one is reversible temperature indicators thermometer. When the temperature become higher and higher, the color of thermal labels are not changed until the temperature that they detect reach the certain level of temperature which they are designed to detect. However, when the temperature that they detect is lower than they are designed to detect, the color of irreversible temperature indicators thermometer will not return to its' original color but the reversible temperature indicators thermometer will. Ordinarily the temperature of coffee cup sleeve is room temperature. After the coffee cup fill with hot coffee, the temperature of coffee cup sleeve will become higher and higher and cause the thermal labels change color. When the temperature of coffee become lower and lower, this study expects the thermal labels will return to its' original color to remind consumer the temperatures of "not too hot" and "not too cold". Therefore, reversible temperature indicators thermometer is adopted for reminding the temperature of coffee.

Due to the coffee cup and coffee cup sleeve can reduce the detecting temperature of thermal labels. The temperature detected by thermal label is lower than the coffee. Moreover, there are several noise (uncontrollable) factors which can affect the detecting of the thermal label. Therefore, this study adopt Taguchi method for determining the optimal specification of thermal labels for detecting the temperatures of “not too hot” and “not too cold” of coffee.

The remainder of this article is organized a follows: a brief introduction to the case study problem is provided in Sect. 2. Section 3 shows the experimental structure can the corresponding results. Finally, Sect. 4 presents the conclusions.

2 Problem Description

This study aims to find the optimal specification of thermal labels for detecting the temperatures of “not too hot” and “not too cold” of coffee. Due to there are several factors which affect the coffee temperature detecting of thermal labels and should be taken into consideration in the experiment. These important factors are illustrated in Fig. 1 and discussed in the following.

2.1 Size of Coffee Cup

In Fig. 1, there are two size of coffee cup. Figure 1a is larger and Fig. 1b is smaller. According to the survey of market, the sleeve, cover and the bottom are all the same between larger and smaller cup. Therefore, the body of smaller cup is more oblique. If the sleeve and larger is totally touch with no gap between both of them, thus gap can be found between sleeve and smaller cup. The gap is illustrated in Fig. 1b. In this study only two sizes are considered.

2.2 Volume of Coffee

When the coffee is full of the cup, most part of cup is touched with the coffee, thus the temperature of coffee would have more opportunity transfer to the sleeve and

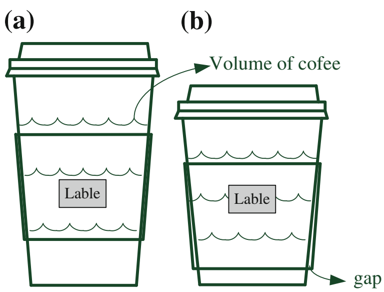


Fig. 1 Factors of the experiment

cause the temperature of the sleeve is higher. However, when there is less coffee in the cup, the opportunity of the temperature transferred to sleeve would be less. Therefore, the temperature detected by the thermal label would be lower. Thus, the volume of coffee in the cup will affect the temperature detected by the thermal label.

2.3 Location of Thermal Label

According to the gap introduced in Sect. 2.1, there is gap between small cup and cup sleeve. However, the gap is different between top and bottom of the cup sleeve. The gap is bigger in the bottom of the cup sleeve but no gap in the top of the cup sleeve. The temperature detected by thermal label would be different when the thermal label is located in the top, middle or bottom of cup sleeve. Therefore, the location that thermal labels cohered with cup sleeve could affect the detecting of coffee temperature.

2.4 Specification of Thermal Label

The specification of thermal label is the temperature that they change color. The color of thermal labels only change when the temperature that they detect pass their corresponding specification. For example, if a thermal label whose specification is 6 °C, when the temperature is rising and the temperature detected by thermal label is 6 °C, the color of the thermal label will change, vice versa.

However, the thermal label can only detect the surface temperature of cup sleeve, and the temperature between coffee and the surface temperature of cup sleeve are different. Determining the most suitable specification of thermal labels for detecting the "not too hot" and "not too cold" temperatures of coffee would be the most important job of the study.

3 Experiment

In this section, the temperature of "not too hot" and "not too cold" is introduced in Sect. 3.1. Based on the two temperatures, the experimental structure and results for optimizing the cup sleeve are provided in Sect. 3.2. Finally the optimal cup sleeve is presented in Sect. 3.3.

3.1 Target Value Determination

This study aims to optimize the cup sleeve design, when the temperature of coffee are "not too hot" and "not too cold", the thermal label can change the color to remind consumers to drink the coffee. Therefore, the temperature of "not too hot" and "not too cold" are the target values of the experiment. Lee and O'Mahony (2002) studied the preferred temperature for drinking coffee. The result show that the mean preferred temperature for drinking black coffee, coffee with creamer and sweetener, stronger black coffee and weaker black coffee are 61.5 °C (79.3–43.7 °C), 59.0 °C (73.7–44.3 °C), 59.3 °C (72.0–46.6 °C), 60.4 °C (73.5–47.3 °C) respectively. The range in the parentheses are 95 % confident interval for each group. Due to the function of the designed sleeve in this study is to remind the consumer that the temperature of coffee is accepted for drinking for wide-ranging consumer, 8 and 43 °C are chosen as the temperature of "not too hot" and "not too cold".

3.2 Experimental Structure

The factors which can affect the experiment are introduced in Sect. 2. The experimental levels for each factor are summarized in Table 1.

In Table 1, factor *A* and *B* are controllable but factor *C* and *D* are uncontrollable. However, according to the prior testing, when the volume is 4 °C %, the temperature is not easy to be detected. Therefore, only factor *C* is viewed as noise factors. The experimental structure generated by orthogonal array $L_8(2^7)$ with an outer orthogonal array $L_4(2^3)$ is illustrated in Table 2. The experimental results are shown in the Table 2.

3.3 Cup Sleeve Optimization

The signal-to-noise ratio (S/N ratio) is an effective way to find significant parameters by evaluating minimum variance. A higher S/N ratio means better

Table 1 Experimental levels of design factors

Factor	Description	Levels of factor			
		1	2	3	4
A	Specification of thermal label	30 °C	40 °C	50 °C	60 °C
B	Location of thermal label	Upper	Bottom		
C	Size of coffee cup	Large	Small		
D	Volume	80 %	40 %		

Table 2 Experimental structure and corresponding results

No.	Inner orthogonal array A (123)	B 4	5	6	7	Outer orthogonal array C: 1 1 1	2 2 1	2 1 2	1 2 2	S/N ratio	Mean
						Observations					
1	1	1	1	1	1	36	36	37	34	30.32	35.75
2	1	2	2	2	2	35	33	46	34	16.97	37.0
3	2	1	1	2	2	56	54	54	54	35.98	54.5
4	2	2	2	1	1	56	52	72	56	17.71	59.0
5	3	1	2	1	2	68	67	67	67	43.82	67.25
6	3	2	1	2	1	70	68	82	77	22.47	74.25
7	4	1	2	2	1	87	88	86	82	31.51	85.75
8	4	2	1	1	2	86	85	92[a]	92[a]	28.67	88.75

[a] the value should be higher than 92 and cannot be detected

performance for combinatorial parameters. The type of characteristic in this study is the nominal the better, Eq. (1) is used for calculating S/N ratio.

$$\text{S/N ratio} = 10 \times \log(\bar{y}^2/s^2) \tag{1}$$

The S/N values of all treatments are shown in the last second column. It can be found that, if the thermal label is located in the top of the of cup sleeve, the S/N ratios are higher. Moreover, due to the factor A can be adjusted to approach the target values. This study selects thermal label with specification 35 °C for detecting coffee with 43 °C, and thermal label with specification 55 °C for detecting coffee with 80 °C.

4 Conclusion

This study aims to design a cup sleeve which can remind consumers the temperature state of coffee. Then the consumers can drink coffee when the temperature of coffee is preferred. Thermal labels are adopt for detecting the temperature and Taguchi method is used for optimizing the specification of thermal label and the location the it to be stuck. The design is a result of a project in a course named IDEA. It is developed by college of management and design. All sophomores in the college are divided into about 5 °C groups. The back ground of students of each group has to cover all department of the college. The course aims to **I**ntegrate students with the background of **D**esign, **E**ngineering and **A**dministration to develop a production. Therefore, the main contribution of this study is education rather than research.

Acknowledgments This work was supported, in part, by the National Science Council of Taiwan, Republic of China, under grant NSC-101-2221-E-131-043.

References

Lee HS, O'Mahony M (2002) At what temperatures do consumers like to drink coffee?: mixing method. J Food Sci 67:2774–2777

Ross PJ (1996) Taguchi techniques for quality engineering: loss function, orthogonal experiments, parameter and tolerance design, 2nd edn. McGraw-Hill, New York

Utilizing QFD and TRIZ Techniques to Design a Helmet Combined with the Wireless Camcorder

Shu-Jen Hu, Ling-Huey Su and Jhih-Hao Laio

Abstract The wireless transmission products become more important and popular in recent years because of their high efficiency and convenience. This study hopes to enhance its function and transform the product into a brand new one as well as to increase the added value of the wireless AV product substantially. In this study, a questionnaire designed with Likert scale is used to understand consumer's demand when wearing a construction site helmet which is combined with the wireless camcorder. With the application of quality function deployment (QFD), the key elements of product design can be more consistent with the voices of consumers. Next in the process of design-conducting and problem-solving, some TRIZ methods, such as selecting pairs of improving and worsening parameter, applying the contradiction matrix and 40 innovative principles, are applied to achieve a creative thinking and innovative approach for the product design. At last, the study provides an innovative design for the wireless video/audio transmission construction site helmet, in which the wide-angle lens camcorder is mounted at the front of the site helmet internally and the asymmetric ventilation holes are designed in the exterior part of the helmet. Finally, the Pro/Engineer drawing software is applied to finish the design drawing.

Keywords TRIZ · QFD · Construction site helmet · Wireless A/V transmission

S.-J. Hu (✉) · J.-H. Laio
Department of Industrial Management, Lunghwa University of Science and Technology, 300, Sec. 1, Wanshou Rd, Guishan, Taoyuan county 33306, Taiwan
e-mail: janicehu12@gmail.com

J.-H. Laio
e-mail: tonyha_717@yahoo.com.tw

L.-H. Su
Department of Industrial and Systems Engineering, Chung Yuan Christian University, 200 Chung Pei Rd, Chung Li 32023, Taiwan, Republic of China
e-mail: linghuey@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_40,

1 Introduction

Nowadays, advanced technology makes people pursue more convenient and efficient life as well as increasingly emphasize the importance of wireless transmission equipment and look forward to the real-time, highly efficiency wireless transmission device. However, it is found that the function and convenience of many wireless video/audio transmission products are incomplete and need to be improved. This study hopes to enhance this kind of product's function or even transform the product into a brand new one, furthermore to increase the added value of the wireless AV product substantially.

In this study, by applying the technology of quality functions deployment (abbr. as QFD) and the theory of inventive problem solving (abbreviated as TRIZ), a construction site helmet integrating of wireless transmission system for audio and video recording is designed to be valuable and practical as well as with better appearance. The objectives of this research are listed as follows:

a. Apply QFD onto the products to fit the consumer demand and improve market competitiveness of the products.
b. Apply TRIZ techniques to assist in product innovation and improvement.
c. Design a construction site helmet combined with a wireless Video/Audio transmission device and use Pro Engineering software to create 3D drawings of the designed product, and to make prototypes using a rapid prototype machine.

2 Literature Review

2.1 TRIZ

The TRIZ method was developed by Altshuller (1988), who analyzed over 400,000 patents and found that only 2 % of the patents are truly pioneering inventions, while the rest are only previous known ideas or concept added with some novel way. The invention process of TRIZ is based on the induction from summarization according to the technical information disclosed by the patent documents. Altshuller inferred that creativity can be systematic inducted and derived. TRIZ is a method to solve the problem by analyzing the problem and identifying the contradictions, then adopting different solutions according to their physical contradictions or technical contradictions. During the problem solving process, TRIZ applies some tools, including separation principle, substance-field analysis, 76 standard solutions, and ARIZ. The most famous and practical methods of TRIZ include 39 engineering parameters, a contradiction matrix, and 40 innovative TRIZ principles (Altshuller et al. 1999). TRIZ tools are used to obtain a general solution for lots of TRIZ problems, and that general solution is transformed into a solution applicable to engineering technology (Kim 2005; Li et al. 2007; Hsao 2011). It is vital for manufacturers and service companies to maintain their competitive power by utilizing TRIZ and relevant patents and continuing research and innovation on new products to differentiate themselves from competitors (Hsieh and Chen 2010; Hu et al. 2011a).

2.2 QFD

QFD was developed by Yoji Akao and Shigeru Mizuno who are Japanese quality management masters, and its main function is to ensure that the product design meets customer needs and customer desire. QFD helps transform customer needs (the voice of the customer [VOC]) into engineering characteristics for a product or service. QFD is a quality engineering management technology that involves multi-level interpretation and analysis for customer demand of the product. It transfers customer needs into product design requirements, then transfer to the characteristics of the components, and then the requirements of process design, finally transfer to the production requirements (Cheng 1996). QFD expresses the relationship matrix and assesses their important degree based on customer needs, quality characteristics, and engineering management measures. Quality Function Deployment can help identify the important quality characteristics and engineering management measures that have greatest influence on customer needs, letting the enterprise focus on the right place to ensure a good match between customer needs and real effectiveness. The QFD techniques have been applied to the field of automotive, home appliances, garments, integrated circuits, construction machinery, agricultural machinery and many other industries (Kuan 2004).

The inertia thinking mode, the depth of knowledge of the product design, and development personnel will affect the effectiveness of product innovation and R & D. And TRIZ theory can be used to assist developers in the conceptual design stage, remove psychological inertia of the engineers, and extend the field of knowledge. Systematic method of TRIZ help engineers correctly define the product and provide innovative approaches. In the part of market development, the use of quality function deployment can help businesses convert the voice of the customer to the product specifications. It is able to accurately grasp the market through QFD, which serves as a key point of making innovative products released earlier and increasing market share (Day and Chiang 2011).

You (2011) expected to find the processes of design management for the innovative product by combining QFD with innovative theoretical. In the conventional mold design process, the way of trial and error and intuitional approach is often used, so that a successful design often takes a long period of time and cost much. Product performance often depends on the designer's experience, ability and other factors, led to the design level is difficult to be controlled. Quality Function Deployment is used to convert customer needs into product features and specifications to improve the product design.

3 Methodology

3.1 *Investigating the Voice of Customer*

In this study, Likert-scaled questionnaire is applied to understand the requirement direction of consumers for the site safety helmet with wireless audio and video recording device. This part of the questionnaire is mainly targeting the construction industry practitioners or persons with experience using site helmets. 110 questionnaires were distributed, and 107 were valid. The questionnaire is reliable with Cronbach's Alpha value of 0.802. The results show that consumers consider important features as follows: durability, heat dissipation, overall weight (lighter the better), wearing comfortableness, camcorder screen coverage, videotaping resolution, video recording set location, as well as price.

3.2 *Quality Elements Deployment*

In order to identify factors affect the camcorder site helmet quality characteristics, several experts familiar with the site helmet construction are interviewed to provide the information about quality elements of this kind of site helmet. Then the table of quality elements deployment is completed as in Table 1.

3.3 *Establish the Correlation Matrix of Customer Requirements and Design Requirements*

The quality correlation matrix is established with the quality elements and the customer requirements in product features obtained from questionnaire analysis.

Table 1 Deployment of quality elements

	1st level	2nd level
Quality elements of the construction site helmet with wireless A/V transmitter	Material properties	Materials
		Corrosion resistance
		High temperature resistance
		Strength
	Design properties	Buckle
		Cap size
		Ventilation holes
		Construction
		Color
	Function properties	Wide-angle lens
		Pixels

Customer Requirements \ Design Requirements		Importance	Material properties				Design properties					Function properties				
			Materials	Corrosion resistance	High temperature resistance	Strength	Buckle	Cap size	Ventilation holes	Construction	Color	Wide-angle lens	Pixels			
High durability		5	7	7		9				5	1					
Good heat dissipation		4	5		9				9	7	5					
Lighter weight		3	9					1	1			2				
Wearing comfortable		3					9	9	1	9	1					
Wide camcorder coverage		2										9				
High videotaping resolution		2											9			
Adequate video recording allocation		2								1		7				
Low price		1	9	5	5	5		1	1	1		7	7			
Technical Importance	Absolute		91	40	41	50	27	31	43	83	28	45	25			
	Relative(%)		18	7.9	8.1	9.9	5.4	6.2	8.5	16	5.6	8.9	5			
Importance Ranking			A	B	B	A	C	C	B	A	C	B	C			

Fig. 1 Correlation matrix of customer requirements and design requirements for the site safety helmet

The strength of the correlation between the customer requirements and design requirements is explored in the matrix and given annotation as score 1–10. The higher the correlation, the higher the score, empty part means no correlation. Then it calculates the absolute weight and relative weight of each quality element. The whole matrix is shown in Fig. 1.

Weights of quality characteristics can be divided into three grades of A, B, and C. Wherein A is the percentage of the weighted scores which are greater than 9 %, B is from 7 to 9 %, and C is less than 7 %. In this study the quality features for the A and B grade items are taken into consideration by further using the method of TRIZ technical for contradiction removing and innovation of product improvement. They are in total 7 design elements include materials, corrosion resistance, high temperature resistance, strength, ventilation holes, the construction and wide-angle lens.

3.4 Applying TRIZ Contradiction Matrix and Inventive Principles

Further discussion of the design requirements for the seven quality features received in previous section is as following:

a. Materials: Lighter material should be used as much as possible so that consumers wearing site cap on the head will not feel the burden of heavy load.
b. Corrosion resistance: Site cap may be exposed to moisture or corrosive places, in order to prevent the site cap corrosion as well as prolong its usage life, a corrosion-resistant material is necessary.

Table 2 Summary of engineering parameters and innovation principles of this study

Problem	Improving parameters	Worsening parameters	Innovation principles
Temperature resistance	15: Durability of moving object	34: Ease of repair	10. Preliminary action
Materials	1: Weight of moving object	14: Strength	40. Composite materials
Ventilation holes	12: Shape	14: Strength	10. Preliminary action
	12: Shape	13: Stability of the object	4. Asymmetry
Construction	12: Shape	8: Volume of stationary	7. Nested doll
	12: Shape	11: Stress or pressure	10. Preliminary action
Wide-angle lens	27: Reliability	2: Weight of stationary	3. Local quality
	35: Adaptability or versatility	30: Object-affected harmful	11. Beforehand cushioning

c. High temperature resistance: When use the site cap in the field of no shade, it may cause cracking of the cap due to the strong sunshine, so that the feature of high temperature resistance is important.
d. Strength: People who work in dangerous places need to wear the site cap with high strength to protect their heads, in case some heavy objects falling from above and hit their heads.
e. Ventilation holes: The cap shell completely sealed site cap will let people feel very hot because of no ventilation, so that the site cap is better designed to set many ventilation holes to let heat dissipation.
f. Construction: Create an easy to wear and comfortable site cap.
g. Wide-angle lens: The video recording device is easily damaged, so that it should be allocated in a more secure place of the site cap, but still need to take into account its shooting angle range.

The improving and worsening parameters and their corresponding innovative solution principles are expressed in Table 2. Whereas only one of the practical innovation principles are chosen to solve the present contradiction problems and are indicated in Table 2.

4 Result

The main results of this study are analysis of the product in the following five aspects and make a structure and appearance design for this product (Hu et al. 2011b). The Pro/Engineer drawing software is applied to finish the design drawing as shown in Fig. 2.

a. The site helmet is produced with ABS plastic material because that this material has good strength and is corrosion resistance as well as high temperature resistance.

Fig. 2 Appearance of the designed helmet

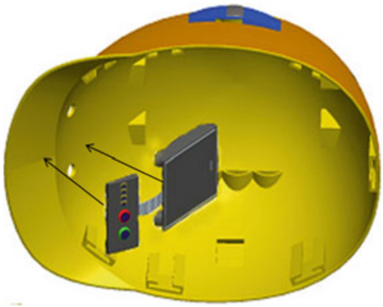


Fig. 3 Internal of the designed helmet

b. The site helmet is designed with many ventilation holes to enhance heat ventilation, while the asymmetric arrangement of the holes may increase the crashworthiness of the site helmet.
c. Design a rope net in the helmet interior, used as a compartment, to allow air circulation and be not hot. Additional sponge is set in the inside of the product to increase the space for heat dissipation, make the product more effectively ventilative with the circulation of the ventilation holes.
d. Cap with double D buckle design, this design can be based on each person's suitability to adjust its tightness.
e. Allocate the camcorder in helmets internal, can reduce collisions and increase service life. The camera is installed on the front of the site cap (as shown in Fig. 3), it will not lead to decline in range of photography shooting space.

5 Conclusion

In the present study, questionnaire survey is conducted to understand the consumer intentions and to identify consumer's expectation of combining the site cap with a wireless video/audio transmission device. Further questionnaire is used to identify consumer expectations and demands for the site cap camcorder, the eight demands with highest weighted score are then taken into QFD analysis. From the correlation matrix of customer needs and quality elements, the technical requirements for the development of the innovative product is obtained.

Next in the process of design-conducting and problem-solving, some TRIZ methods such as improving parameter and worsening parameter selection, application of contradiction matrix and 40 innovative principles are applied to achieve a creative thinking and innovative approach for the product design.

After then, the study provides an innovative design for the combination of wireless video/audio transmission device and a construction site helmet. For the design requirement of good material, corrosion resistance, high temperature resistance, and high strength, ABS material is used in the main part of the helmet. Amount of ventilation holes are added on the helmet to enhance ventilation. In addition, a thin sponge is installed inside served as a cushion to diminish the impact of falling objects. The double-D buckle design allows users to adjust the strap tightness more easily. Finally the wireless audio video AV sender transmitter is installed in the internal front part of the site cap to avoid being hit by heavy falling objects. Finally, the Pro/Engineer drawing software is applied to finish the design drawing of the helmet combined with wireless camcorder.

References

Altshuller G (1988) Creativity as an exact science. Translated by Anthony Williams. Gordon & Breach Science Publishers, New York

Altshuller G, Shulyak L, Rodman S (1999) The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical Innovation Center Inc, Worcester

Cheng CS (1996) Quality management. San Min Book Co., Taipei

Day JD, Chiang WC (2011) The research of the innovative design by QFD theories- on-road bicycle as an example. J Commercial Modernization 6(6):133–150

Hsao YC (2011) TRIZ technology for innovation (Original author: Isak Bukhman). Cubic Creativity Co, Taipei

Hsieh HT, Chen JL (2010) Using TRIZ methods in friction stir welding design. Int J Adv Manuf Technol 46:1085–1102

Hu SJ, Su LH, Lee KL, Chen JC, Chang CH (2011a) Applying TRIZ methodology to assist product improvement—take folding bicycle as an example. Key Eng Mater 450:27–30

Hu SJ, Su LH, Lee KL, Chen JC, Huang AC (2011b) Using TRIZ methods in product design and improvement of a presenter mouse. Key Eng Mater 486:13–16

Kim IC (2005) 40 principles as a problem finder. The TRIZ J, March 4. 2005. http://www.triz-journal.com/archives/2005/03/04.pdf

Kuan SP (2004) SPC continuous improvement simply. Chinese Society for Quality

Li Y, Wang J, Li X, Zhao W (2007) Design creativity in product innovation. Int J Adv Manuf Technol 33(3–4):213–222

You CS (2011) Integration of QFD, TRIZ and Taguchi method to develop disruptive innovation in bicycle sprocket process design, Master Thesis, National Chaughua U of Education. Interactive TRIZ matrix and 40 principles. http://www.triz40.com/

South East Asia Work Measurement Practices Challenges and Case Study

Thong Sze Yee, Zuraidah Mohd Zain and Bhuvenesh Rajamony

Abstract South-East-Asia has been producing wide range of products since decades ago, and hence it is often dubbed as the world's manufacturing-hub. In terms of operation, physical size and capital investment, there are family-owned businesses and Fortune 100 companies' biggest off-shore facilities co-existing. As for its workforce portfolio, the majority used to be of the kind that was non-skilled labor intensive. However, there had been workforce capability substantial upgrading, resulting in the niches and specialties development in automation. Nevertheless, the awareness of work measurement impact on productivity performance remained low. The literature shows that studies on work measurement practices in this region are very limited. It is an absolute waste if there have been tremendous improvements deployed in the machinery, systems, and tools, but they do not function to their maximum capacity because their interaction with the labor is not optimized, and if there is poor work measurement to understand the 'productivity-leak-factor' in the operation. This paper shares the literature on work measurement-related studies that are carried out in this region. It also discusses data collection and preliminary findings of the impact of work measurement method. It is found that much needs to be done to instill the appropriate awareness and understanding of work measurement.

Keywords Work measurement · Industrial engineering · Time study · Labor productivity · South East Asia manufacturing practices · Work sampling

T. S. Yee (✉) · Z. M. Zain · B. Rajamony
Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
e-mail: szeyee2@gmail.com; g1240510789@studentmail.unimap.edu.my

Z. M. Zain
e-mail: zuraidah@unimap.edu.my

B. Rajamony
e-mail: bhuvenesh@unimap.edu.my

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_41,

1 Introduction

Method Study is the systematic recording and critical examination of ways of doing things in order to make improvements. It studies the steps and works for the task, identifies unnecessary/excess/non—optimized movements and eliminates ineffective time as a result of product/process shortcoming.

Work Measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specific task at a defined rate of working. It can also be leveraged to compare the time consumed by different methods, and hence to pick the best methods to set challenging and yet achievable standards.

The combination of Method Study (to analyze, combine, simplify, eliminate unnecessary movement in order to make the job more economically to carry out) and Work Measurement (to evaluate, determine, eliminate ineffective time and set the standard to perform the task) work hand in hand to increase productivity by following a series of systematic steps and repeat the steps over and over again.

1.1 Introduction of Work Measurement Practices in South East Asia Industries

Research in Work Measurement started more than one century ago in the West. Among the famous ones are Frederick Taylor for his scientific management studies in the 19th century, and the Gilbreths' motion study research and development of "therbligs" that are based on the manufacturing environment. Subsequently, the concepts and models are included in university courses in Industrial Engineering (IE) during the pre-war period. Despite the fact that there were many scientific research and publications about work measurement, motion and time study in the next few decades, work measurement remained practices in the West only.

1960s was a period where the goods industry mushroomed after World War II. Over this period, the expansion of manufacturing boomed in SEA with the foreign investment. There were industrial parks established, of which many large-scale Americans' and Europeans' Original Equipment Manufacturer (OEM) set up their off-shore facilities. The entire economy was expanding, fuelled by large-scale labor workforce transformation from agriculture-base to industry-base.

During this time, foreign companies brought in their technical and scientific innovation as well as their production management systems. Work measurement was one of the production systems introduced. Some companies set up Industrial Engineering (IE) departments for work measurement and other basic IE functions. For smaller plants, the planning, production, or engineering departments were usually assigned to handle the work measurement-related functions.

1.2 Current Practices in South East Asia Industries

There had been steady and positive growth in the manufacturing sector in the past five decades in this region. As a result, there had been a substantial upgrading of human resource capability, resulting in the development of a range of niches and specialties, particularly in automation.

Nevertheless, the awareness of work measurement impact on productivity performance remains low. The literature shows that studies on work measurement practices in this region are very limited. It is an absolute waste if there have been tremendous improvements deployed in the machinery, systems and tools, but they do not function to their maximum capacity because their interaction with labor is not optimized. To comprehend further this region's work measurement practices, a survey is carried out. The findings will form part of the research on the impact of work measurement method on manufacturing productivity. The finding will enable South East Asian manufacturing industries to understand the trends and benefits of work measurement in order to set strategic moves in this direction so as to unleash maximum potential in this area.

2 Factors of Work Measurement Practices

According to *Work Measurement in Skilled Labor Environments* and the Industrial Engineering Publication *IE Terminology*, work measurement is "a generic term used to refer to the setting of a time standard by a recognized industrial engineering technique." While this definition may depict a simplistic image of work measurement, the process of determining a time standard in a complex labor setting is far from easy. Thus, the survey enlists all possible influencing factors on the work measurement practice as shown in Fig. 1.

2.1 Influencing Factors for Work Measurement Practices

There are four key influencing factors that contribute to the work measurement profile, and they are practitioner's knowledge, environmental circumstances, work measurement methods, and targets of measurement. For *practitioner's knowledge,* work measurement is about how humans interact with tools, processes, people, technologies and combinations of them. Knowledge learned in the books seldom suffix to cope with work measurement implementation. It has to be stated that a practitioner's skill set for analytical reasoning is critical to the success of the work measurement program. *Environmental* circumstances refer to the type of working environment. A wafer fabrication plant facility versus garment manufacturer impacts the workplace physical setting, work methods, capability, productivity

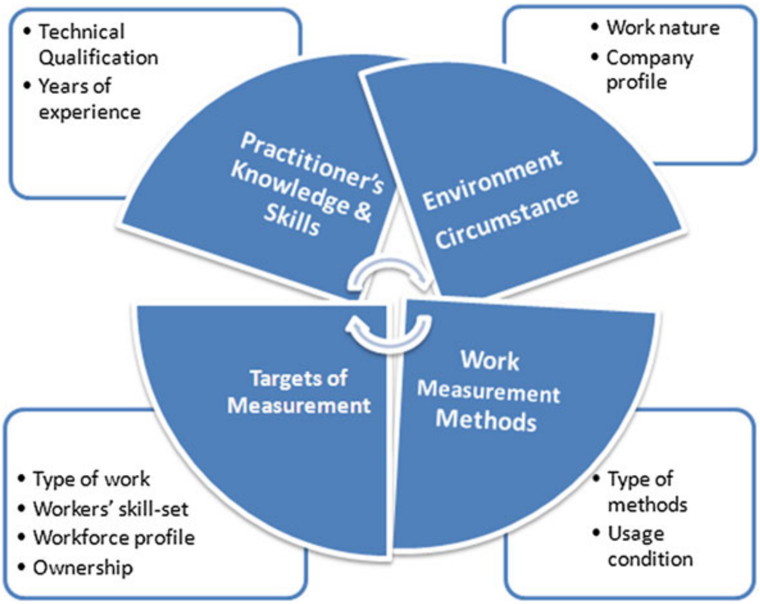


Fig. 1 Influencing factors for work measurement practices

rate setting, and workforce ratio differently, and these must certainly be taken into account. To effectively counter measure the factors, different *work measurement methods* must be applied. The availability and freedom to use a number of alternative methods is equally important. The *targets of measurement* is a set of complex raw data that must be considered in the work measurement process. This makes the analysis complicated and hence these become influencing factors.

2.2 The Approach of Data Collection

Surveys with questionnaires that cover the four influencing factors have been distributed to 400 manufacturers around the SEA countries, namely Indonesia, Malaysia, Singapore, Vietnam, Philippines, Thailand and Cambodia. There was no specific company selection criteria used. This is so as to widen the range of diversity in terms of service and product type. The questionnaires were written in English and designed in an e-survey format and Microsoft Excel for softcopy delivery, whilst hardcopies were delivered through postal service or door- to-door delivery to organizations located within the vicinity of where the study is carried out.

2.3 The Survey Response

The overall survey response rate is approximately 41 % (164/400) from all countries except Cambodia. Despite a good return rate, only 9 % (36 companies) provide complete or usable information. Out of those, 26 companies (6.5 %) report that their organizations have IE departments and confirm practicing work measurement. This percentage seems like a small population. Unfortunately, there is no track record to testify that this figure represents a healthy growth of work measurement practices in this region.

3 Case Study

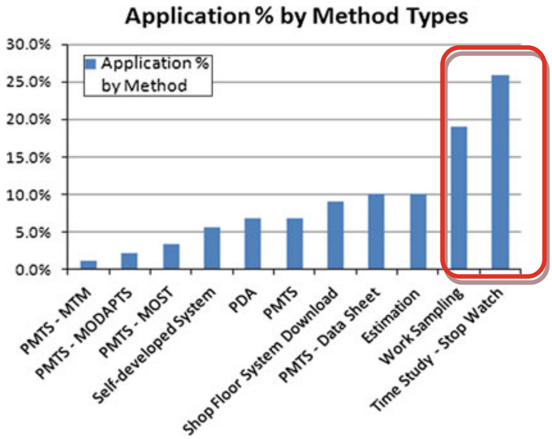
The 36 companies which have completed the survey are categorized to 13 categories of industry sectors (see Table 1). 11 of them which are from the manufacturing sectors, fully or partially practice work measurement whilst the other two non-manufacturing industries from Finance and Research and Development (R&D) totally do not. There are a few different aspects observed between the groups of work measurement versus non-work measurement practice companies.

1. Work Measurement is used mainly in the manufacturing sectors with large headcount pool in workplace. Non manufacturing organizations which have small groups (<200 persons) of dedicated individuals with 100 % specialized skill who work in laboratory and office do not use work measurement.
2. Among the manufacturers, all (100 %) wafer fabrication, garment, and automobile sectors use work measurement systems in a variety of formats.
3. For small manufacturing plants ($\sim$200 workers), one or two types of work measurement systems are used. It is observed that tool types increase proportionally with worker population. Up to five types of work measurement methods are used in bigger plants.

The survey results also lead to the comprehension of how work measurement data is used. For example, despite the fact that approximately 50 % of the companies appoint Industrial Engineers to set the productivity rate (quantity of products produced within a period of time by a person) for their companies, only about 24 % of the companies use IE or work measurement method. Instead, the companies prefer to refer to "past records" and "estimations" as their main or cross reference method. In fact, all the manufacturing companies in this survey use more than one method for work measurement to set productivity rate.

Table 1 Comparison of company profile on work measurement practices

Company's work measurement practices	Environment	Workers' quantity range	Workers' skill set profile
Electronics manufacturer			
Wafer plant			
LED manufacturer			
Box-build assembly plant			
Heavy tooling manufacturer			
Petroleum			
Garment manufacturer			
Chemical production			
Automobile manufacturer			
Medical device manufacturer			
Finance organization			
R&D organization			
Food processing industry			
Legend			
All companies in this category practice work measurement	Manufacturing facilities	1,000 persons and above	50 % or more non skilled work
Some companies in this category do not practice or partially practice work measurement	Special type of work	Mixture of "1–200" and "1,000 and more"	Mixture of skilled and non skilled work
100 % companies in this category do not practice work measurement	Non manufacturing work	1–200 persons	100 % full skill or specialized work skill required



For companies that practice work measurement, time study stopwatch is the most popular work measurement method followed by work sampling. Work measurement practitioners also cast the rating on the most favorable and least preferred methods.

Fig. 2 Types of work measurement methods and percentage of use. *Note* MOST—Maynard Operation Sequence Technique; MODAPTS—Modular Arrangement of Predetermined Time Standards; PMTS—Predetermined motion time system; MTM—Methods Time Measurement

3.1 The Popular Work Measurement Method

The survey shows that work measurement using time study-stopwatch is the most popular method used (Fig. 2). Work measurement practitioners who use other methods (non 'time study—stopwatch') also rate 'time study—stopwatch' as the most preferred method (see Table 2 for details).

3.2 Relationship of Favorable Methods

There is no absolute conclusion drawn to the reason why time study-stopwatch is the favorable method, but the possible contributing factors could be:

- About 40 % of the work measurement practitioners pose Bachelor or Master Degree in IE, whilst 24 % learned work measurement-related subjects through internal company training programs.
- The top three work measurement courses that the practitioners have taken are, in order of popularity, Stopwatch, Work Sampling and PMTS.
- Majority of the companies use Time Study–stopwatch and the practitioners have two to five years of hands on experience using this method. Moreover, they work in small teams of five to ten persons. This is a good learning environment to continuously polish the work measurement skills.

The findings indicate that preference is driven from the users' academic background and the peers' interaction, which provides the technical support.

Table 2 Comparison of preferred work measurement method rated by users

Category of preference	Type of systems	Group of work measurement users who rate this	Remarks
Least preferred	MTM	Time study-stop watch, PTS in general, MOST	
Consider good	Time study—stop watch	Time study-stop watch, PTS in general, MOST, MODAPTS, estimation, PDA, self-developed systems	Stop watch is rated the most popular method among companies that use stop watch, work sampling, PTS, MOST, and all other methods listed
Best method	(1) Time study—stop watch (2) Work sampling	Time study-stop watch, PTS in general, MOST, MODAPTS, estimation, PDA, self-developed systems	Time study—stop watch remains as the popular one in the category of "best method". However, work sampling is also popular followed by that

Table 3 Influencing factors rating of switching work measurement type

Factor(s) and rate of influence level	The most	The least
Company's preference or standard	14	3
Follow majority staff's expertise	0	1
No or lack of certification	0	9
Constraint in budget, time or resources	2	3
Licensing and consultation fees is too high	1	7
Too many changes to manage to switch method	2	1
Others	1	0

3.3 Targets of Measurement

As discussed in Sect. 3.1, most companies use more than one work measurement method as the primary and/or cross reference/supporting function. Among the survey participants, only garment manufacturers are completely satisfied with their current method -GSD (A type of PMTS called General Sewing Data). The survey results also show that it is not easy to switch to other methods. For big corporation, there is usually a company standard that controls/influences the decision. On the other hand, small firms are most concerned about cost and the availability of resources to manage the transition. The least influencing factor is "certification" and this is probably due to the fact that the survey target population is corporate instead of individually-owned, whereby the companies are likely to afford paying for the training and certification (Table 3).

4 Conclusions

The research, at this stage, uncovers some fundamental work measurement facts in this region. It is a reflection of the current phenomenon. Despite the importance of determining productivity from an academic stand point, it is not a common practice among the industries. Even though there are many established work measurement tools available, the preferred and frequently used method narrowed down to the more traditional methods, namely, time study through stopwatch and work sampling, based on the practitioners' technical training, on-the-job experience and existing company practice. Except for the garment industry, which has already found the best fit method, others in the survey are neither satisfied nor unsatisfied with the present method. Switching of work measurement method is highly driven by the company rather than the individual's preference, technical relevance, or needs. There is no conclusion possibly drawn to the selection of method is based on the four key influencing factors as discussed in Sect. 2.1. It is also not conclusive that the presently-used methods contribute effectively to improvise manufacturing productivity in this region.

5 Future Work

The next phase of research will concentrate on the correlation factors of the choice of the labor work/motion study and work measurement methods based on actual practice in the workplace. A comparison between the productivity levels versus the work study methods applications will be carried out based on on-site observations.

Acknowledgments The authors would like to thank the companies which have completed the surveys and acknowledge the helpful comments. Intel Penang, B. Braun Medical Industries, Intel Kulim, Fairchild, B. Braun Vietnam, Agilent Penang, Philips Lumileds Penang, Osram Penang, Faeth Asia Pacific, Plexus Penang, Brady Penang, Smart Modular Technologies (M), Silterra (M), ST Microelectronics Singapore, Flextronics Senai, Talisman (M), Renesas Semiconductor (M), Sugihara Grand Industries, Pen Apparel, Flextronics Prai, Motorola Solutions (M), First Solar (M), Honeywell Aerospace Avionics, Square, Nokia, Hitachi Chemical, Perusahaan Otomobil Nasional, Pouchen Group, Flextronics Singapore, Tri Quint, KCK Garment, AUO Sunpower, Delphi Automotive System, AMD (M), CPF Public Company, Central Almenario de Tarlac and ProPlanner Asia.

References

Time and Motion Study, Wikipedia http://en.wikipedia.org/wiki/Time_and_motion_study

Tom Best, Work Measurement in Skilled Labor Environment. http://www.iienet2.org/uploadedFiles/SHS_Community/Resources/Work%20Measurement%20in%20Skilled%20Labor%20Environments.pdf

Decision Support System: Real-Time Dispatch of Manufacturing Processes

Chung-Wei Kan and An-Pin Chen

Abstract This research has highlighted the role of real-time dispatching (RTD) tools in the development of 300 mm manufacturing machinery systems. Dispatching production and distribution in the real-world 300 mm manufacturing environment is an extremely complex task requiring the consideration of numerous constraints and objectives. Decision support system (DSS) created for this purpose can potentially be used to provide support for related tasks, such as real-time optimization, operational planning, quality certificated, service and maintenance. The DSS comprises the ability to reinforce the RTD system which support both process operator and manager in the decision making process, allowing them to take full-scale of the physical system to implement it in a way where the optimized process control variables are under statistical control, resulting in optimized output that, in turn, secure higher productivity and improved quality.

Keywords Manufacturing systems · Industrial and systems engineering · Decision support system · Real-time dispatching

1 Introduction

In today's highly automated 300 mm fabs, operators would not make or validate scheduling decisions. Instead, real-time dispatching (RTD) system will decide what to do next, where the necessary materials are, and when they will arrive. Nor

C.-W. Kan (✉) · A.-P. Chen
Institute of Information Management, National Chiao Tung University,
1001 University Road, Hsinchu 300, Taiwan, Republic of China
e-mail: russntu@gmail.com

A.-P. Chen
e-mail: apc888888@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_42,

will operators move materials manually; instead, overhead hoist vehicles (OHVs), and rail-guided vehicles (RGVs) will transport materials and products as needed, with little or no human intervention.

This level of manufacturing sophistication can be archived only through the complete integration of other essential systems, such as: automated material handling system (AMHS), material control system (MCS), manufacturing execution system (MES) and real-time dispatching system.

Manufacturing system evaluation, design and selection issues have developed considerably over the part 3–4 decades. On the dispatching side, emphasis has shifted from dispatching conventional manufacturing systems to dispatching automated systems due to uncertainly in product demand and day to day technological developments. The spirit of these attempts is to justify the installation of RTD in phased manner or total.

2 Real Time Dispatching System

The dispatching system was implemented using the Real Time Dispatcher (RTD) application from Brooks Automation Inc. RTD accesses the status of the shop floor via the RTD repository and executes scheduling rules whenever signaled to do so by the MES. RTD performs the following functions:

- Allows detailed criteria to be used for dispatching lots.
- Uses the current state of the RTD repository to dispatch.
- Displays dispatch list in the fab (Gurshaman and Hoa 2001).

The dispatching application requires the detailed routing information for every product, which can be processed in the fab including the list of qualified tools for each operation, and theoretical and planned cycle times for each of the operation.

In addition, the fab produces low volume products. Rules were developed to support the manufacturing philosophy. RTD provides a critical link in the value chain by linking the manufacturing management directives and philosophy directly to the manufacturing floor.

2.1 Dispatching Architecture

It is very critical that the right information is displayed to the right people and that the information can be easily accessed. The dispatch architecture takes into account the information needs of all stakeholders and ensures that the right levels of detail are available to them. The stakeholders included operators of single tools and group of tools, manufacturing supervisors for different processing areas, manufacturing shift coordinators production planners, and fab management. In addition to the list of lots waiting for processing at a given tool, various other views of the ranked list of lots are available within the RTD system to meet the needs of different stakeholders. As an illustration, a ranked list of lots on hold is available by processing areas for the manufacturing supervisors. Another view includes a list of lots which cannot be processed or dispatched due to setup issues. These views facilitate managing the WIP which cannot be currently processed in the fab.

2.2 The Principle of "Real-Time" in Manufacturing

What is the real meaning of "real-time" in the context of manufacturing and operational processes? In a strict sense, real-time refers to application that have a time critical nature. A real-time process must perform a task in a determined length of time. For example, a typical "normal" program may be considered to perform correctly if it behaves as expected and gives the right answer. This means that data must be read and processed before the shaft rotates another revolution, otherwise the sampling rate will be compromised and inaccurate calculation may result.

A real-time program is considered to be correct only if it gives the right answer within a specified deadline. In other words, "real-time" adds a time constraint to the notion of a program being correct. The phrase "real-time" does not directly relate to how fast the program responds, even though many people believe that "real-time" means "real fast". This is a direct fall-out from the fact that it is easier to meet deadlines with a fast system. However, many operating systems now run on powerful hardware and are "fast", but that speed does not necessarily imply "determinism". Determinism is more important than average speed for real-time systems.

The research aims at developing an autonomous decision support system (DSS) for real-time dispatch of manufacturing systems, and this system is planned to be an integral part of the currently executed RTD system at all famous foundry companies, such as Taiwan Semiconductor Manufacturing Company Ltd. (TSMC), Powerchip Semiconductor Corp. (PSC) and others. The principle manifest in the development of the DSS, described in general terms below, and then designed tailored according to the requirements for practical control of the real-time dispatching process.

3 Decision Support System

The concept of a decision support system (DSS) is extremely broad and its definitions vary depending upon the author's point of view (Druzdzel and Flynn 1999). A DSS can take many different forms and the term can be used in many different ways (Alter 1980). On the one hand, Finlay (1994) and others define a DSS broadly as "a computer-based system that aids the process of decision making." In a more precise way, Turban (1995) defines it as "an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights."

Other definitions fill the gap between these two extremes. For Keen and Scott Morton (1978), DSS couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions ("DSS are computer-based support for management decision makers who are dealing with semi-structured problems"). For Sprague and Carlson (1982), DSS are "interactive computer-based systems that help decision makers utilize data and models to solves unstructured problems."

On the other hand, Keen (1980) claims that it is impossible to give a precise definition including all the facets of DSS ("there can be no definition of decision support systems, only of decision support"). Nevertheless, according to Power (1977), the term decision support system remains a useful and inclusive term for many types of information systems that support decision making.

3.1 Design of the DSS

The decision support system (DSS) allows the application sponsors in the design, implementation and use of computerized systems that support business managers in the decision-making process. A DSS is a computer system that typically encompasses mathematical models as well as informational databases and a user interface in order to provide recommended decisions to manager-users. A DSS differs from a traditional information system (IS) or management information system (MIS) in that it not only provides the user with information or database as does an IS or MIS, but it also provides answers to user queries, i.e., decisions, through its modeling component. In essence a DSS is a computer system that helps managers makes decisions.

Users in the DSS option take a variety of specialized utilities in the information technology field that enhances the ability of their current developed computer systems. A completed set of DSS includes information systems, database management, networks and telecommunications, decision support system development and implementation, visual interface design, artificial intelligence, client/server systems, object-oriented programming, the internet, and simulation as well as various mathematical modeling techniques.

3.2 The DSS System Architecture of RTD

Sprague (1982) pointed out that a listing of the characteristic of DSS is more useful than definitions—the main features of DSS include these:

- Aimed at underspecified or less
- Well-structured problems
- Use models and analytic techniques as well as traditional data access and retrieval functions.
- Interactive and user-friendly
- Flexible and adaptive to environmental changes and accommodate the decision-making approach of the user.

Since part of the required system is already in place and some more are either in the process of upgrading or procurement, while the rest still to be designed, the overall design approach manifests in a combination of the above known approaches. Before we start building the DSS, it is essential to understand the detailed data flow, such as where information generated, how it is transferred to the operations managers or fab operators and how it is intended to incorporate the information in the decision making and control of the process. To simplify the operation of the DSS to be designed for the real-time dispatching system, the requirements for first, a real-time dispatch (RTD) system, second, the system approach of the DSS and third, control of the implemented RTD process, are detailed in the individual sections to follow.

3.3 DSS: An Alias for RTD

In the previous two sections, a brief review of the definitions, scopes and introduction of RTD and DSS were presented. Before defining the criteria by which RTD and DSS will be affiliated, a note about the RTD definitions is in order.

The RTD is a client and sever process. Dispatch client request dispatch list from the RTD, a server process on RTD system. At the meanwhile, the DSS should replicate with the same request coming from RTD as a secondary server process. These internal data comes from the RTD's micro-command calculation, the DSS will absorb them as a reference to its data generation. The DSS has to be an ongoing, dynamic system that continuously updates itself. Based on the information contained in the RTD, the solution-result from "what-if" analysis generated from DSS, the operators and operation manager are able to make decisions regarding process performance or improvement.

Both RTD and DSS are ultimately systems, hence making the system approach a suitable one. The basic premise of the system approach is that systems, regardless of their specific context, share a common set of elements, (Churchman 1998). The DSS has to assist the operators in making decisions, based on the real-time data (of the control variable) received from the RTD, while dispatching. It continuously monitors the process by comparing the real-time data with the corresponding benchmark data in the production configuration database, and alarms the operators when any control variable goes beyond the control limits. An additional aspect of the DSS is the inter-functional interaction between MES and RTD of the manufacturing systems.

DSS is an integrated decision support system with focus on the system-wide issues rather than being an individual or cloistered backup tool. It supports manufacturing decision activities by integrating model base with RTD database (Repository) and communication components (Adapter, Writer and Monitor). Originally, DSS was deemed only appropriate for clerical processing, i.e., for tasks that are well structured. However, the DSS proposed in this paper builds upon the industrial project and continue research. All the management levels (operational, tactical, and strategic) are targeted. In DSS, the strategic and tactical management level (top levels) were originally the primary targets, but more recent research suggest and provide evidence that DSS is appropriate at any level.

RTD renders most support in dispatch phase, and to a lesser extent in the intelligent and monitor phase. Exception reports (log files) generated by RTD itself give clues to existing problems thus aiding the intelligence phase. DSS too provides best support for the monitor phase. It is, however, appropriate for problem formulation and problem diagnosis to be collected and analyzed on the same system. Moreover, for DSS with the similar hardware specification towards RTD, it would not only for controlling the optimized process but a concomitant when RTD server is down.

Besides the ordinary RTD coupling to the MES database and MES Application, the DSS is connected hard-wire to the process control factors, i.e., only necessary data being collected for DSS to monitors the current activity and performance levels, anticipates future activity and forecasts the resources needed to provide desired levels of service and productivity. This control component of the real-time dispatch process is indicated by the secondary right block in Fig. 1. The DSS, a sub-system of RTD on the independent server, is clearly shown, indicating the information flow and the relationship MES and RTD.

4 Discussion

Research has indicated the importance of matching IT application or manufacturing systems with the competitive strategy of each company. Justification and implementation of advanced manufacturing technology involved decisions that are crucial for the practitioner regarding the survival of business in the present day uncertainties in the manufacturing world. Since advance systems require huge capital investment and offer large number of intangible benefits such as flexibility, quality, competitiveness, customer satisfaction etc.

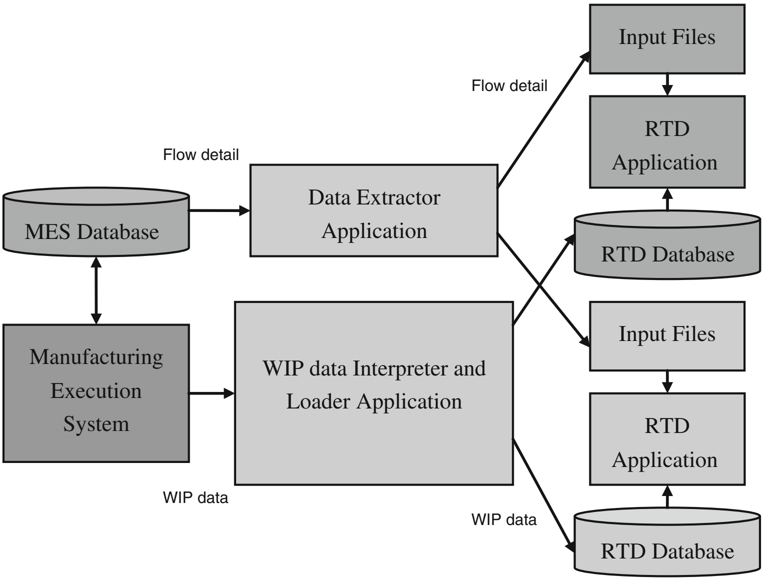


Fig. 1 A decision support system for RTD manufacturing process

In such a manner, this system will facilitate effective decision making in selecting appropriate applications that best match an organization's manufacturing strategy. The DSS may offer the user company the competitive edge it seeks. Furthermore, operators and operation managers can get authentic advice and alarm from the DSS in a timely, cost-effective manner.

5 Conclusions

The long-term goal for the research presented above is to develop a semi-autonomous decision support system. In most cases, decision making is a "man-in-the-loop" activity requiring adequate support. However, the DSS monitors the process control factors and compares the captured data on a real-time basis to against the production configuration database. Probably the most significant advantage of the "real-time" mode of DSS, is that the complex operating instructions and procedures are coded instead of having operators perform activities manually.

This prosperous implementation of the decision support system can be successfully expended to other areas of the manufacturing environment. Though the extended use of DSS, offers a powerful tool for decision support in the runtime phase of manufacturing system, decisions regarding which simulations to run, identification of abnormal conditions and so on, remains a human task. However, though the use of soft computing techniques such as artificial intelligence (AI) and genetic algorithms, these tasks can be supported as well, which will also be addressed in the future works.

References

Alter SL (1980) Decision support systems: current practice and continuing challenges. Addison-Wesley, Reading

Churcham CW (1998) The systems approach. Dell, New York

Druzdzel MJ, Flynn RR (1999) Decision support systems. Encyclopedia of library and information science. A Kent, Marcel Dekker, Inc

Finlay PN (1994) Introducing decision support systems. NCC Blackwell; Blackwell Publishers, Oxford, UK, Cambridge, Mass

Gurshaman SB, Hoa TL (2001) Real-time lot dispatching for semiconductor Fab, future Fab Intl. vol 11

Keen PGW, Scott Morton MS (1978) Decision support systems: an organizational perspective. Addision-Wesley, Reading

Keen PGW (1980) Decision support systems: a research perspective. Decision support systems: issue and challenges. In: Fick G, Sprague RH Pergamon Press, Oxford, New York

Power DJ (1977) What is a DSS? The on- line executive journal for data-intensive decision support 1(3)

Sprague RH (1982) A framework for the development of decision support system. MIS Q 4(4)

Sprague RH, Carlson ED (1982) Building effective decision support systems. Englewood Cliffs, Prentice-Hall

Turban E (1995) Decision support and expert systems: management support systems. Englewoood Cliffs, Prentice Hall. M. Young, The technical writer's handbook. University Science, Mill Valley, CA

The Application of MFCA Analysis in Process Improvement: A Case Study of Plastics Packaging Factory in Thailand

Chompoonoot Kasemset, Suchon Sasiopars and Sugun Suwiphat

Abstract This research aims to apply the Material Flow Cost Accounting (MFCA) for process improvement of the target product, 950 cc. plastic water bottles, a case study company in Thailand. The production line of this product consists of five processes, crushing, mixing, blow molding, printing, and packing. The data collection was carried out for all processes and analyzed based on MFCA procedure. During the process of MFCA, quantity of input and output material, material cost, system cost and energy cost were presented. Then, the cost of positive and negative products can be distinguished based on mass balancing for all processes. The results from MFCA calculation showed that the highest negative product cost occurred at blow molding process. Then, the operations flow at blow molding process was analyzed using motion study and ECRS concept in order to eliminate production defects. Finally, the improvement solution was proposed and the results showed that the defects were reduced 26.07 % from previous negative product cost.

Keywords Material flow cost accounting (MFCA) · Positive product · Negative product · Cost reduction

1 Introduction

The concept of manufacturing process improvement commonly concentrates on lead time reduction, waste or defect decreasing, and others which lead to increase productivity of any production line without interpreting the improvement in term

C. Kasemset (✉) · S. Sasiopars · S. Suwiphat
Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
e-mail: chompook@gmail.com; chompoonoot.kasemset@cmu.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_43,

of cost or monetary terms that is sometimes difficult for management persons to understanding the improvement results.

Material Flow Cost Accounting (MFCA) is developed to help organizations to better understand the effects of environment and finance of their used material and energy, and seek opportunities to gain both environmental and financial improvements.

This research paper aims to present the application of MFCA in manufacturing process improvement of one plastics packaging factory in Thailand.

2 Preliminaries

2.1 Material Flow Cost Accounting

MFCA is one of the environmental management accounting methods aimed to reduce both environmental impacts and costs. MFCA seeks to reduce costs through waste reduction, thereby improving business productivity. The detail of MFCA is addressed in many sources and also published as international standard ISO 14051:2011 as well.

The difference between MFCA and traditional cost accounting was presented in Nakajima (2004). Based on traditional cost accounting, the total production cost is put to products without considering waste production cost (i.e., defective parts, material losses, etc.). Product price is normally set from combination of total cost and profit. As long as companies satisfy with their profit, they will not care about how much of their losses in the production system.

Based on MFCA concept, cost can be classified as; material cost (cost of both direct and indirect material), system cost (cost of operating production system), energy cost (cost of energy used in production system) and waste management cost (cost of waste treatments). From those costs, each cost can be divided as positive and negative costs. Positive or product cost is the cost attached with the output of each process. Negative or material loss cost is the cost of loss from each process. Cost allocation between positive and negative cost is carried out based on the portion from material balancing between input and output materials. Finally, the operations with high negative cost are identified and improved in order to reduce negative cost.

The detail of MFCA implementation steps is explained in “Guide for Material Flow Cost Accounting” by Ministry of Economy, Trade and Industry, Japan (2011). There are seven steps as (1) preparation, (2) data collection and compilation, (3) MFCA calculation, (4) indentifying improvement requirement, (5) formulating improvement plans, (6) implementing Improvement and (7) evaluating improvement effects by re-calculating MFCA.

Many case studies in Japan applied MFCA for improving their production systems. The detail can be found in MFCA case examples 2011 published by Ministry of Economy, Trade and Industry, Japan.

For Thailand, MFCA is not widely known by Thai manufacturers. Some early MFCA applications in SMEs were presented in 2013. Kasemset et al. (2013) applied MFCA to reduced negative material cost in one small textile factory as a case study. Chompu-inwai et al. (2013) proposed to use MFCA to analyze the production of one type of wood product and applied the concept of design of experiment (DOE) to determine optimal parameters for wood cutting process in order to reduce defective wood sheets. Laosiritaworn et al. (2013) applied MFCA to analyze lost-wax casting process and proposed to recycle some material waste in order to reduce the cost of indirect materials. Another advanced study of MFCA was addressed in Chattinnawat (2013) when MFCA was combined with the concept of dynamic programming in order to identify the improvement plan that is economical when considering both cost of improvements and the benefit from increasing positive product cost or reducing negative product cost at the same time.

From those research works of MFCA application, MFCA is the effective tools in identifying the critical point that should be improved in the production system. Moreover, when MFCA is applied, the interpretation of the improvement in term of monetary is attractive and easy to be understood by management peoples as well.

2.2 Motion Study and ECRS

The purpose of motion study is to find the greatest economy of effort with due regard for safety and the human aspect. Through the use of motion study, the job can be broken down into steps, and each step can be analyzed to see if it is being done in the simplest, easiest, and safest possible manner. The improved systems based on motion study employed less number of workers while maintaining the same or extra amount of throughput.

ECRS is one of motion study technique used to improve production lines. E is to eliminate unnecessary work. C is to combine operations. R is to rearrange sequence of operations. Finally, S is to simplify the necessary operations.

Recently, there are many research works adopted ECRS as a tool for operations improvement. Lan (2010) applied ECRS to improve hands operations of electric motor assembly. Miranda (2011) proposed to adopt ECRS in increasing man efficiency of the clean room assembly process that can help in manpower cost reduction for one electronics manufacturer in Philippines. Wajanawichakon and Srimitee (2012) applied ECRS in drinking water production plant to increase the productivity of the case study factory by reducing the cycle time. Sindhuja et al. (2012) also applied ECRS to improve horn assembly line at the bottleneck process to increase the production rate of this assembly line.

Those research works of ECRS show that ECRS is the effective tool for manufacturing cycle time reduction as giving effect on production cost reduction as well.

3 Case Study

One plastics packaging factory in Chiang Mai, Thailand, was selected to be a case study. Main products of this factory are plastics baskets and bottles. To implement MFCA procedure (as the detail in Sect. 2.1), target product and process should be selected at firstly. Then, the data collection can be carried out. The detail of data collection can be addressed as follows.

The 950 cc. plastics bottle is selected to be the target product of this study (shown in Fig. 1). The production process of this product is shown in Table 1.

The data collection was carried out at this product/process. Data collected were all input materials and costs, all machines in this process, operating cost and labor cost and they were used in MFCA calculation.

4 Results

In this section, the results of MFCA implementation to the case study were presented as follows.

Fig. 1 Target product 950 cc. bottle

Table 1 Target process and details

Input	Process	Output
Recycled plastics from defective/ waste products	Plastics Crushing	Recycled plastics granules
New plastics granules and Recycled plastics granules	Mixing	Mixture plastics granules
Mixture plastics granules	Blow Molding	Plastics bottles
Printing Toner	Printing	Plastics bottles with label
Plastics bottles with label and plastics bags	Packing	Pack of plastics bottles

4.1 Material Flow Model

Figure 2 showed the material flow model of the target process. Wastes can be found only at blow molding and printing processes.

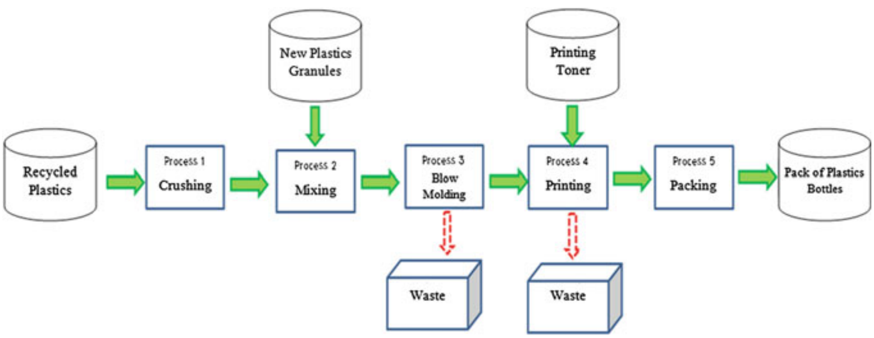


Fig. 2 Material flow model

4.2 Cost Allocation

Cost allocation of all processes is shown in Table 2.

There are only two processes generating wastes, blow molding and printing processes, and the results from cost calculation and allocation showed that blow molding process has the highest negative product cost and the largest portion of negative cost is material cost (shown in Table 3).

4.3 Identifying Improvement Requirement

At blow molding process, there are two types of material waste that are (1) defective bottles (5.54 %) and (2) normal waste from head and bottom cutting method (94.46 %) (shown in Fig. 3a, b).

Normal waste is the major of material waste at this process but the only way to reduce this waste is to invest new machine that need more technical detail in machine specification. Thus, only defective products are studied to find their root-cause using 7-QC tool. Major defective bottle is bottle with out-of-spec thickness that is 52.5 % from all defectives, so the cause-effect diagram is used to find the root cause of this defect (shown in Fig. 4).

The cause from inappropriate working method is basic way to improve, so motion study and ECRS were used to design new working procedure for reducing wastes from inappropriate working method.

Table 2 Cost allocation of all processes (in Thai Baht)

Process	Positive product (%)	Negative product (%)	MC	SC	EC
Crushing	100	0	160,569	4,286	3,823
Mixing	100	0	982,800	5,811.75	3,524
Blow molding	66.03	33.97	895,488	182,598	113,625
Printing	99.82	0.18	540,068	15,224	9,668.99
Packing	100	0	570,717.90	10,040	0

Table 3 Cost allocation of blow molding process (in Thai Baht)

	MC	SC	EC	WC	Total
Positive product	591,318.00	120,576.58	75,031.02	0.00	786,925.60
	49.62 %	10.12 %	6.30 %	0.00 %	66.03 %
Negative product	304,170.00	62,021.42	38,593.98	0.00	404,785.40
	25.52 %	5.20 %	3.24 %	0.00 %	33.97 %
Total	895,488.00	182,598.00	113,625.00	0.00	1,191,711.00
	75.14 %	15.32 %	9.53 %	0.00 %	

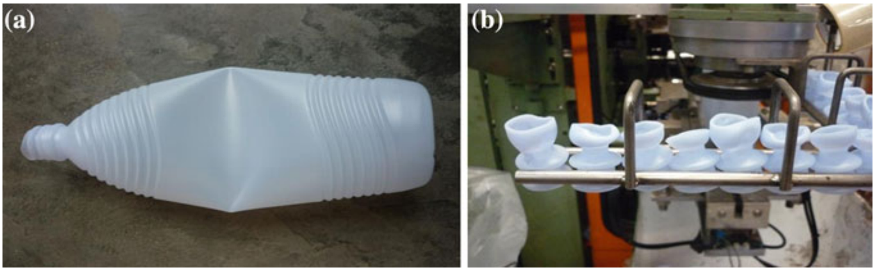


Fig. 3 **a** Defective bottle **b** Normal waste

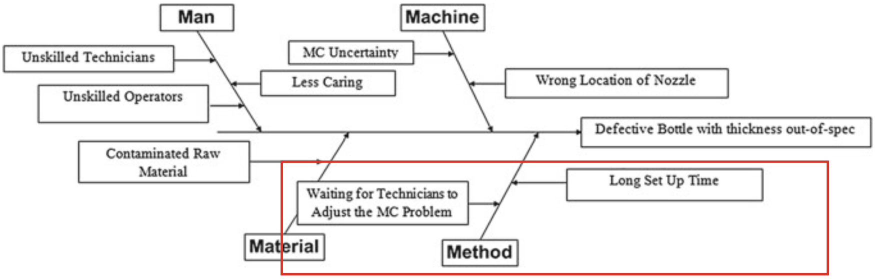


Fig. 4 Cause-effect diagram

Currently, when the operator at this process detects out-of spec product, he/she will walk to maintenance section and ask some technician to correct the problem without stopping machine so if he/she spend more time to find any technician, the more defective is continually produced. The solution procedures are (1) training operators to stop machine by him/herself, (2) introducing fast communication among operators and technician using radio communication devices and (3) reducing set up time by investing new digital weight scales. The first improvement solution is developed based on R as rearranging operations step of work and the second and third methods are developed based on E as eliminating unnecessary movements.

4.4 Evaluating Improvement Effects

After three solutions were implemented, MFCA calculation is carried out again to see how improvement in waste reduction as shown in Table 4.

After the improvement, positive material cost is increased to 49.81 from 49.62 % and negative material cost is reduced to 25.24 from 25.52 %.

Considering weight of material loss from defectives at blow molding process, the weight of material loss is reduced from 469 to 346.74 kg that is 26.07 %.

Table 4 Cost allocation of blow molding process (in Thai Baht) (improved)

	MC	SC	EC	WC	Total
Positive product	591,318.00	121,183.76	75,408.85	0	787,910.60
	49.81 %	10.21 %	6.35 %	0.00 %	66.37 %
Negative product	299,671.62	61,414.24	38,216.15	0.00	399,302.02
	25.24 %	5.17 %	3.22 %	0.00 %	33.63 %
Total	890,989.62	182,598.00	113,625.00	0.00	1,187,212.62
	75.05 %	15.38 %	9.57 %	0.00 %	

5 Conclusion and Discussion

This study aims to present the application of MFCA in process improvement of one plastics packaging factory as a case study. While MFCA was applied, the highest negative cost was identified at blow molding process. From data collection and observation, material loss can be classified as defective products and normal loss. The improvement procedure for work operations is introduced to reduced defective products. The results after improvement are increasing in positive material cost from 49.62 to 49.81 % and negative material cost reducing from 25.52 to 25.24 %. The effect on reducing in material loss weight is 26.07 %.

Although, normal loss from this process is larger portion of blow molding process than defective products, to reduce normal loss, some detail in machine specification and some investment are required. When investment is needed, the return on investment should be considered as well. However, the advantage of MFCA is material loss identification pointing not only defectives but also normal loss as well. Without MFCA application, producers will not care too much on normal loss because they think that it is a behavior of process that cannot be improved.

Acknowledgments The authors gratefully acknowledge support from National Science and Technology Development Agency, Thailand.

References

Chattinnawat W (2013) Identification of improvement for multistage serial processes with respect to material flow cost accounting via dynamic programming. In: EMAN-EU 2013 conference on material flow cost accounting conference proceedings, pp 30–33

Chompu-inwai R, Jaimjit B, Premsuriyanunt P (2013) Gainning competitive advantage in an SME using integration of material flow cost accounting and design of experiments: the case of a wood products manufacturing company in northern Thailand. In: EMAN-EU 2013 conference on material flow cost accounting conference proceedings, pp 141–144

Kasemset C, Chernsupornchai J, Pala-ud W (2013) The application of MFCA in textile factory: a case study. In: EMAN-EU 2013 conference on material flow cost accounting conference proceedings, pp 84–88

Lan S (2010) Optimization of electric motor assembly operation with work study. In: 2010 international conference on logistics systems and intelligent management. doi:10.1109/ICLSIM.2010.5461128

Laosiritaworn W, Kasemset C, Tara C, Poovilai W (2013) Application of material flow cost accounting technique in lost-wax casting process. In: EMAN-EU 2013 conference on material flow cost accounting conference proceedings, pp 80–83

Ministry of Economy, Trade and Industry, Japan (2011) MFCA case examples 2011. Ministry of Economy, Trade and Industry, Japan

Miranda FAA (2011) Application of work sampling and ECRS (Eliminate, Combine, Re-lay out and Simplify) principles of improvement at TO1 assembly. 21st ASEMEP National Technical Symposium. http://www.onsemi.com/ Accessed 24 April 2013

Nakajima M (2004) On the differences between material flow cost accounting and traditional cost accounting—reply to the questions and misunderstandings on material flow cost accounting. Kansai Univ Rev Bus Commerce 6:1–20

Sindhuja D, Mohandas GN, Madhumathi P (2012) Redesigning of horn assembly line using ECRS principles. Int J Eng Innovative Technol 1(3):214–217

Wajanawichakon K, Srimitee C (2012) ECRS's principles for a drinking water production plant. IOSR J Eng 2(5):956–960

Discussion of Water Footprint in Industrial Applications

Chung Chia Chiu, Wei-Jung Shiang and Chiuhsiang Joe Lin

Abstract Economic growth in the past half century brought an unprecedented comfortable life, but also had over-consumed Earth's natural resources. Species extinction and global warming caused by CO_2 emission make us start thinking highly of the surrounding environment. Therefore, the concepts of ecological footprint and carbon footprint have been proposed for assessing the extent of destruction on global environment. In year 2002, Dr. Hoekstra put forward the concept of water footprint for water consumption issues. The main concern is the freshwater used directly and indirectly by consumers or producers, including tracing the three key constituents as blue-, green-, and gray-water. Past studies of the water footprint have gathered a lot of information about agricultural water consumptions, but relatively few were studied for industrial applications. To face the possible shortage of water resources in the future, industries should take a serious attitude to water footprint issues. This study suggests that the water footprint in industrial applications can be used as a basis for improving process water usage, sewage treatment method, water cycle reuse and factories design.

C. C. Chiu (✉) · W.-J. Shiang
Department of Industrial and System Engineering, Chung Yuan Christian University, Chungli, Taiwan, Republic of China
e-mail: ccchiu@iner.gov.tw

W.-J. Shiang
e-mail: Wjs001@cycu.edu.tw

C. C. Chiu
Institute of Nuclear Energy Research, Atomic Energy Council, Executive Yuan, Taoyuan, Taiwan, Republic of China

C. J. Lin
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: cjoelin@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_44,

It will eventually help reach the objectives of saving water, reducing manufacturing costs, complying with international environmental protection requirements, and enhancing the corporate image and visibility.

Keywords Water footprint · Greenhouse effect · Water cycle

1 Introduction

Twentieth century, especially after mid-stage, is the most developed period of human science and technology. In order to boost the economy and improve the living standard, the world is continuously mining the earth's natural resources (for example: biomass, fossil fuels, metal ores and other minerals), and the exploitation has been increased nearly 45 % in the past 25 years (Giljum et al. 2009; Krausmann et al. 2009). These changes have already sacrificed the planet's ecosystems (Haberl 2006; Nelson et al. 2006; Rockstrom et al. 2009). The world population has increased more than 2 times at the end of twentieth century, and the consumption rate of global resources is far beyond Earth's renewed speed (Haberl et al. 2007; Hoekstra 2009). Among all the resources, the greatest impact on human living is due to the requirement for freshwater.

In the past half-century, the demand for freshwater has increased more than four times (Uitto and Schneider 1997). Due to population growth and lifestyle changes, agriculture and some industries also have been increasing the demand for freshwater besides household consumers. Freshwater has quickly become an important global resource, which is resulted from the rapid growing of the global trades on water-intensive products (Hoekstra et al. 2011), as well as a scarce and over-used resource (Bartram 2008; Falkenmark 2008; Vörösmarty et al. 2010). This has caused earthshaking effect upon aquatic ecosystems and livelihood. In recent years, nearly 80 % of the world's population is under a significant threat of water security (Vörösmarty et al. 2010). Climate change and increasing energy-crops consumptions have led to a greater demand for water (Dominguez-Faus et al. 2009; Liu et al. 2008). Regarding the application and management of water resource, in addition to water supply, the measurement of water needs can allocate water resource more effectively. Water footprint was recently promoted as an important indicator for water consumptions (Chapagain and Hoekstra 2004; Hoekstra and Chapagain 2007, 2008). In the past 10 years, quite a few studies about water footprint have been presented, but are mostly related with the water consumptions in agriculture and its relevant products. There lacks research in industrial and operational fields, which leave a new developing opportunity and space for the industrial engineering.

The purpose of this study is to investigate the water footprint for applying in the industrial field. The result of water footprint assessment can be the basis for improvement of operating procedures or a part of the evaluation on new engineering projects. It also can be used to establish international standards. The promotion and implementation of water footprint should have a positive meaning, and can be a supplement to the assessment on product supply chain as well.

2 The Concept of Water Footprint

The idea of considering water use along supply chains has gained interest after the introduction of the 'water footprints' concept by Hoekstra in 2002 (Hoekstra 2003). The water footprint thus offers a better and wider perspective on how a consumer or producer relates to the use of freshwater systems. It is a volumetric measure of water consumption and pollution. Water footprint accounts give spatiotemporally explicit information regarding how water is appropriated for various human purposes. The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint can be regarded as a comprehensive indicator of freshwater resources appropriation, next to the traditional and restricted measure of water withdrawal (Hoekstra et al. 2011). The WF consists of three components: blue, green and grey water footprint (Fig. 1).

- Blue water footprint: The blue water footprint is an indicator of consumptive use of so-called blue water, in other words, fresh surface or groundwater.
- Green water footprint: The green water footprint is an indicator of the human use of so-called green water. Green water refers to the precipitation on land that

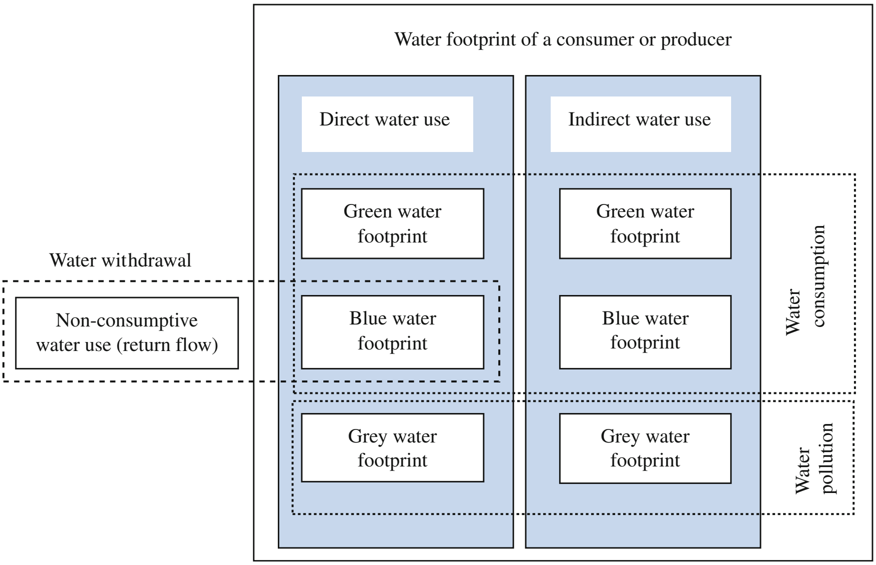


Fig. 1 Schematic representation of the components of a water footprint. (Hoekstra et al. 2011)

does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation.
- Grey water footprint: The grey water footprint of a process step is an indicator of the degree of freshwater pollution that can be associated with the process step. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards.

One can assess the water footprint of different entities, so it is most important to start specifying in which water footprint one is interested. One can be interested, for instance, in the:

- Water footprint of a process step.
- Water footprint of a product.
- Water footprint of a consumer.
- Water footprint a geographically delineated area.
- National water footprint accounting.
- Water footprint of catchments and river basin.
- Water footprint accounting for municipalities, provinces or other administrative units.
- Water footprint of a business.

3 Paper Survey of Water Footprint

This study has surveyed 61 water footprint related journal papers published in Water Footprint Network (WFN) and Science Direct Onsite (SDOS) during year 2005 to January 2013. The research fields and amounts are shown in Table 1.

Nearly 30 % of these papers were related to researches on water footprint in agriculture and its products, including plants such as: coffee and tea (Chapagain and Hoekstra 2007), cotton (Chapagain et al. 2006), tomato (Page et al. 2012), sweet carbonated drinks (Ercin et al. 2011), rice (Chapagain and Hoekstra 2011), sugar cane and cassava (Kongboon and Sampattagul 2012), spaghetti and pizza (Aldaya and Hoekstra 2010), paste and M&M's peanut (Ridoutt and Pfister 2010). For adapting to the development of renewable energy, quite attention has been paid to biomass such as the water footprint information of bioethanol (Winnie and Hoekstra 2012, Chiu and Wu 2012), and water footprint research for sweetener and bio-ethanol (Leenes and Hoekstra 2012). Almost all these papers investigated water footprint consumed for growing bio-crops, like corn, sugar cane and beet in different regions. These researches' field and methodology are the same as that for agricultural products, but different in final uses. There are 13.1 % of the total journal papers which are in the fields of water resource management and application; five of them are related to management. Studies on water resource applications have been started in recent 2 years. Investigations of virtual water flow direction are commonly seen in water footprint research, and actually involved in

Table 1 Research fields and amount of the journal papers related to water footprint

Research field	Numbers presented	Percentage	Main content
Management and utilization	8	13.1	Management and utilization of water resource
Virtual water	7	11.5	Virtual water flow of international trade
(*Water footprint assessment*)			
Agriculture and its products	18	29.5	Water footprint assessment for animals, crops and their products
Biomass crops	9	14.8	Water footprint assessment for bio-ethanol or bio-diesel crops
Energy carriers	3	4.9	Water footprint assessment for primary energy carrier, hydropower and microalgae
Industries applications	3	4.9	Applications of water footprint assessment results including: sweet carbonated drinks, paper, industries
Assessment technology	7	11.5	Development of water footprint assessment technologies: LCA, remote sensing, space coordinates
Others	6	9.8	Various water footprint assessments such as: footprint family, water conservation policy, national water footprint, water footprint for livelihood consumption, river water footprint

many agriculture water footprint studies mostly before year 2010. It is worth notice that literature on water footprint in relevant applications has been presented since year 2011. Although only three essays were surveyed in this study, it should be thought as a beginning of this kind of research anyhow.

From current literature, but most researches only emphasized the import and export flow directions of virtual water of agriculture or agricultural food products. The trade-off of water resource applications between agriculture and industry based on comparative advantage has not been studied. This study considers such a lack shall be filled with industrial engineering concept and technique.

4 Application and Development of Water Footprint

Mekonnen and Hoekstra (2012) thought water footprint assessment shall be an item for evaluating new and existing equipments. This suggestion is a very good footnote for water footprint application. In the past, industry development stressed how to make the best and the most products in the shortest time and how much resources were consumed or wasted during manufacture was not an important issue. After entering the 21st century, people paid more attention to earth's environmental and resources problems. How to reduce the harm to environment and conserve resources have become a new subject and a new aspect to strive for. Water footprint assessment can identify the hot-spot of water consumptions, and the corresponding improvement can be carried out on that hot-spot then. For example, Ercin et al. (2011) chose raw materials based on water footprint in the study of sweet carbonated drinks. Other researches such as: understanding the applications of water resource through computer games (Hoekstra 2012) and blue water footprint of hydroelectricity (Mekonnen and Hoekstra 2012) all utilized the results of water footprint assessment as the basis for improving existing facilities and building new facilities.

Although applications of water footprint in industries have been quietly implemented in the industrial circles, but not many papers related to industrial applications were presented in the academia. This may result in the lack of supply-chain products information for industrial promotion, because most industries use only blue water and grey water. Moreover, all the water consumption data can be acquired from production line except that of the products provided by supply-chain; this makes the calculation of water footprint easier than that for agriculture. Water is an important factor for the growth of agricultural crops. It needs irrigation (blue water) to satisfy the demand for crop growth in water shortage (green water) area, and will then inevitably increase the stress of water shortage. Though fertilization could increase crop's yield, it also consumes more grey water. All these are conflicts among agricultural water uses. The biggest difference from that of agriculture is the industrial water consumption hot-spots can be improved by many physical measures such as: changing the process and operating procedures, change of water-use habit, decreasing the concentration and amount of wastewater, water-cycle reuse and steam-recovery reuse so as to accomplish the purpose of reducing products' water footprint. These measures can achieve greater effects on lowering production cost and environmental protection compliance if they were implemented during design stage.

5 Conclusions

Freshwater resource has become an important global resource as well as a scarce and over-used resource due to world population growth and change of life style, and the resulted increase of water demand. Hoekstra proposed a water footprint concept of using actual water consumption instead of water taken in year 2002 and thus has raised a new wave of research in the field of water resource management application. But most of the abundant research literatures were focused on the water consumptions during agricultural crops growth and the extended virtual water trade flow amounts. This study collected the journal papers about water footprint in recent 8 years, 30 % of which were assessment or discussion on the water footprint of agriculture and relevant products, a total of more than 5 C % were related to agriculture. This shows water footprint in industrial applications is severely neglected.

Industries provide various kinds of products required for human living, large quantity of freshwater is consumed and different wastewaters are generated during manufacturing process. If we could adequately apply physical measures of industrial engineering discipline such as: changing the process and operating procedures, change of water-use habit, decreasing the concentration and amount of wastewater, water-cycle reuse and steam-recovery reuse so as to accomplish the purpose of reducing products' water footprint. The direct benefit is to lower production cost, reduce freshwater consumption and decrease the competing pressure with domestic water. The indirect benefit is to be in compliance with international environment protection requirement and promote enterprise's image and reputation.

The contribution of this study is to sort a direction for the research of water footprint in industrial applications and provide a clear target for follow-up researchers. Meanwhile through the establishment of water footprint information for various products, so that industries could choose materials accordingly and achieve the goal of efficient use of water resource.

References

Aldaya MM, Hoekstra AY (2010) The water needed for Italians to eat pasta and pizza. Agric Syst 103:351–360

Bartram J (2008) Improving on haves and have-nots. Nature 452(7185):283–284

Chapagain AK, Hoekstra AY (2011) The blue, green and grey water footprint of rice from production and consumption perspectives. Ecol Econ 70:749–758

Chapagain AK, Hoekstra AY (2004) Water footprints of nations. Research report series no. 16, UNESCO-IHE, Netherlands

Chapagain AK, Hoekstra AY (2007) The water footprint of coffee and tea consumption in the Netherlands. Ecol Econ 64(1):109–118

Chapagain AK, Hoekstra AY, Savenije HHG, Gautam R (2006) The water footprint of cotton consumption: an assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Ecol Econ 60(1):186–203

Chiu YW, Wu M (2012) Assessing county-level water footprints of different cellulosic-biofuel feedstock pathways. Environ Sci Technol 46:9155–9162

Dominguez-Faus R, Powers SE, Burken JG, Alvarez PJ (2009) The water footprint of biofuels: a drink or drive issue? Environ Sci Technol 43(9):3005–3010

Ercin EA, Aldaya MM, Hoekstra AY (2011) Corporate water footprint accounting and impact assessment: The case of the water footprint of a sugar-containing carbonated beverage. Water Resour Manage 25:721–741. doi:10.1007/s11269-010-9723-8

Falkenmark M (2008) Water and sustainability: a reappraisal. Environment. http://www.environmentmagazine.org/Archives/Back%20Issues/March-April%202008/Falkenmark-full.html. Accessed 30 Mar 2013

Giljum S, Hinterberger F, Bruckner M, Burger E, Fruhmann J, Lutter S, Pirgmaier E, Polzin C, Waxwender H, Kernegger L, Warhurst M (2009) Overconsumption? Our use of the world's natural resources. Seri, Global 2000, Friends of the Earth Europe

Haberl H (2006) The global socioeconomic energetic metabolism as a sustainability problem. Energy 31:87–99

Haberl H, Erb KH, Krausmann F, Gaube V, Bondeau A, Plutzar C, Gingrich S, Lucht W, Fischer-Kowalski M (2007) Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proc Nat Acad Sci 104:12942–12947

Hoekstra AY (ed) (2003) Virtual Water trade. In: Proceedings of the international expert meeting on virtual water trade. Delft, The Netherlands, 12–13 December 2002, Value of water research report series no. 12, UNESCO-IHE, Delft, The Netherlands. www.waterfootprint.org/Reports/Report12.pdf. Accessed 10 Oct 2010

Hoekstra AY (2009) Human appropriation of natural capital: a comparison of ecological footprint and water footprint analysis. Ecol Econ 68:1963–1974

Hoekstra AY, Chapagain AK (2008) Globalization of water: sharing the planet's freshwater resources. Blackwell Publishing, Oxford

Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen MM (2011) The water footprint assessment manual. Earthscan, Washingtong

Hoekstra AY (2012) Computer-supported games and role plays in teaching water Management. Hydrol Earth Syst Sci 16:2985–2994. doi:10.5194/hess-16-2985-2012

Kongboon R, Sampattagul S (2012) The water footprint of sugarcane and cassava in northern Thailand. Procedia—Soc Behav Sci 40:451–460

Krausmann F, Gingrich S, Eisenmenger N, Erb KH, Haberl H, Fischer-Kowalski M (2009) Growth in global materials use GDP and population during the 20th century. Ecol Econ 68(10):2696–2705

Leenes WG, Hoekstra AY (2012) The water footprint of sweeteners and bio-ethanol. Environ Int 40:202–211

Liu JG, Yang H, Savenije HHG (2008) China's move to higher-meat diet hits water security. Nature 454(7203):397

Mekonnen MM, Hoekstra AY (2012) The blue water footprint of electricity from hydropower. Hydrol Earth Syst Sci 16:179–187. doi:10.5194/hess-16-179-2012

Nelson GC, Bennett E, Berhe AA, Cassman K, DeFries R, Dietz T, Dobermann A, Dobson A, Janetos A, Levy M, Marco D, Nakicenovic N, O'Neill B, Norgaard R, Petschel-Held G, Ojima D, Pingali P, Watson R, Zurek M (2006) Anthropogenic drivers of ecosystem change: an overview. Ecol Soc 11(2):29. http://www.ecologyandsociety.org/vol11/iss2/art29/. Accessed 10 Oct 2010

Page G, Ridoutt B, Bellotti B (2012) Carbon and water footprint tradeoffs in fresh tomato production. J Cleaner Prod 32:219–226

Ridoutt BG, Pfister S (2010) A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob Environ Change 20:113–120

Rockstrom R, Steffen W, Noone K, Persson A, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sorlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley JA (2009) A safe operating space for humanity. Nature 461:472–475

Uitto JI, Schneider J (1997) Fresh resources in Arid Lands. United Nations University Press, Tokyo

Vörösmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Reidy Liermann C, Davies PM (2010) Global threats to human water security and river biodiversity. Nature 467(7315):555–561

Winnie GL, Hoekstra AY (2012) The water footprint of sweeteners and bio-ethanol. Environ Int 40:202–211

Mitigating Uncertainty Risks Through Inventory Management: A Case Study for an Automobile Company

Amy Chen, H. M. Wee, Chih-Ying Hsieh and Paul Wee

Abstract In recent years, global environment has changed dramatically due to unpredictable operational risks, disruption risks, natural and man-made disasters, global financial and European debt crisis. This greatly increases the complexity of the automotive supply chain. In this paper we investigate the inventory policy of the aftermarket parts for an automotive company. The key findings and insights from this study are: (1) to mitigate the risk of disruptive supply chain, enterprises need to reduce the monthly supplies of high priced products, (2) to improve profit, cash flow and fill rate, the use of A, B and C inventory management system is critical, (3) the case study provides managerial insights for other industries to develop an efficient inventory management system in a competitive and uncertain environment.

Keywords Supply chain risk management · ABC inventory management system · Fill rate · Sensitivity analysis · Uncertainty

A. Chen (✉) · H. M. Wee · P. Wee
Department of Industrial and System Engineering, Chung Yuan Christian University, Chung-Li, Taiwan, Republic of China
e-mail: chenamy999@gmail.com

H. M. Wee
e-mail: weehm@cycu.edu.tw

P. Wee
e-mail: pwee@ford.com

C.-Y. Hsieh
Department of Business, Vanung University, Chung-Li, Taiwan, Republic of China
e-mail: cishieh@vnu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_45,

1 Introduction

In an elaborate automobile network, aftermarket part is a major if not the biggest contributor to a company's profits. In the aftermarket part business, custom satisfaction is critical; and a quick response to customers' needs have become a basic requirements. Therefore, a good fill rate is crucial for a company to maintain a reasonable profit and cash flow. In order for a company to maintain an efficient fill rate, inventory management is critical.

In recent years, crisis that result in supply chain disruption are prevalent, for example the Japanese earthquake in March 2011, the Turkey earthquake in October 2011 and the Thailand floods in May 2012, these uncertain events have made the inventory control of aftermarket parts more complicated than production. Since aftermarket parts do not have a controllable volume and timing schedule, to quickly response to the unpredictable risks and maintain customer satisfaction, we need to identify an optimal inventory and fill rate with an automobile company as an example.

The aftermarket parts of the automotive company under study are managed by the PANDA system (Parts and Accessory logistic system). PANDA is an integrated system of aftermarket parts to run the complete parts operation. The system supports critical aspects of the aftermarket parts supply chain process including parts' ordering, demand forecast, delivering, storage and inventory management, the PANDA system is not only parts supply flow but also accounting flow to link dealers, service part's center and part's sources. Figure 1 shows an automotive network and Table 1 provides the definition of the ABC aftermarket parts' inventory system.

2 Literature Review

2.1 Supply Chain Risk Management

Wee et al. (2009) identified the supply chain risks in the automotive and electronic industries in Brazil and highlighted the urgency of the supply chain risk management (SCRM) and implementation. Sabio et al. (2010) presented an efficient decomposition method in order to expedite the solution of the underlying multi-objective model by exploiting its specification. They illustrated the capabilities of the proposed model framework and solution strategy through the application of a real case study in Spain. Blome and Schoenherr (2011) used in-depth case studies conducted among eight European enterprises and highlighted their approach to risk management and how they are related to Enterprise Risk Management.

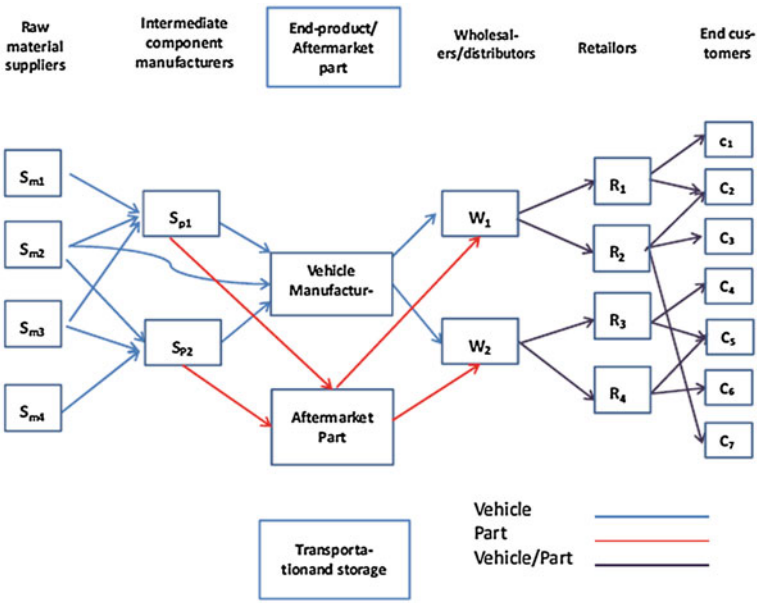


Fig. 1 The network of automobile industry

Table 1 The definition of ABCD inventory system

Categories	Annual sales forecast	Dealer demand
A Type	Sales forecast > 20 pieces	Average 1 piece per month
B Type	$3.3 \leq$ Sales forecast ≤ 20	Average 1 piece per 3 month
C Type	$0 <$ Sales forecast < 3.3	Average 1 piece more than 3 month
D Type	Sales forecast $= 0$	• No demand • Obsolete parts—no order in over 2 years • New parts—last order within 2 years

2.2 Inventory Management

Schmitt (2011) modeled a multi-echelon system and evaluate multiple strategies for protecting customer service, also demonstrated that the greatest service level improvements can be made by providing both proactive inventory placement to cover short disruptions or the start of long disruptions, and reactive back-up methods to help the supply chain recover after long disruptions. Gupta et al. (2000) utilizes the framework of mid-term, multisite supply chain planning under demand uncertainty to safeguard against inventory depletion at the production sites and excessive shortage using a change constraint programming approach in conjunction with a two-stage stochastic programming methodology. Yu (2011) compared artificial-intelligence (AI)-based classification techniques with traditional multiple discriminant analysis (MDA), support vector machines (SVMs), backpropagation networks (BPNs), and the k-nearest neighbor (k-NN) algorithm and suggested that ERP systems can be used to implement AI-based classification techniques with multiple criteria in ABC analysis. The use of these techniques will improve the effectiveness and efficiency of inventory management.

2.3 Fill Rate

Silver et al. (2011) presented a news derivation of the fill rate and (R, S) system under normally distributed demand. A commonly used approximate method for selecting the value of the safety factor can lead to an appropriate service level. Axsater (2006) provided an alternative approximation technique for determining the order quantities for (R, Q) policy under a fill rate constraint and normal lead-time demand.

3 Model Development and Analyze

3.1 Data Source and Definition

The purpose of this model is to analyze inventory, monthly supply, inventory turnover and fill-rate of the aftermarket parts by Sensitivity Analysis so as to improve cash flow and profit. Aftermarket parts are sourced mainly from European and US markets, some parts are sourced from Taiwan and other Asian suppliers. This automotive company holds an average aftermarket part inventory of $340 million to support about $2,958.5 million in annual sales with a fill-rate of 92.8 %.
Fill-rate:

The first pick availability rate at the warehouse to meet dealer orders; including stock orders and urgent orders. That is critical for customer's satisfaction.

Monthly supply:

Inventory turnover: Cost of sales divided by Inventory amount.
Profit per part item is $500.
Fill-rate change of 1 % is around 13,500 items.
Carrying cost is 20 % of inventory.

Inventory ABC categories are defined in Table 1. This study combines both C and D inventory types into C inventory category.

3.2 Model

3.2.1 Tool: Excel Solver—Simple Linear Programs

3.2.2 Modeling

Propose: Using an Excel Solver to identify the optimal inventory level to drive the best practice in the after sales service parts business including cash flow, profit and customer' satisfaction.

Step 1 Define variances

Known variances (F): F_{ij}—fill-rates for each inventory categories by sources, i inventory category, j supply source

Unknown variances (S): S_{ij}—each inventory categories, i inventory category, j supplier source

Step 2 Functional target—an optimal solution to get reasonable inventory combination for a higher fill-rate Maximum of

$$\sum_{i \geq 1}^{n} (F_{ij} \times S_{ij}) / \sum_{i \geq 1}^{n} S_{ij}$$

Step 3 Constraint

Each source has a lead-time constraint considering the logistics of shipment. Therefore monthly supplies from each source are different.

$$M_{ij} > \; = 0$$

3.3 Data Analysis

3.3.1 Sensitivity Analysis Report

From the Sensitivity Analysis report generated from the Excel Solver, we found 4 top shadow prices; $S_{A\text{-}LC}$ (82.6), $S_{A\text{-}JA}$ (22.8), $S_{A\text{-}EU}$ (14) then $S_{B\text{-}LC}$ (8.4). If we plan to improve the service level in the short term, an increase in the monthly supply of $S_{A\text{-}LC}$ (82.6) is necessary. The impact of fill-rate includes customer satisfaction, cash flow, profit and visible cash improvement. The improvements include $S_{A\text{-}JA}$ (22.8), $S_{A\text{-}EU}$ (14) then $S_{B\text{-}LC}$ (8.4) where uncertain environment and limited resources are present. The details are shown in Table 2.

Table 2 Simulation report

Cell	Name	Final value	Reduced cost	Objezctive coefficient	Allowable increase	Allowable decrease	Minumun	Name	Maximun
Adjustable cells									
B8	A EU	57.1	0.0	0.98	1E + 30	0.98	0.00	A EU	1E + 30
C8	A JA	58.1	0.0	0.98	1E + 30	0.98	0.00	A JA	1E + 30
D8	A US	25.9	0.0	0.98	1E + 30	0.98	0.00	A US	1E + 30
E8	A LC	126.4	0.0	0.98	1E + 30	0.98	0.00	A LC	1E + 30
B9	B EU	10.7	0.0	0.85	1E + 30	0.85	0.00	B EU	1E + 30
C9	B JA	11.6	0.0	0.85	1E + 30	0.85	0.00	B JA	1E + 30
D9	B US	4.9	0.0	0.85	1E + 30	0.85	0.00	B US	1E + 30
E9	B LC	9.9	0.0	0.85	1E + 30	0.85	0.00	B LC	1E + 30
B10	C EU	9.9	0.0	0.60	1E + 30	0.60	0.00	C EU	1E + 30
C10	C JA	16.1	0.0	0.60	1E + 30	0.60	0.00	C JA	1E + 30
D10	C US	4.5	0.0	0.60	1E + 30	0.60	0.00	C US	1E + 30
E10	C LC	5.0	0.0	0.75	1E + 30	0.75	0.00	C LC	1E + 30
Cell	Name	Final value	Shadow price	Constraint R. H. side	Allowable increase	Allowable decrease	Minumun	Name	Maximun
Constraints									
B15	A EU	4.0	14.0	4.0	1E + 30	4.0	0.00	A EU	1E + 30
C15	A JA	2.5	22.8	2.5	1E + 30	2.5	0.00	A JA	1E + 30
D15	A US	4.0	6.4	4.0	1E + 30	4.0	0.00	A US	1E + 30
E15	A LC	1.5	82.6	1.5	1E + 30	1.5	0.00	A LC	1E + 30
B16	B EU	3.0	3.0	3.0	1E + 30	3.0	0.00	B EU	1E + 30
C16	B JA	2.0	4.9	2.0	1E + 30	2.0	0.00	B JA	1E + 30
D16	B US	3.0	1.4	3.0	1E + 30	3.0	0.00	B US	1E + 30
E16	B LC	1.0	8.4	1.0	1E + 30	1.0	0.00	B LC	1E + 30
B17	C EU	5.0	1.2	5.0	1E + 30	5.0	0.00	C EU	1E + 30
C17	C JA	5.0	1.9	5.0	1E + 30	5.0	0.00	C JA	1E + 30
D17	C US	5.0	0.5	5.0	1E + 30	5.0	0.00	C US	1E + 30
E17	C LC	1.0	3.7	1.0	1E + 30	1.0	0.00	C LC	1E + 30

3.3.2 From the Simulation Reports Below, a Summary is Listed

Figure 2, we can find the sensitivity for 0.1 month-supply interval for A/B/C inventory categories.

Category A, the profit impact is getting better as monthly supply is decreasing, also cash flow is improved significantly resulted from lower inventory levels, but the fill- rate becomes worse. That is because Category A is fast moving parts, month-supply change impacts fill-rate, profit, cash flow and fill-rate a lot.

Category B and C's profit and inventory impact are not significantly due to slow moving parts. Also the fill-rate of category B and C worsen as monthly supply is increased.

This study examines two cases, Case A to reduce 1 month supply for category A, B and C, Case B to increase 1 month supply for category A, B and C. The

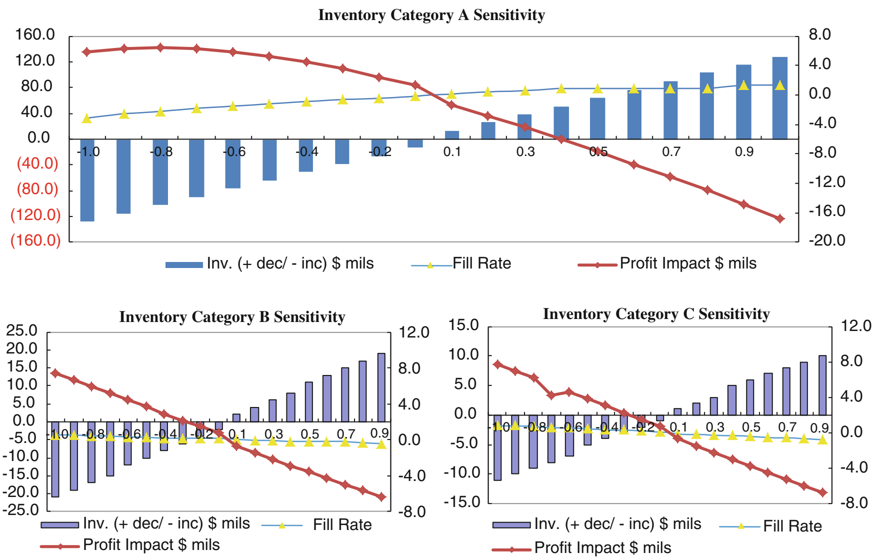


Fig. 2 Sensitivity analysis report

results are shown in Table 3: Case A has a higher profit impact with approximately $24.69 million but lower fill rate at 91.7 %; which means we will lose some loyal customers in the long term. Case B achieves a higher fill-rate 93.3 %, but the profit impact is the worst because it keeps the highest inventory levels. Therefore, we need to consider the optimal solution of monthly supply for category A, B and C pondering fill-rate and profit impact. Other cases are considered after simulation.

3.3.3 More Cases are Simulated Here

- Case C (Table 3)

  A category: 0.5 month decrease
  B category: 1 month decrease
  C category: 1 month decrease
  Fill-rate of 93.3 %, profit impact of $22.37 million at $244 inventory level
- Case D (Table 3)

  A category: no change
  B category: 1 month decrease
  C category: 1 month decrease
  Fill-rate of 94.3 %, and a profit impact of $15.67 million at $308 inventory level

Although Case C's profit impact is $22.37 million; $6.7 million higher than Case D, its fill-rate is 1 point lower than that of Case D. Other than profits; a

Table 3 The summary of 4 cases

Monthly adjustment	Case A A(−1) B(−1) C(−1)	Case B A(+1) B(+1) C(+1)	Case C A(−0.5) B(−1) C(−1)	Case D A(−1) B(−1) C(−1)
Inventory $ million	180	500	244	308
Month supply	1.1	3.1	1.5	1.9
Inventory turn	10.69	3.84	7.88	6.24
Fill rate (%)	91.7	93.3	93.3	94.3
Compared with original level				
Inventory (+dec/−inc) $ million	−160	160	−96	−32
Month supply	−1.0	1.0	−0.6	−0.2
Inventory turn	4.99	−1.86	2.18	0.54
Fill rate (%)	−1.1	0.5	0.5	1.5
Profit Impact ($ million)	24.69	−29.41	22.37	15.67

company should consider customer satisfaction (higher fill-rate) and cash flow (inventory level) to maintain a high profit.

4 Conclusion and Contribution

In this study, we optimize the ABC inventory management system to mitigate the risks of supply chain disruption. The case example provides the proposed enterprise with a strategy to improve profit, cash flow and fill-rate during the times of uncertainty and global financial economic pressures. Key findings in this study provide useful insights to enterprises:

1. To manage and control inventory, enterprises need to reduce the monthly supplies of high priced products as priority, the impact on the fill-rate (customer satisfaction) and profit can quickly be observed.
2. To improve profit, cash flow and fill rate, inventory management using A, B and C system is very critical for uncertain environment with limited resources.
3. The model developed in this study is user friendly and can be applied to other enterprises. It provides instantaneous fill-rate and inventory monitoring for senior management.

Finally, the case study provides managerial insights for other industries to develop an efficient and effective inventory management system in a competitive and uncertain environment.

References

Axsater S (2006) A simple procedure for determining order quantities under a fill rate constraint and normally distributed lead-time demand. Eur J Oper Res 174:480–491

Blome C, Schoenherr T (2011) Supply chain risk management in financial crises-A multiple case-study approach. Int J Prod Econ 10:1016

Gupta A, Maranas CD, McDonald CM (2000) Mid-term supply chain planning under demand uncertainty: customer demand satisfaction and inventory management. Computers and Chemical Engineering 24:2613–2621

Sabio N, Gadalla M, Guillen-Gosalbez G, Jimenezl L (2010) Strategic planning with risk control of hydrogen supply chains for vehicle use under uncertainty in operating costs: a case study of Spain. Int J Hydrogen Energy 35:6836–6852

Schmitt AJ (2011) Strategies for customer service level protection under multi-echelon supply chain disruption risk. Transp Res Part B 45:1266–1283

Silver EA, Bischak DP (2011) The exact fill rate in a periodic review base stock system under normally distributed demand. Omega 39:346–349

Wee HM, Blos MF, Quaddus M, Watanabe K (2009) Supply chain risk management (SCRM): a case study on the automotive and electronic industries in Brazil. Supply Chain Manage: Int J 14(4):247–252

Yu M-C (2011) Multi-criteria ABC analysis using artificial-intelligence-based classification techniques. Expert Syst Appl 38:3416–3421

Service Quality for the YouBike System in Taipei

Jung-Wei Chang, Xin-Yi Jiang, Xiu-Ru Chen, Chia-Chen Lin and Shih-Che Lo

Abstract In this study, we focused on the service quality for the public bicycle system, YouBike System, in Taipei, and used the station setting at the National Taiwan University of Science and Technology (NTUST) for the case study. YouBike System refers to the "rent-it-here, leave-it-there" bike sharing service provided by the Taipei City Government. We adopted the service quality models developed by Parasuraman, Zeithaml and Berry in 1970s to conduct the research. In the first stage before launching the station at the NTUST, a pre-using questionnaire was designed and distributed to the students at the NTUST to collect the opinions and their expectations about the YouBike System. Then, an after-using questionnaire was designed and distributed to the students at the NTUST to investigate whether the service quality of the YouBike System meet their expectations and what is the service level provided by the YouBike system. The after-using survey was conducted after one month of launching the station at the NTUST. The results analyzed from both sets of surveys would provide valuable information for the Taipei City Government to continuing improves their public transportation policy.

Keywords Service quality · Likert scale · Bike sharing service · Bike sharing network · Service science

1 Introduction

Due to the trend of saving power to protect environment and riding bicycles for citizens' health, big cities over the world established their public bicycle systems for many years. In addition to reducing traffic congestion during peak hours, riding

J.-W. Chang · X.-Y. Jiang · X.-R. Chen · C.-C. Lin · S.-C. Lo (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, No. 43, Keelung Road, Taipei 106, Taiwan, Republic of China
e-mail: sclo@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_46,

Table 1 Ten cities having bicycle sharing systems

Country	City	System	No. stations	No. bikes
Belgium	Brussels	Villo!	1,800	2,500
Canada	Montreal	Bixi	405	5,050
China	Hangzhou	Hangzou public bicycle	2,700	66,500
Denmark	Copenhagen	Bycylken	125	1,300
France	Lyon	Vélo'v	340	4,000
France	Paris	Vélib	1,450	20,600
Netherlands	Amsterdam	OV-fiets	240	6,000
South Korea	Changwon	NUBIJA	235	3,300
Spanish	Barcelona	BICING	420	6,000
UK	London	Barclays cycle hire	507	8,000

bicycles for commuters can also reduce gas emissions from vehicles (Frederick et al. 1959). Moreover, establishing public bicycle system has become a prosperous target to know the internationalism, the freedom, and the respect of environmental issue for big cities around the world (Brandt and Scharioth 1998).

Table 1 summarized 10 cities providing public bicycle sharing systems that are currently active. All systems listed in Table 1 allow users to pick up and drop off bicycles at any of the kiosk stations within the bicycle networks.

Taiwan is famous for manufacturing bicycles. Brand names, such as Giant Bicycles and Merida Bikes, are the companies making public bikes and the Taipei City Government is optimistic to the development of the public bike system in Taipei City and the vicinity. With the cooperation between enterprises and government officials, the YouBike system in Taipei had been established since 2009. For more than 7 years, Taipei City Government is in charge of supervising the engineering process, network expansion, and operations management of the YouBike. Moreover, the contractor is responsible for setting up, operation and maintenance of the YouBike. They hope that the YouBike can not only reducing the air pollution level and heavy traffic situation in Taipei City, but also providing a convenient travel method for the citizens and tourists (Huang 2010). There are twelve administrative districts in the Taipei City. In each district, the YouBike begins with setting stations near MRT stations, bus stops, markets, and residential area because of the stream of people. There are seventy stations in the Taipei City now and there will be 160 stations total at the end of this year.

In order to know users' considerations about service quality of the YouBike system in Taipei City, we adopted the service quality models developed by Parasuraman, Zeithaml and Berry in 1970s to conduct the research (Parasurman et al. 1984, 1985) in this paper. In the first stage before launching the station at the NTUST, a pre-using questionnaire was designed and distributed to the students at the NTUST to collect the opinions and their expectations about the YouBike System. Then, an after-using questionnaire was designed and distributed to the students at the NTUST to investigate whether the service quality of the YouBike System meet their expectations and what is the service level provided by the YouBike system (Noriaki et al. 1984).

The remainder of the paper is organized as follows. Section 2 is the design of both questionnaires and initial analysis of the data collection quality. Section 3 presents the experimental results and findings from the questionnaires. Section 4 offers conclusions, following the references in the final section.

2 Research Methodology

A before-using the YouBike system questionnaire was designed and a total of 868 questionnaires were collected to research expectations from students with/without using the YouBike service in NTUST before the kiosk station setting at the NTUST launched. Then the after-using questionnaire was designed and conducted to collect opinions from 162 students who have experience using the YouBike service at the NTUST station.

2.1 Reliability

Reliability is a way to test if a method is reliable by showing consistency and stability in the result. We use Cronbach α in five-point Likert scale to identify reliability of our questionnaire (Carman 1990). Cronbach's α is ranged between zero and one to represent its consistency. Generally, Cronbach's α falls at least larger than 0.5 and smaller than or equal to 0.7. If Cronbach's α larger than 0.7, it represents that the results from the questionnaire is very reliable. Table 2 summarized Cronbach's α values for both sets of questionnaires for the reliability analysis. The calculation of Cronbach's α is shown in the following equation.

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum S_t^2}{S_H^2}\right), \tag{1}$$

where S_t^2 is the deviation of every question and S_H^2 is the deviation of total questionnaire.

Table 2 Cronbach α from questionnaires

Questions	α (before-using)	α (after-using)
1 I am glad to see that the YouBike station setting at the NTUST	0.9031	0.8022
2 It is appropriate to set the YouBike station at the NTUST	0.9015	0.7842
3 I want to use the YouBike at the NTUST	0.8927	0.7757
4 It is convenient to set the YouBike kiosk station at the NTUST	0.8918	0.7775
5 It is helpful to set the YouBike station at the NTUST	0.8912	0.7671
6 If the YouBike is set at my destination, I will go there by the YouBike	0.9272	0.8695

Table 3 Cronbach α in users' opinions from Kano's model

Questions		α
1	Renting a well-functioned bike	0.8783
2	There is an available parking place to return the bike	0.8840
3	Instructions from the kiosk machine are in detail and clear	0.8776
4	If the kiosk machine can inform you the condition at every YouBike station	0.8720
5	When your easy card is locked with unknown reasons, the kiosk machine can teach you how to solve the problem	0.8776
6	You can rent a bike for free within 30 min	0.8810
7	You can apply the association member by both kiosk machine and on Internet	0.8849
8	The kiosk can inform you that your easy card has insufficient money	0.8794
9	The sensor can inform you when easy card touch the sensor	0.8759
10	If staff can arrive within 10 min when the YouBike station ran out of bikes or parking place	0.8792
11	You can return a bike by the kiosk machine when the station is full loaded	0.8970
12	You can get 1 h more for free when the parking space is full loaded	0.8856
13	You can get a transfer discount after using the YouBike service	0.8808

As shown in Table 2, α values from before-using questionnaire are around 0.9 and α values from after-using questionnaire are around 0.8. All values are bigger than 0.7 which confirmed that the data collected for our analysis is reliable.

Table 3 shows α values of after-using questionnaire designed from Kano model are around 0.88, which also confirmed that the data collected for our analysis is reliable.

2.2 *Questionnaire Design*

The before-using questionnaire was designed and focused on the users' expectation about the soon-to-be-launched YouBike station at NTUST. There are two sections in our questionnaire: (1) user information and (2) user's expectation about the YouBike service. Some of the questions in the first questionnaire are specially designed in order to compare the results from the second questionnaire. Next, the after-using questionnaire was designed and focused on the users' satisfaction and the service quality of the YouBike service. There are three sections in the second questionnaire: (1) user information, (2) users' satisfaction, and (3) users' opinion about the YouBike service provided by the YouBike station at NTUST. We integrated the Kano's model (Matzler and Hinterhuber 1998; Chang 2011) to design the second questionnaire in order to acquire more information for students after using the YouBike station at NTUST. Since we aim at the students having the YouBike service experience, so number of samples from the second questionnaire that we collected is smaller than number of samples from the first questionnaire. We analyzed the before-using results and after-using results to analysis if the

Table 4 Two-dimensional quality key elements

Service Requirements		Dysfunctional form of questions				
		I like it that way	It must be that way	I am neutral	I can live without it that way	I dislike it that way
Functional form of the questions	I like it that way	Q	A	A	A	O
	It must be that way	R	I	I	I	M
	I am neutral	R	I	I	I	M
	I can live without it that way	R	I	I	I	M
	I dislike it that way	R	R	R	R	Q

establishment of the YouBike station at NTUST fits in with students' expectations and the factors that they pay more attention to the YouBike service. A Two-dimensional quality key elements and quality improvement index (Kano 1984) were also used to calculate level of satisfaction and level of dissatisfaction from users, as shown in the following equations, where A: Attractive, O: One-dimensional, M: Must-be, I: Indifferent, R: Reverse, and Q: Questionable (Table 4).

$$\text{Satisfaction increment index} = (A + O)/(A + O + M + I). \quad (2)$$

$$\text{Dissatisfaction decrement index} = (O + M)/(A + O + M + I).$$

3 The Experimental Results

Table 5 shows the comparison results of before-using questionnaire and after-using questionnaire, where 5: very agree, 4: agree, 3: no comments, 2: disagree, and 1: very disagree.

Table 6 shows the before-using questionnaire results related to users' expectations before launching the new station of the YouBike service at NTUST with ranking these conditions. The first priority column means users believed that statements should be pay more attention, and the least priority means users usually do not pay more attention to these statements.

The results show that before launching new station at NTUST, up to 30% students pay much attention to "canceling 30 min free rental policy," and the second place in the first priority column is "no bike to be rent when you need a bike." Moreover, the first place in second priority column falls in "no place to

Table 5 The results of before-using questionnaire and after-using questionnaire

Questions	Before-using (first)					After-using (second)				
	5	4	3	2	1	5	4	3	2	1
1. Glad to see the YouBike station at NTUST	0.72	0.25	0.03	0	0	0.84	0.15	0	0.01	0
2. It is appropriate to set the YouBike station at NTUST	0.69	0.25	0.05	0.01	0	0.80	0.19	0.01	0	0
3. I want to use the YouBike at NTUST	0.65	0.23	0.11	0.01	0	0.83	0.16	0.01	0	0
4. It is convenient to have the station at NTUST	0.64	0.24	0.11	0.01	0	0.79	0.17	0.03	0.01	0
5. It is helpful to have the station at NTUST	0.57	0.25	0.15	0.02	0.01	0.76	0.19	0.04	0.01	0
6. If my destination has YouBike service, I will go there by the YouBike	0.33	0.26	0.32	0.08	0.01	0.54	0	0.17	0.04	0

Table 6 The before-using questionnaire results with users' expectations

Situations	First priority	Second priority	Least priority
No bike to rent when I need	0.21	0.19	0.08
No place to park bike at the station when returning	0.18	0.30	0.03
The YouBike station occupies more space of sidewalk	0.05	0.06	0.39
Renting a fault bike	0.09	0.13	0.06
Inconvenient to inform staff of the YouBike service	0.05	0.12	0.08
The kiosk machine cannot help you to solve your problem	0.09	0.13	0.07
30 min free rental policy cancelled	0.33	0.07	0.29

park a bike when returning," and the second place in second priority column is "no bike to be rent when you need a bike." Therefore, "canceling 30 min free rental policy," "no bike to be rent when you need a bike" and "no place to park a bike when returning" are the most important factors for students at NTUST. Also, there are approximately 40 % students do not care that the YouBike station occupies more space of sidewalk in the surrounding area. However, there are approximately 30 % of students do not care about "canceling 30 min free rental policy."

Table 7 summarizes the service quality analysis about users' considerations by the Kano's model. Moreover, the level of satisfaction and level of dissatisfaction analysis from the Kano model is shown in the following Table 8.

Table 7 The service quality analysis from users' considerations by Kano's model

Questions	Quality key elements (%)				Kano's model
	(A)	(O)	(M)	(I)	
1. Renting a well-functioned bike	20.3	48.4	17.6	13.7	O
2. There is an available parking place to return the bike	14.8	47.2	27.5	10.6	O
3. Instructions from the kiosk machine are in detail and clear	21.1	30.3	21.8	26.8	O
4. If the kiosk machine can inform you the condition at every YouBike station	26.1	37.3	15.5	21.1	O
5. When your easy card is locked with unknown reasons, the kiosk machine can teach you how to solve the problem	13.4	42.3	27.5	16.9	O
6. You can rent a bike for free within 30 min	31.3	54.2	8.3	6.2	O
7. You can apply the association member by both kiosk machine and on Internet	34.3	24.5	7.7	33.6	**A**
8. The kiosk can inform you that your easy card has insufficient money	20.6	29.8	18.4	31.2	**I**
9. The sensor can inform you when easy card touch the sensor	20.8	36.8	20.1	22.2	O
10. If staff can arrive within 10 min when the YouBike station ran out of bikes or parking place	29.9	43.8	12.5	13.9	O
11. You can return a bike by the kiosk machine when the station is full loaded	30.8	50	11.9	8.4	O
12. You can get 1 h more for free when the parking space is full loaded	32.8	43.1	13.1	10.9	O
13. You can get a transfer discount after using the YouBike service	45.8	37.5	6.9	9.7	**A**

Table 8 The level of satisfaction and level of dissatisfaction

	1	2	3	4	5	6	7
Satisfaction increment	0.68	0.62	0.51	0.63	0.56	0.85	0.59
Dissatisfaction decrement	−0.66	−0.75	−0.52	−0.53	−0.7	−0.63	−0.32
	8	9	10	11	12	13	
Satisfaction increment	0.50	0.58	0.74	0.8	0.76	0.83	
Dissatisfaction decrement	−0.48	−0.57	−0.56	−0.61	−0.56	−0.44	

4 Conclusions

After using the new YouBike station at NTUST, the satisfaction level from students increased with the YouBike system in Taipei City. Among 13 service criteria that we investigated, 10 of the service criteria fall in one-dimensional requirements, leading to the conclusions that these services remain in steady service quality. Users' satisfaction level about these services is easy to achieve and easy to increase.

From the analysis and results of quality improvement index, “canceling 30 min free rental policy,” “no bike to be rent when you need a bike” and “no place to park a bike when returning” are the most important factors for students at NTUST. Both Taipei City Government and contractor of the YouBike system should consider providing hardware and software improvement plans to continue upgrade service level for users to provide the world class bicycle sharing system to the commuters and visitors in the Taipei City.

Acknowledgments The authors thank the Department of Transportation, Taipei City Government, for providing useful information about the YouBike System in Taipei, Taiwan.

References

Brandt DR, Scharioth J (1998) Attribute life cycle analysis. Alternatives to the Kanomethod in 51. ESOMAR-Congress, pp 413–429

Carman JM (1990) Consumer perceptions of service quality: an assessment of the SERVQUAL dimensions. J Retail 66(1):33–55

Chang YC (2011) The enhancement of customers’ satisfaction for security industries using Kano and PZB Models: using P Company in Taiwan as an example. National Cheng Kung University, Dissertation

Frederick H, Mausner B, Snyderman BB (1959) The motivation to work, 2nd edn. Wiley, New York

Huang HJ (2010) The relationship among riding characteristics, service convenience and riding satisfaction of public bicycle—the case study of Taipei City YouBike. Dissertation, Chaoyang University of Technology

Kano N (1984) Attractive quality and must-be quality. Hinshitsu (Quality) 14(2):147–156

Matzler K, Hinterhuber HH (1998) How to make product development projects more successful by integrating Kano’s model of customer satisfaction into quality function deployment. Technovation 18(1):25–38

Noriaki K, Seraku N, Takahashi F, Tsuji S (1984) Attractive quality and must-be quality. J Jpn Soc Qual Control 14(2):39–48

Parasurman A, Zeithaml VA, Berry LL (1984) A conceptual model of service quality and its implications for future research. J Mark 49:41–50

Parasurman A, Zeithaml VA, Berry LL (1985) Problems and strategies in services marketing. J Mark 49:33–40

Replenishment Strategies for the YouBike System in Taipei

Chia-Chen Lin, Xiu-Ru Chen, Jung-Wei Chang, Xin-Yi Jiang and Shih-Che Lo

Abstract In this study, we focused on the bike replenishment strategies for the public bicycle system, YouBike System, in Taipei. YouBike System refers to the "rent-it-here, leave-it-there" bike sharing service provided by the Taipei City Government. Recently, the bicycle system has become popular and has been used by over one million riders. During the rush hours, when people go on or off duty, there would be: (1) no bicycle for renting at the particular rental stations; or (2) no space to park bicycles at the rental stations near schools or MRT stations. These problems can be troublesome to many users/members of the YouBike System. In order to mimic the YouBike System in Taipei, we used computer simulation software to simulate the movement of the bicycles from one bicycle station to other bicycle station. As a result, our goal is to build an on-line monitoring system to provide real-time usage of the bikes and parking space of all YouBike stations. Feasible solutions and optimal strategies were proposed in this study to move bicycles between bicycle rental stations to balance: (1) number of bicycles in the rental station; and (2) number of available parking space for the bicycles in the bicycle rental station.

Keywords Inventory replenishment · Simulation · Bike sharing service · Bike sharing network · Service science

1 Introduction

As the conscience of environmental protection rises, many people ride bicycles for a short travel distance instead of other transportation modes such as private cars or motorcycles. In response to this trend, the Department of Transportation, Taipei

C.-C. Lin · X.-R. Chen · J.-W. Chang · X.-Y. Jiang · S.-C. Lo (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, No. 43, Keelung Road, Taipei 106, Taiwan, Republic of China
e-mail: sclo@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_47,

City Government, has carried out a public bicycle sharing system since 2008 (Chang 2000; Tzeng 2013). With the help from bicycle manufacturing company, Giant Bicycles, eleven bicycle rental stations with 500 bikes were firstly built in Xinyi District in Taipei City. The newly started public bicycle sharing system, the YouBike system, is established and operated by Giant Bicycles. Currently, there are more than 160 stations scattered in Taipei City and its vicinity, and the system has been used by more than one million riders.

The “rent-it-here, leave-it-there” bike sharing service of the YouBike brings much convenience to the citizens in Taipei City. Firstly, the YouBike system is tightly connected with mass rapid transit (MRT) system serving Taipei metropolitan area while the rental stations are often built near the entrance of the MRT stations. Riding the public system from MRT stations to people’s home can greatly save time. Secondly, the well-designed rental stations and colorful vehicles with led lights can not only provide users a safety riding environment but also add energy into the busy city. The reduction of using private vehicles or motorcycles can also keep the air of the city clean and tidy.

However, many problem rises as the system become more and more popular. By asking the expectations from the users, major problems of the YouBike come out inevitably. During rush hours when people go on and off duty, there would be no bicycle for renting or no parking space at several stations, especially those near MRT stations or schools. The feasible solution to improve the YouBike system is a big issue for the Department of Transportation, Taipei City Government. One possible solution is to prepare a set of spare vehicles arranged besides existing rental stations in order to ensure that there would always bikes available to the riders. This method comes from double queue concept from inventory management study (Wang 2006). Another possible solution is that if renters bumped into a full rental station when returning bikes, they would be granted a free 1 h of time to ride to the nearest station which has enough empty parking spaces.

We found out that these problems happened mainly because the people in charge cannot be instantly informed of when and which stations need to add vehicles or to take the superfluous bikes away. Real-time monitoring system can be implemented by current information technology and traditional safety stock polity from inventory management can be applied to solve the situations (Li 1999; Graves and Willems 2003; Thomopoulos 2006; Humair and Willems 2011).

In this paper, we proposed several inventory replenishment strategies to provide a more convenient and feasible solution for solving this complicate problem. However, the problem itself is quite different from traditional inventory management studies since we need to move bikes from near full stations (no parking space available) to almost empty stations (no bike to rent). The inventory property in the problem is not only to control safety stock level, but also to avoid full queue situation. In order to mimic the situation, we used computer simulation software to simulate the movement of the bicycles from one bicycle station to other bicycle station. Moreover, several bikes inventory replenishment strategies were proposed and simulated through the simulation software. The replenishment strategies that we proposed can be implemented into an on-line monitoring system.

Table 1 Ten cities having bicycle sharing systems

Country	City	System	No. stations	No. bikes
Belgium	Brussels	Villo!	1,800	2,500
Canada	Montreal	Bixi	405	5,050
China	Hangzhou	Hangzou public bicycle	2,700	66,500
Denmark	Copenhagen	Bycylken	125	1,300
France	Lyon	Vélo'v	340	4,000
France	Paris	Vélib	1,450	20,600
Netherlands	Amsterdam	OV-fiets	240	6,000
South Korea	Changwon	NUBIJA	235	3,300
Spanish	Barcelona	BICING	420	6,000
UK	London	Barclays cycle hire	507	8,000

Therefore, the goal of our research is to balance the number of bikes and the available parking space for all rental stations in the YouBike network in Taipei City.

The public bicycle systems have been set up for a long time in other countries. It is common to see people riding bicycles through the city. We compared 10 cities known by bicycle sharing systems that are currently active as shown in Table 1. The remainder of the paper is organized as follows. Section 2 is the research methodology for the inventory replenishment strategies. Section 3 presents the experimental results and findings from the simulation software. Section 4 offers conclusions, following the references in the final section.

2 Research Methodology

In the first step of the research, we have to build the basic model to simulate real world YouBike System, and then we can develop several strategies to solve the problems by modifying the basic model with strategies applied. Finally, we compare the strategies from performance index, and propose the optimal solution.

The objective of the study is to find several feasible solutions to deal with the lack or surplus of bikes by simulation software. In order to mimic the operation of the YouBike System into our simulation model, there are four properties in our simulation models: (1) each station has different usage rate due to the location factors; (2) each station has different maximal capacity and different initiative amount of bikes (data obtained from the ratio of the total amount of bikes to the total parking space for every station from on-line website); (3) the travel distance between two stations must be considered and a proper distribution were used; (4) because of the "rent-it-here, leave-it-there" bike sharing service, it is possible for bicycles from all stations to reach each other.

Firstly, the basic model of the YouBike System is built and helps us to discover the bottleneck. We choose the 17 rental stations in Xinyi District in Taipei City to build our basic simulation model because the YouBike system in Xinyi District is the most mature one. For example, the lack of bikes is mostly happened in Citizen Square Station, Songde Station, as well as Wuchang Park Station, and the lack of parking space is mostly happened in MRT Taipei City Hall Station as well as MRT S.Y.S Memorial Hall Station. Secondly, we establish several models of different policy and use the statistical distributions to show the individual performance. In order to balance the quantity of bikes in all stations, we need to allocate the bicycles according to the statistical output data. One of our major concept of building the strategies for building simulation model is to monitor the operation of the YouBike System by a "double-queue" method. That is, prepare a set of bicycles as a second inventory queue and when original queue's inventory level reduce to 0, replenish the bikes to the station immediately.

Moreover, each station has a two-sided queue level to consider: (1) one is how many bikes waiting for the parking space when the parking space is full, and (2) the other condition is how many people currently waiting for bikes to rent. Hence, we use the concept of safety stock for both ends. Therefore, when the parking spaces are filled up over a particular level, the surplus bikes will be moved to other station based on some particular rules, such as moving to the nearest station. Also, if the available bicycles are less than a certain safety level, we will dispatch the appropriate amount of bikes from the other station to the target station.

To build an on-line monitoring system, it is necessary to use computer simulation software. Any Logic is a set of system simulation software providing both coding (by Java) and visual elements. It can be used on dynamic simulation analyzing, discrete simulation analyzing, etc. The users can take advantage of it to build up basic models with several fields.

In this paper, two sets of bicycles inventory replenishment policies were proposed: (1) policies focused on no bike to rent situation and (2) policies focused on no space to park the bikes situation. In order to shorten the length of the paper, all proposed inventory replenishment strategies are listed in Tables 3 and 4.

3 Experiment Results

All simulation models were running 30 days and two performance indexes were used to evaluate the proposed strategies. Table 2 shows the performance of the basic model which served as benchmark for number of average available bikes and number of average lack of parking space from basic model (without any strategy).

Table 2 Benchmark from the basic model

Benchmark (from basic model)
a. number of average available bikes: 75.13
b. number of average lack of parking space: 180.74

Table 3 Policies for no bike to rent situation

The description of the policy	Performance (30-day average)		Improvement from basic model	
	Bike	Space	Bike (%)	Space (%)
1. If the available bikes in one station are less than 20 % of the maximal capacity of the station, one bike is replenished in the order of the supply cycle which is developed according to the usage rate of each station	223.44	12.04	197.40	93.34
2. If the available bikes in one station are less than 10 % of the maximal capacity of the station, one bike is replenished in the order of the supply cycle which is developed according to the usage rate of each station	221.22	14.35	197.40	92.06
3. If the available bikes in one station are less than 20 % of the maximal capacity of the station, 10 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	223.44	12.00	197.40	93.36
4. If the available bikes in one station are less than 10 % of the maximal capacity of the station, 10 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	221.30	14.29	194.56	92.09
5. If the available bikes in one station are less than 20 % of the maximal capacity of the station, 20 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	223.90	11.86	198.00	93.44
6. If the available bikes in one station are less than 10 % of the maximal capacity of the station, 20 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	221.28	14.28	194.52	92.1
7. If the available bikes in one station are less than 20 % of the maximal capacity of the station, to increase the available bikes to 50 % of the station's maximal available bikes, 30 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	223.87	11.90	197.98	93.42
8. If the available bikes in one station are less than 10 % of the maximal capacity of the station, to increase the available bikes to 50 % of the station's maximal available bikes, 40 % of the station's maximal available bikes are replenished in the order of the supply cycle which is developed according to the usage rate of each station	221.27	14.31	194.51	92.08

Table 4 Policies for no space to park the bikes situation

The description of the policy	Performance (30-day average)		Improvement Rate from basic model	
	Bike	Space	Bike (%)	Space (%)
1. If the parking space is 80 % full, one bike is moved to another station which is nearest	86.61	168.06	15.28	7.02
2. If the parking space is 70 % full, one bike is moved to another station which is nearest	170.68	83.97	127.17	53.54
3. If the parking space is 80 % full, one bike is moved to another two stations which are nearest	230.19	18.51	206.38	87.76
4. If the parking space is 70 % full, one bike is moved to another two stations which are nearest	214.66	31.83	185.70	82.40
5. If the parking space is 80 % full, 10 % of the station's maximal parking bikes are moved to another station which is nearest	86.31	168.47	14.88	6.79
6. If the parking space is 70 % full, 10 % of the station's maximal parking bikes are moved to another station which is nearest	83.62	171.06	11.3	5.36
7. If the parking space is 80 % full, 20 % of the station's maximal parking bikes are moved to another station which is nearest	87.01	167.53	15.82	7.31
8. If the parking space is 70 % full, 20 % of the station's maximal parking bikes are moved to another station which is nearest	233.52	64.00	210.82	97.61
9. If the parking space is 80 % full, 20 % of the station's maximal parking bikes are moved respectively to another two stations which are nearest. The moved bikes are in a total of 40 % of the station's maximal parking bikes	227.02	18.10	202.16	89.98
10. If the parking space is 70 % full, 20 % of the station's maximal parking bikes are moved respectively to another two stations which are nearest. The moved bikes are in a total of 40 % of the station's maximal parking bikes	213.33	31.79	183.94	82.41

Tables 3 and 4 show policies focused on no bike to rent situation and policies focused on no space to park the bikes situation, respectively.

The two performance indexes that we used to evaluate the performance from the proposed strategies have different meanings. For "number of average available bikes," the better policy will result in bigger value. However, for "number of average lack of parking space," the better policy will result in smaller value. Therefore, the improvement rates (IR) are defined and calculated by the following Eqs. (1) and (2).

$$IR_{\text{Bike}} = \frac{\overline{\text{available bike(with policy)}} - \overline{\text{available bike(benchmark)}}}{\overline{\text{available bike(benchmark)}}} \times 100\,\%. \tag{1}$$

$$IR_{\text{Space}} = \frac{\overline{\text{available space(with benchmark)}} - \overline{\text{available space(with policy)}}}{\overline{\text{available space(with policy)}}} \times 100\,\%. \tag{2}$$

4 Conclusions

In this study, through balancing the number of available bikes and parking space, our goal is to maximize the efficiency of the public bicycle sharing system, the YouBike system in Taipei. As a result, we use simulation software to build an on-line monitoring system which provides a real-time usage of bikes or the occupation of parking spaces of all rental stations. Moreover, according to this basic monitoring system, we developed several policies to solve the two main problems of the YouBike system: (1) no bike to rent and (2) no space to park the bikes in particular rental stations. Base on the result of simulation, we can obtain better performance from all strategies that we proposed and measure whether the policies could effectively solve the troublesome problems or not. Of all strategies that we proposed, the optimal policy that can increase 210.82 % available bikes and reduce 97.61 % lack of parking space strategy is "if the parking space is 70 % full, 20 % of the station's maximal parking bikes are moved to another station which is nearest." Further experiments can be done by expanding the model to the full size to verify that this strategy can efficiently solve the bicycle inventory replenishment problem.

Acknowledgments The authors thank the Department of Transportation, Taipei City Government, for providing useful information about the YouBike System in Taipei, Taiwan.

References

Chang L-C (2000) Design and management of urban bike sharing systems. Dissertation, National Cheng Kung University

Graves SC, Willems SP (2003) Optimizing strategic safety stock placement in supply chains. Manuf Serv Oper Manag 5:176–177

Humair S, Willems SP (2011) Optimizing Strategic Safety Stock Placement in General Acyclic Networks. Oper Res 59:781–787

Li J-R (1999) The study of optimal stock strategy under changeable lead time. Dissertation, National Taiwan University of Science and Technology

Thomopoulos NT (2006) Safety stock comparison with availability and service level. Paper presented at the international applied business research conference in Cancun, Mexico, 20–24 Mar 2006

Tzeng W-C (2013) Pricing of urban public bicycle-sharing system—Taipei YouBike, a case study. Dissertation, Tamkang University

Wang J-R (2006) Inventory policy for items with different demand patterns under continuous review. Dissertation, National Taiwan University of Science and Technology

A Tagging Mechanism for Solving the Capacitated Vehicle Routing Problem

Calvin K. Yu and Tsung-Chun Hsu

Abstract The Vehicle Routing Problem (VRP) is one of the difficult problems in combinatorial optimization and has wide applications in all aspects of our lives. In this research, a tag-based mechanism is proposed to prevent the formation of subtours in constructing the routing sequences, while each tour does not exceed the capacity of the vehicles and the total distance travelled is minimized. For each node, two tags are applied, one on each end, and to be assigned with different values. Two nodes can be connected, only if the tag value at one end of a node matches one of the end tag values of another node. The model is formulated as a mixed integer linear programming problem. Some variations of the vehicle routing problems can also be formulated in a similar manner. If the capacity of the vehicles is infinite, i.e., capacity restrictions are removed, the VRP reduces to the multiple Travelling Salesman Problem (mTSP). Computational results indicate that the proposed model is quite efficient for small sized problems.

Keywords Combinatorial optimization · Mixed Integer programming · Tagging mechanism · Traveling salesman problem · Vehicle routing problem

1 Introduction

Traveling Salesman Problem (TSP) is the basic type of Vehicle Routing Problems (VRPs) and is widely used in many industrial applications and academic researches. For example, applications can be found in the studies of production process,

C. K. Yu · T.-C. Hsu
Department of Industrial Engineering and Management, Ming Chi University of Technology, 84 Gungjuan Road, Taishan, New Taipei 24301, Taiwan, Republic of China
e-mail: calvinyu@mail.mcut.edu.tw

T.-C. Hsu
e-mail: darksnowii@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_48,

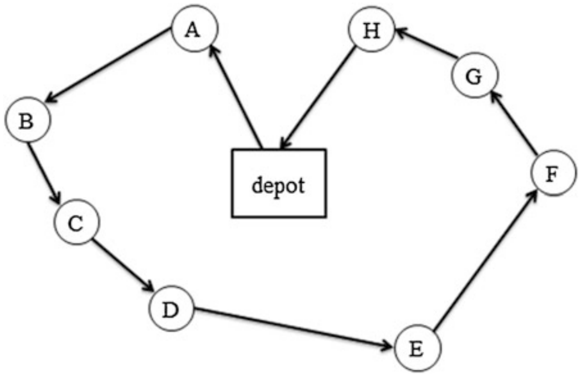


Fig. 1 The traveling salesman problem

transportation scheduling, biological engineering and electronic engineering, etc. Although TSP has proven its importance either in academy or in practice, however, it belongs to a large family of problems classified as NP-complete (Karp 1972).

The TSP contains a depot and several cities (nodes), and the distances between any two cities in the road network are known. A salesman departures from the depot and visits each city exactly once before returning back to the depot (Fig. 1). For economic consideration, the salesman has to find the shortest tour to visit all the cities.

The Multiple Traveling Salesman Problem (mTSP) is an extension of the well-known TSP, where more than one salesman is used in finding multiple tours. Moreover, the characteristics of the mTSP seem more appropriate for real life applications, and it is also possible to extend the problem to a wide variety of VRPs by incorporating some additional side constraints.

VRP is a derivative of the TSP (Lin 1965), and was first introduced in 1959 (Dantzig and Ramser 1959). The VRP can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scatted cities or customers, subject to side constrains. The VRP lies at the hearts of distribution management. There exist several versions of the problem and a wide variety of exact and approximate algorithms have been proposed for its solution. Exact algorithms can only solve relatively small problems (Laporte 1992).

Capacitated VRP (CVRP) is a VRP where vehicles have limited carrying capacity of the goods that must be delivered. Let one of the nodes be designated as the depot. With each node i, apart from the depot, is associated a demand Q_i that can be a delivery from or a pickup to the depot. The problem is to minimize the total distance traveled, such that the accumulated demand up to any node does not exceed a vehicle capacity. Each tour must start and end at the depot and all problem parameters are assumed to be known with certainty. Moreover, each customer must be served by exactly one vehicle (Fig. 2).

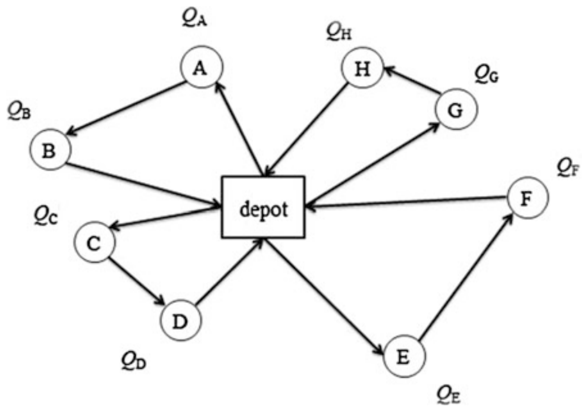


Fig. 2 The capacitated vehicle routing problem

The VRP is a NP-hard problem which makes it difficult to solve it to optimality. A survey by Laporte (1992) might be a good starting point to find out exact algorithms and heuristic algorithms in solving the VRPs.

In this paper, an exact algorithm is developed by applying tagging mechanism to each city to be visited, and a mixed integer program formulation is established in finding the optimal tours with minimum cost.

2 Analytical Approach

2.1 Notations

n	Number of cities
m	Number of salesman
c_{ij}	Travel cost from city i to city j
L_i	Left sequence tag of city i
R_i	Right sequence tag of city i
Q_i	Demand of city i
A_i	Cumulative quantity of arriving vehicle in city i
$vcap$	Capacity of the vehicles
x_{ij}	$\begin{cases} 1, & \text{if city } i \text{ precedes city } j \\ 0, & \text{otherwise} \end{cases}$

2.2 Assumptions

- Single depot with fixed location.
- Distances between nodes are known.

- Each node is served by a single salesman and each node is served exactly once.
- All salesmen shall start their tour from the depot and return to the depot to end their tour.
- There is no time limitation.

2.3 Tagging Mechanism

For each node, two tags are associated, namely, left and right, and let the value of the right tag always larger than the value the left tag by one. If two nodes i, j are connected to each other, and node i is visited prior to node j, then the right tag value of node i must equal to the left tag value of node j (Fig. 3). In this case, the subtours then can be eliminated.

To employ this mechanism on traveling sequence, first set $R_i = L_i + 1$ to each node i. If two nodes i and j are not directly connected (i.e., $x_{ij} = 0$), then the difference between R_i and L_j can be any value from $-(n–m)$ to $n–m$. If two nodes i and j are directly connected (i.e., $x_{ij} = 1$), then R_i must equal to L_j, which are:

when $x_{ij} = 0 : R_i - L_j \le n - m$
when $x_{ij} = 1 : R_i - L_j = 0$

Rewriting these equations, we have:

$$R_i - L_j \le (n - m)\left(1 - x_{ij}\right) \quad \text{where } x_{ij} = 0$$
$$R_i - L_j = \left(1 - x_{ij}\right) \quad \text{where } x_{ij} = 0$$

Combining these two equations, we have:

$$R_i - L_j \le (n - m)\left(1 - x_{ij}\right) \quad \text{where } x_{ij} = 0 \text{ or } 1$$

The same procedure can be applied to the capacity restriction. If two nodes are not directly connected (i.e., $x_{ij} = 0$), then the difference between $Q_i + A_i$ and A_j

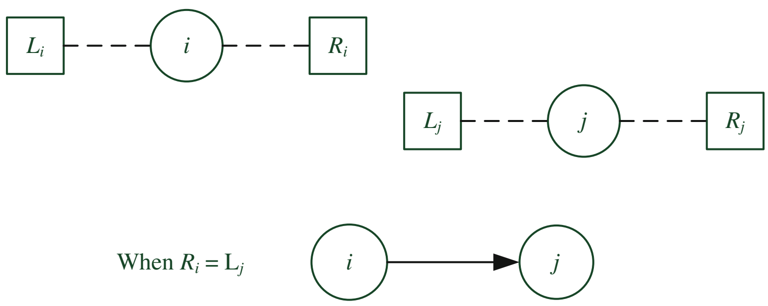


Fig. 3 The tagging mechanism

can be any value from $-vcap$ to $vcap$. If two nodes i and j are directly connected (i.e., $x_{ij} = 1$), then $Q_i + A_i$ must equal to A_j, which are:

when $x_{ij} = 0 : Q_i + A_i - A_j \leq vcap$
when $x_{ij} = 1 : Q_i + A_i - A_j = 0$

Rewriting these equations, we have:

$Q_i + A_i - A_j \leq vcap(1 - x_{ij})$ where $x_{ij} = 0$
$Q_i + A_i - A_j = (1 - x_{ij})$ where $x_{ij} = 1$

Combining these two equations, we have:

$Q_i + A_i - A_j \leq vcap(1 - x_{ij})$ where $x_{ij} = 0$ or 1

The complete formulation is:

$$\text{minimize} \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \quad (1)$$

$$\text{subject to} \sum_{i=1}^{n} x_{1j} = m \quad (2)$$

$$\sum_{i=1}^{n} x_{1j} = m \quad (3)$$

$$x_{ii} = 0 \quad (i = 1, 2, \ldots, n) \quad (4)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad (i = 2, 3, \ldots, n) \quad (5)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad (j = 2, 3, \ldots, n) \quad (6)$$

$$x_{\mathrm{ij}} + x_{ji} \leq 1 \quad (i = 2, 3, \ldots, n;\ j = 2, 3, \ldots, n) \quad (7)$$

$$R_i = L_i + 1 \quad (i = 1, 2, \ldots, n) \quad (8)$$

$$R_i - L_j \leq (n - m)(1 - x_{ij}) \quad (i = 1, 2, \ldots, n;\ j = 2, 3, \ldots, n) \quad (9)$$

$$Q_i + A_i - A_j \leq vcap(1 - x_{ij}) \quad (i = 1, 2, \ldots, n;\ j = 2, 3, \ldots, n) \quad (10)$$

$$x_{ij} \in \{0, 1\} \quad (11)$$

In this formulation, Eq. (1) is the objective function, by summing up all distances between each city. Equations (2) and (3) ensure there is exactly m salesmen start from the depot and finally must return to the depot. Equation (4) ensures each node will not be connected to itself. Equations (5) and (6) ensure each node can only be visited once. Equation (7) ensures there is no loop occurs in each pairing nodes. Equations (8)–(10) are the tagging constraints discussed earlier.

3 Illustrative Example

Given an area, in which only 1 depot exists and the goods should be delivered to 6 cities and 3 vehicles are available. Each city shall be visited by one vehicle exactly once and each vehicle shall start its tour from the depot (starting point) and return to the depot to end its tour. Table 1 shows the distance matrix of city *i* (1–7) and city *j* (1–7) where node 1 represents the depot—the starting point.

The developed MIP formulation has been implemented in the LINGO software package and the results are shown in Table 2 and Fig. 4 respectively.

The optimal solution is $x_{15} = x_{16} = x_{17} = x_{23} = x_{31} = x_{41} = x_{54} = x_{61} = x_{72} = 1$ with minimum traveling distance 165.

By dropping constraint (10), the model becomes the mTSP, and the result is shown in Fig. 5. Further by setting the number of salesman $m = 1$, the model then becomes the TSP, and the result is shown in Fig. 6.

Table 1 Distance matrix for illustrative example

city *j* / city *i*	1	2	3	4	5	6	7
1	0	24	19	20	27	16	12
2	24	0	17	31	44	36	23
3	19	17	0	16	29	35	25
4	20	31	16	0	15	34	28
5	27	44	29	15	0	40	37
6	16	36	35	34	40	0	11
7	12	23	25	28	37	11	0

Table 2 Result for illustrative example

Li	Node *i*	*Ri*	Q*i*	A*i*
0	1	1		
2	2	3	6	15
3	3	4	3	18
2	4	3	7	14
1	5	2	7	7
1	6	2	18	18
1	7	2	4	4

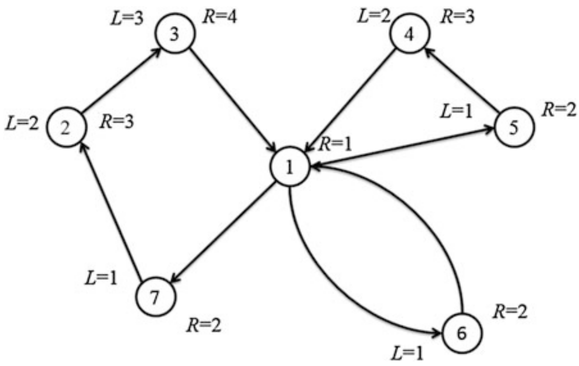


Fig. 4 Optimal tours with 3 vehicles

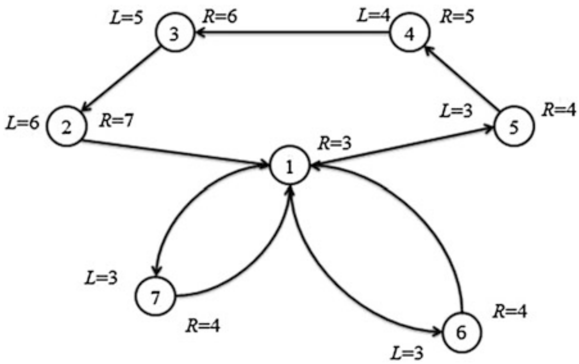


Fig. 5 Optimal mTSP tours

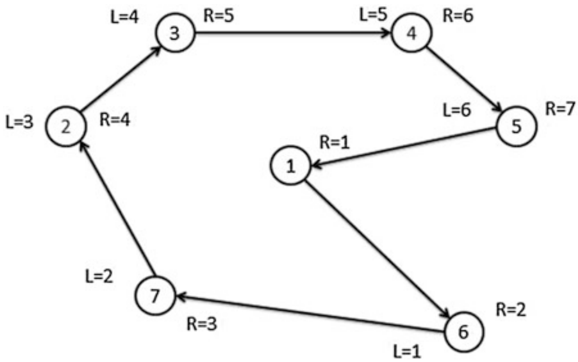


Fig. 6 Optimal TSP tour

4 Conclusions

In this research, a MIP formulation of the CVRP is developed. By employing simple tagging mechanism to each node, the subtour elimination constraints are easy to implement and understand. For small size problem, this formulation is quite efficient, however, when the problem size gets larger, the time to obtain the optimal tours is also getting longer. Two variants of the CVRP are also presented in this paper. Simply by dropping or replacing value in the constraint, the formulation can easily be transformed into mTSP or classical TSP.

References

Dantzig GB, Ramser JH (1959) The truck dispatching problem. Manage Sci 6(1):80–91

Karp RM (1972) Reducibility among combinatorial problem. In: Miller R, Thatcher J (eds) Complexity of computer computations. Plenum Press, New York, pp 85–103

Laporte G (1992) The vehicle routing problem: an overview of exact and approximate algorithms. Eur J Oper Res 59(3):345–358

Lin S (1965) Computer solutions of the traveling salesman problem. Bell Syst Tech J 44(10):2245–2269

Two-Stage Multi-Project Scheduling with Minimum Makespan Under Limited Resource

Calvin K. Yu and Ching-Chin Liao

Abstract Project scheduling is one of the key components in the construction industry and has a significant effect on the overall cost. In business today, project managers have to manage several projects simultaneously and often face challenges with limited resources. In this paper, we propose a mixed integer linear programming formulation for the multiple projects scheduling problem with one set of limited resource to the identical activities within the same project or among different projects and minimum makespan objective. The proposed model is based on the Activity on Arrow (AOA) networks, a two-stage approach is applied for obtaining the optimal activities scheduling. At the first stage, the minimum makespan for completing all projects is computed. By fixing the minimum completion time obtained from the first stage, the second stage computation is then to maximize the slack time for each activity in order to obtain the effective start and finish time of each activity in constructing the multiple projects schedule. The experimental results have demonstrated practical viability of this approach.

Keywords Activity on arrow network · Mixed integer programming · Project management

C. K. Yu (✉) · C.-C. Liao
Department of Industrial Engineering and Management, Ming Chi University of Technology, 84 Gungjuan Road, Taishan District, New Taipei City 24301, Taiwan
e-mail: calvinyu@mail.mcut.edu.tw

C.-C. Liao
e-mail: louis_liao@furong.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_49,

1 Introduction

CPM and PERT have been successfully used in scheduling large complex projects that consist of many activities. When planning and evaluating the projects, project managers usually have to face the issue that the available resource is limited. Sometimes different projects have to share one set of valuable resource, which affects the effectiveness of project scheduling and timelines. Therefore, how to allocate these limited resources among the various projects and complete all projects in an acceptable time then becomes a big challenge to the project managers.

Demeulemeester et al. (2013) collects 11 carefully selected papers which deal with optimization or decision analysis problems in the field of project management and scheduling. This paper covers a considerable range of topics, including:

- solution methods for classical project scheduling problems
- mixed integer programming (MIP) formulations in order to solve scheduling problems with commercial MIP-solvers
- models and solution algorithms for multi-project scheduling
- extensions of the classical resource-constrained project scheduling problem
- models and solution approaches integrating decisions at different managerial levels such as selection and scheduling, or scheduling and control
- risk in project management and scheduling
- the assignment of resources to different stakeholders

Demeulemeester et al. also point out that the operations research techniques employed include common approaches such as metaheuristics and mixed-integer programming, but also specific approaches such as scenario-relaxation algorithms, Lagrangian-based algorithm, and Frank-Wolfe type algorithm.

In this paper, we propose a two stage approach by using the mixed integer programming models to generate optimal project schedules where all identical tasks have only one set of resource available and have to share among different projects. The objective is to complete all projects as early as possible.

2 Analytical Approach

Consider a multi-project scheduling problem where there is only one set of resource available for each task and the duration of each task is known with certainty. To avoid conflict in resource usage within the same project or among different projects, all identical tasks have to be scheduled either before or after each other. Therefore, a MIP model based on the AOA network is developed to help allocating valuable resources. The objective is to complete all projects as early as possible, i.e., minimize makespan.

2.1 Notations

t_{ij} activity time of task j in project i
ns_{ij} possible start time of task j in project i
nf_{ij} possible finish time of task j in project i
et_{ij} earliest start time of task j in project i
lt_{ij} latest finish time of task j in project i
s_{ij} slack time of task j in project i
$y_{ijj'}$ $\begin{cases} 1, \text{ if task } j \text{ finished before tase } j' \text{ within project } i \\ 0, \text{ otherwise} \end{cases}$
$z_{ikjk'}$ $\begin{cases} 1, \text{ if task } k \text{ in proj } i \text{ finished before tase } k' \text{ proj } j \\ 0, \text{ otherwise} \end{cases}$
M a large positive number
T finish time for all projects, i.e., makespan

2.2 Task Representation

Since the AOA network is used in developing the MIP model, the representation for each task j in project i is shown in Fig. 1.

The hollow circles in Fig. 1 are used to construct the project network, while the distance between the solid circles are the actual available time for completing a task. The dotted line represents the unusable time.

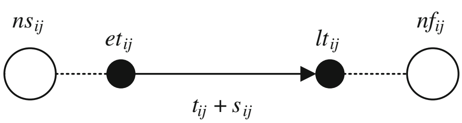
2.3 Stage 1 Computation

The first stage computation is to obtain the minimum makespan for all projects. The complete formulation is:

$$\text{minimize } T \tag{1}$$

subject to

Fig. 1 Task representation



(for each project i where task j precedes task k)

$$ns_{ik} \geq ns_{ij} + t_{ij} \tag{2}$$

$$nf_{ij} \leq nf_{ik} - t_{ik} \tag{3}$$

$$nf_{ij} = ns_{ik} \tag{4}$$

(for each project i and each task j)

$$et_{ij} \geq ns_{ij} \tag{5}$$

$$lt_{ij} \leq nf_{ij} \tag{6}$$

$$s_{ij} = lt_{ij} - et_{ij} - t_{ij} \tag{7}$$

(for each pair of identical tasks j and j' within the same project i)

$$et_{ij} + My_{ijj'} \geq lt_{ij'} \tag{8}$$

$$lt_{ij} + My_{ijj'} \geq et_{i'} \tag{9}$$

$$et_{ij'} + M\left(1 - y_{ijj'}\right) \geq lt_{ij} \tag{10}$$

$$lt_{ij'} + M\left(1 - y_{ijj'}\right) \geq et_{ij} \tag{11}$$

(for each pair of identical tasks k and k' between project i and j)

$$et_{ik} + Mz_{ikjk'} \geq lt_{jk'} \tag{12}$$

$$lt_{ik} + Mz_{ikjk'} \geq et_{jk'} \tag{13}$$

$$et_{jk'} + M\left(1 - z_{ikjk'}\right) \geq lt_{ik} \tag{14}$$

$$lt_{jk'} + M\left(1 - z_{ikjk'}\right) \geq et_{ik} \tag{15}$$

(for each project i)

$$lt_{i,finish} \leq T \tag{16}$$

$$y_{ijj'}, z_{ikjk'} \in \{0, 1\} \tag{17}$$

In this formulation, Eq. (1) is the objective function, by minimizing the total completion time T for all projects. (2–4) ensure the precedence relationship for each task j in project i. (5–7) ensure the actual time for each task falls in the available time range. (8–11) ensure the identical tasks within the same project to be staggered. (12–15) ensure the identical tasks among different projects to be staggered. (16) ensures all projects to be completed before time T.

2.4 Stage 2 Computation

At the completion of the first stage computation, the minimum makespan for all projects should be obtained without any question. However, in stage 1 computation, the possible finish times for tasks were pushed forward which causing most of the slack times for tasks are 0. To reclaim the slack times for tasks, therefore, the second stage computation is required. By fixing the minimum makespan obtained from stage 1, the stage 2 computation is simply by maximizing the sum of all slack times.

The MIP formulation for the second stage computation is basically the same as the first stage computation. The differences between these two formulations are:

- in objective function, Eq. (1) in stage 1 is to be replaced with:

$$\text{maximize} \sum_{i} \cdot \sum_{j} S_{ij} \tag{1'}$$

- in fixed makespan, Eq. (16) in stage 1 is to be replaced with:

$$lt_{i,finish} \leq minimum\ makespanobtained\,from\ stage\ 1 \tag{16'}$$

3 Illustrative Example

Consider three buildings construction projects where there is only one set of resource available for each task. The data is given in Table 1.

The AOA networks representation of these projects are shown in Fig. 2.

The developed MIP formulations have been implemented in the LINGO software package. After completing the first stage computation, the minimum makespan for all projects is 18 days, and the results are shown in Table 2. The Gantt chart representation of Table 2 is shown in Fig. 3.

Table 1 Data for illustrative example

Task		Project 1		Project 2		Project 3	
		Duration (days)	Predecessor(s)	Duration (days)	Predecessor(s)	Duration (days)	Predecessor(s)
A	Skeleton	2	×	3	×	2	×
B	Piping	3	A	4	A	3	A
C1	Wallboard	3	A	3	A	3	A
C2	Wallboard	2	B	–	–	2	B
D	Rock wool	2	C1	3	B	2	C1
E	Varnish	3	C2, D	2	D	3	C2, D

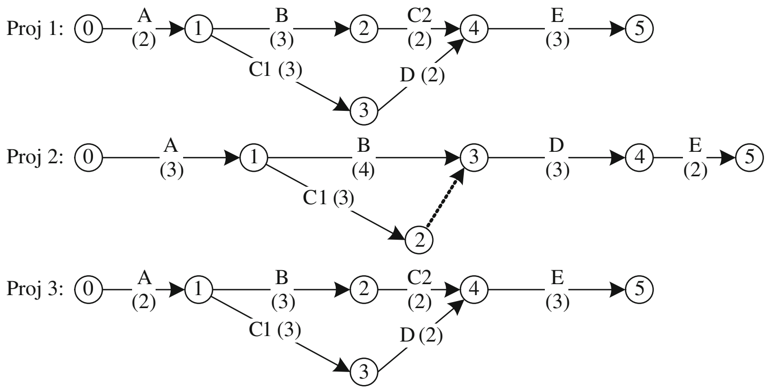


Fig. 2 Project network diagrams for illustrative example

Note that in Table 2, all tasks have zero slack time, which makes the finding of critical path somewhat difficult. Therefore, the second stage computation is applied, and the results are shown in Table 3. The Gantt chart representation of Table 3 is shown in Fig. 4. In Table 3, task E in project 1, task B in project 2 and task A in project 3 each has non-zero slack times, while the remaining tasks all with zero slack time. In this case, the critical path for each project is easy to find simply by taking the tasks with zero slack time.

Table 2 Solution from stage 1 computation

ns_{ij}		et_{ij}		et_{ij}		lt_{ij}		s_{ij}	
1A	0	1A	9	1A	7	1A	9	1A	0
1B	9	1B	13	1B	9	1B	12	1B	0
1C1	9	1C	13	1C	13	1C	13	1C	0
1C2	13	1C2	15	1C2	0	1C2	15	1C2	0
1D	13	1D	15	1D	13	1D	15	1D	0
1E	15	1E	18	1E	15	1E	18	1E	0
2A	0	2A	5	2A	2	2A	5	2A	0
2B	5	2B	10	2B	5	2B	9	2B	0
2C1	5	2C2	10	2C2	7	2C2	10	2C2	0
2D	0	2D	13	2D	10	2D	13	2D	0
2E	13	2E	18	2E	13	2E	15	2E	0
3A	0	3A	2	3A	0	3A	2	3A	0
3B	2	3B	5	3B	2	3B	5	3B	0
3C1	2	3C1	5	3C1	2	3C1	5	3C1	0
3C2	5	3C2	7	3C2	5	3C2	7	3C2	0
3D	5	3D	7	3D	5	3D	7	3D	0
3E	7	3E	18	3E	7	3E	10	3E	0

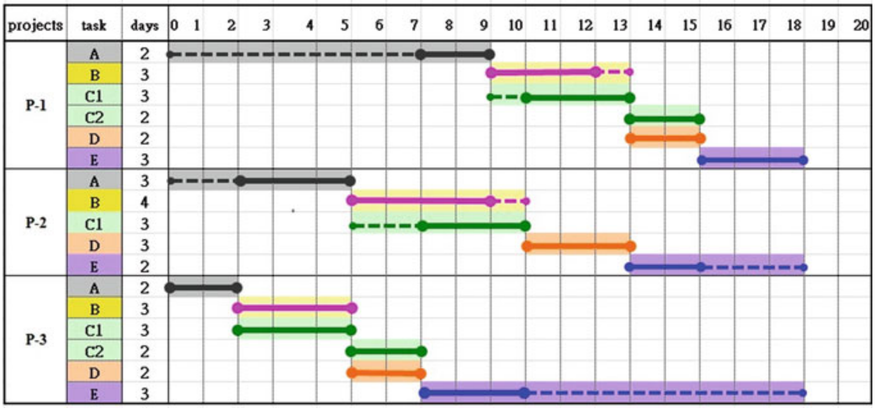


Fig. 3 Gantt chart representation for the stage 1 results

Table 3 Solution from stage 2 computation

ns_{ij}		et_{ij}		et_{ij}		lt_{ij}		s_{ij}	
1A	0	1A	2	1A	0	1A	2	1A	0
1B	2	1B	5	1B	2	1B	5	1B	0
1C1	2	1C1	5	1C1	2	1C1	5	1C	0
1C2	5	1C2	7	1C2	5	1C2	7	1C2	0
1D	5	1D	7	1D	5	1D	7	1D	0
1E	7	1E	18	1E	7	1E	13	1E	3
2A	0	2A	5	2A	2	2A	5	2A	0
2B	6	2B	10	2B	5	2B	10	2B	1
2C1	6	2C1	10	2C1	7	2C1	10	2C1	0
2D	10	2D	13	2D	10	2D	13	2D	0
2E	13	2E	18	2E	13	2E	15	2E	0
3A	0	3A	10	3A	5	3A	10	3A	3
3B	10	3B	13	3B	10	3B	13	3B	0
3C1	10	3C1	13	3C1	10	3C1	13	3C1	0
3C2	13	3C2	15	3C2	13	3C2	15	3C2	0
3D	13	3D	15	3D	13	3D	15	3D	0
3E	15	3E	18	3E	15	3E	18	3E	0

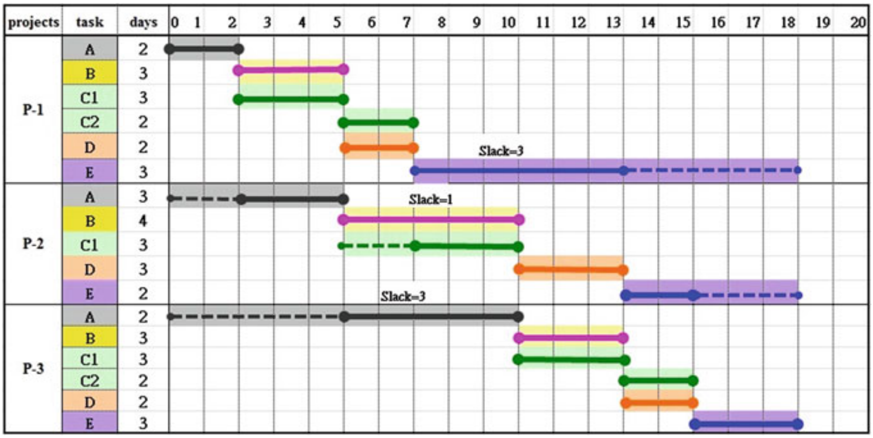


Fig. 4 Gantt chart representation for the stage 2 results

4 Conclusion

In this research, the MIP formulations of the multiple project networks scheduling with limited resource have been developed. In order to obtain the minimum makespan and construct the critical path, a two-stage computation approach is used. The first stage computation is to minimize the makespan for all projects, after that, the optimal solution obtained from the first stage is then used on the second stage to identify the critical path. The results show that this model is capable in allocating limited resources among several projects with minimum total completion time.

Reference

Demeulemeester E, Kolisch R, Salo A (2013) Project management and scheduling. Flex Serv Manuf J 25(1–2):1–5

A Weighting Approach for Scheduling Multi-Product Assembly Line with Multiple Objectives

Calvin K. Yu and Pei-Fang Lee

Abstract A flexible production scheduling in the assembly line is helpful for meeting the production demands and reducing the production costs. This paper considers the problem of scheduling multiple products on a single assembly line when multiple objectives exist. The specific objectives are to reduce the production changeovers and minimize overtime cost with the restrictions on production demands, due dates, and limited testing space. This system model derives from a real case of a company producing point of sale systems and a mixed integer programming model is developed. Different sets of weights that represent the priorities of specific objectives are applied to the model. By manipulating and adjusting these weights, it is capable to generate the desired production schedule that satisfies production managers' need. An example has been solved for illustrating the method. Preliminary findings suggest that the weighting approach is practicable and can provide valuable information for aggregate planning.

Keywords Assembly line · Mixed integer programming · Multi-objective optimization · Multi-product scheduling

1 Introduction

Business organizations continue to introduce new products, innovation and creativity to fulfill customer demands, and the control of cost is very necessary to the successful operation of business organizations. Scholars in the field of industrial

C. K. Yu (✉) · P.-F. Lee
Department of Industrial Engineering and Management, Ming Chi University of Technology, 84 Gungjuan Road, Taishan District, New Taipei City 24301, Taiwan
e-mail: calvinyu@mail.mcut.edu.tw

P.-F. Lee
e-mail: carollee68952003@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_50,

engineering have proposed many methods to reduce costs and improve quality which cover a wide range of business sizes and activities. In manufacturing organizations, product quality, delivery flexibility and cost of production are some important evaluation index of production management. Production management includes responsibility for product and process design, planning and control issues involving capacity and quality, and organization and supervision of the workforce. How to under limited resource to achieve effective production goal is testing the management ability of production managers. A good production schedule helps manufacturing organizations lower cost, reduce inventory, and improve customer service over all applicable time horizons.

Scheduling is the process of deciding how to commit resources between a variety of possible tasks. Multi-product scheduling can usually be treated as a multi-objective problem in which the planning schedule has multiple goals. Chang and Lo (2001) proposed an integrated approach to model the job shop scheduling problems, along with a genetic algorithm/tabu search mixture solution approach. The multiple objective functions modeled include both multiple quantitative (time and production) and multiple qualitative (marketing) objectives. Some illustrative examples are demonstrated using the genetic algorithm/tabu search solution approach. Lee (2001) evaluates artificial intelligence search methods for multi-machine two-stage scheduling problems with due date penalty, inventory, and machining costs. The results show that the two-phase tabu search is better in solution quality and computational time than the one-phase tabu search. Esquivel et al. (2002) shows how enhanced evolutionary approaches can solve the job shop scheduling problem in single and multi-objective optimization.

In this paper, we propose a weights method in determining the optimal production schedule for multi-product assembly line with multiple objectives. The objectives including consideration of production due date, number of time product types switched and necessity of overtime production.

2 Analytical Approach

2.1 Notations

n	number of product types
t	available production period (in days)
q_{ij}	production quantity of product type i on day j
dd_i	due date for product type i
d_i	demand for product type i
cap	capacity of testing room
chg_j	number of time product types switched on day j
ut_i	unit production time for product type i
rh	regular production hours per day

oh	overtime production hours per day
st	setup time for switching product types
y_{ij}	$\begin{cases} 1, & \text{if product type } i \text{ is produced on day } j \\ 0, & \text{otherwise} \end{cases}$
ot_j	$\begin{cases} 1, & \text{if overtime is required on day } j \\ 0, & \text{otherwise} \end{cases}$
$shift_{ij}$	$\begin{cases} 1, & \text{if product type } i \text{ is getting on (off) line on day } j \\ 0, & \text{otherwise} \end{cases}$
$span_{ij}$	$\begin{cases} 1, & \text{if only product type } i \text{ can be produced on day } j \\ 0, & \text{otherwise} \end{cases}$
wt_j	weight of production quantity on day j
wt_chg	weight on switching product types
wt_ot	weight on overtime
M	a large positive number

2.2 Assumptions

- All required material are ready prior to production
- Quality of raw material is stable
- Only one type of the product can be assembled at the same time
- Testing room has capacity restriction

2.3 Multi-objective Mixed Integer Programming Model

$$\text{Minimize} \sum_{i=1}^{n}\sum_{j=1}^{ddi} wt_j q_{ij} + \sum_{j=1}^{t} wt\_chg(chg_j) + \sum_{j=1}^{t} wt\_ot(ot_j) \tag{1}$$

$$\text{subject to} \sum_{j=1}^{ddi} q_{ij} \geq d_i \quad (i = 1, 2, \ldots, n) \tag{2}$$

$$\sum_{i=1}^{n} q_{ij} \leq cap \quad (j = 1, 2, \ldots, t) \tag{3}$$

$$\sum_{i=1}^{n} y_{ij} = chg_j \quad (j = 1, 2, \ldots, t) \tag{4}$$

$$\sum_{i=1}^{n} ut_i q_{ij} \leq rh + oh(ot_j) - st(chg_j) \quad (j = 1, 2, \ldots, t) \tag{5}$$

$$q_{ij} \leq My_{ij} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, t) \tag{6}$$

$$shift_{i1} = y_{i1} \quad (i = 1, 2, \ldots, n) \tag{7}$$

$$y_{ij} - y_{ij+1} = s_{ij+1} - t_{ij+1} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, t-1) \tag{8}$$

$$shift_{ij+1} = s_{ij+1} + t_{ij+1} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, t-1) \tag{9}$$

$$\sum_{j-1}^{ddi} shift_{ij+1} \leq 2 \quad i = 1, 2, \ldots, n \tag{10}$$

$$y_{ij} + y_{ij+1} + y_{ij+2} \geq 3span_{ij+1} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, t-2) \tag{11}$$

$$y_{ij} + y_{ij+1} + y_{ij+2} \leq 2 + span_{ij+1} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, t-2) \tag{12}$$

$$\sum_{i=1}^{n} span_{ij} \leq Mz_j \quad (j = 1, 2, \ldots, t) \tag{13}$$

$$\sum_{i=1}^{n} y_{ij} \leq 1 + M(1 - z_j) \quad (j = 1, 2, \ldots, t) \tag{14}$$

$$q_{ij} \in \text{integer} \tag{15}$$

$$ot_j, y_{ij}, shift_{ij}, span_{ij}, s_{ij}, t_{ij}, z_j \in \{0, 1\} \tag{16}$$

Objective function (1) uses weights to control the production quantity, number of time product types switched and necessity of overtime production. The objective is minimizing the total weights gathered from all goals. The weight of production quantity on day j (wt_j), if setting it to a larger value, the production quantity on day j will be decreased, vice versa. If set relative large value to the weight on changing product types (wt_chg), it will make less product types switching during the production process. Increasing the weight of switching the assembly lines can avoid unnecessary switching. If set relative large value to the weight on overtime (wt_ot), it will make overtime unavailable.

Constraint (2) ensures the production quantity will meet the demand and due date. (3) ensures the daily production quantity will not exceed the capacity of testing facility. (4) counts the number of time product types switched. (5) ensures the daily production hours will not exceed the available working hours. (6) will force $y_{ij} = 1$, if $q_{ij} > 0$. (7–10) ensure per product type can only be on and off the production line one time, make it total less than 2 to fulfill batch processing requirement. (11–14) ensure the production will not be interrupted by another product type if the on line product type requires more than 3 days in production.

3 Illustrative Example

Consider a computer manufacturing factory carries out assembly operations during next 7 days and there are 6 operators working 8 h per day with additional available daily overtime of 2 h. A burn-in test should be run after the product is assembled. The capacity of burn-in test room is 400 computers. The time for switching product types is 20 min. Table 1 provides additional information on the product types, unit production times, demands and due dates.

The developed MIP formulations have been implemented in the LINGO software package. At first, overtime is not put into consideration (i.e., put heavy weight on overtime). By manipulating the weights of the production quantity, the resulting schedule is shown in Table 2. Since the weight on day 1 is much larger than the other days, we can expect a lower product quantity on day one. Due to the products due dates, the effect of day 2 is not obvious.

Table 1 Product demand and due date

Product type	Unit production time (min)	Demand	Due date
A	8	957	5
B	8	500	4
C	7	158	5
D	7	68	6
E	7	42	7
F	8	530	7
G	16	22	3
H	6	69	5

Table 2 Production schedule by assigning larger weights on the first two days

Day j Product i wt_j assigned	1 25	2 5	3 1	4 1	5 1	6 1	7 1	Total qty
A		81	357	357	162			957
B	266	274						500
C					158			158
D						68		68
E						42		42
F						256	274	530
G	22							22
H					69			69
Total qty	288	355	357	357	389	366	274	
Total time (min)	2,520	2,880	2,876	2,876	2,876	2,878	2,212	

Table 3 Production schedule by assigning larger weights on the last two days

Day j Product i wt_j assigned	1 1	2 1	3 1	4 1	5 1	6 5	7 25	Total qty
A			328	357	272			957
B	116	357	27					500
C	158							158
D					50	18		68
E					42			42
F						339	191	530
G	22							22
H	69							69
Total qty	365	357	355	357	364	357	191	
Total time (min)	2,880	2,876	2,880	2,876	2,880	2,878	1,548	

Table 4 Production schedule by assigning a smaller value to *wt_chg*

Day j Product i	1	2	3	4	5	6	7	Total qty
A		111	273	357	216			957
B	303	197						500
C					158			158
D						68		68
E						42		42
F						175	355	530
G		22						22
H	69							69
Total qty	372	330	273	357	374	285	355	
Total time (min)	2,878	2,876	2,204	2,876	2,874	2,230	2,860	

If the production is to be finished as early as possible, we can set larger weights on those days that near the end of the production period. The resulting schedule when we reverse the weights from the previous example is shown in Table 3.

By setting equal weighs on the production quantity, Table 4 show the result of putting smaller weight on the switching product types, while Table 5 uses a larger weight. The total switching times in Table 4 is 6, however, in Table 5, the switching times is 5 which is one time less than putting the smaller weight on the switching product types.

Table 6 shows the result of putting relatively smaller weight on overtime. As we can see, available working hours are fully used to fill up the capacity of the testing room most of the days.

Table 5 Production schedule by assigning a larger value to *wt_chg*

Day *j* Product *i*	1	2	3	4	5	6	7	Total qty
A			357	357	243			957
B	170	330						500
C	158							158
D						68		68
E						42		42
F						173	357	530
G	22							22
H					69			69
Total qty	350	330	357	357	312	283	357	
Total time (min)	2,878	2,660	2,876	2,876	2,398	2,214	2,876	

Table 6 Production schedule by assigning a smaller value to *wt_ot*

Day *j* Product *i*	1	2	3	4	5	6	7	Total qty
wt_j assigned	1	1	1	1	1	5	25	
A			341	400	216			957
B	268	232						500
C		158						158
D	68							68
E	42							42
F					184	346		530
G	22							22
H		10	59					69
Total qty	400	400	400	400	400	346	0	
Total time (min)	3,346	3,082	3,122	3,220	3,240	2,788	0	
Over time (min)	466	202	242	340	360	0	0	

4 Conclusion

The model developed in this research can quickly obtain the optimal production schedule for each product type with the limitations of space, time and operators. Weights are used in this model, by manipulating and adjusting these weights, it is capable to generate the desired production schedule that satisfies production managers' need and make the production schedule more flexible.

References

Chang PT, Lo YT (2001) Modelling of job-shop scheduling with multiple quantitative and qualitative objectives and a GA/TS mixture approach. Int J Comput Integ M 14(4):367–384

Esquivel S, Ferrero S, Gallard R, Salto C, Alfonso H, Schütz M (2002) Enhanced evolutionary algorithms for single and multiobjective optimization in the job shop scheduling problem. Knowl-Based Syst 15(1):13–25

Lee I (2001) Artificial intelligence search methods for multi-machine two-stage scheduling with due date penalty, inventory, and machining costs. Comput Oper Res 28(9):835–852

Exploring Technology Feature with Patent Analysis

Ping Yu Hsu, Ming Shien Cheng, Kuo Yen Lu and Chen Yao Chung

Abstract The patent literature has documented 90 % of the world's technological achievements, which are protected by the patent law of each country. But with the increasingly competitive technology, enterprises have started the patent strategy research and attached great importance to patent analysis. The patent analysis uses statistics, data mining, and text mining to convert the information into a competitive intelligence that facilitates corporate decision making and prediction. Thus, the patent analysis has become a corporate weapon for long-term survival and protection of commercial technologies. The patent analysis in the past, compared with the trend analysis, mostly conducted the predictive analysis of a number of keywords and patents through the statistical analysis approach. However, the keywords found were limited to the already mature technology and could not locate the implicit emerging terms, so the patent analysis in the past could only find the words of obvious importance, but fail to find the emerging words that are unobvious yet will have a major impact on future technologies. Therefore, how to find these words of a low-frequency nature to make prediction of the correct trend is an important research topic. This study used the Chinese word segmentation system to find the words of the patent documents and extracted the words according to the probability model of the Cross Collection Mixture Model. This model targets the words under changes in the time series. The background model and the common theme in the model will eliminate frequent words without the meaning of identification and collect words persistently appearing across time. This method can quickly screen enormous volumes of patent documents, extract

P. Y. Hsu · K. Y. Lu · C. Y. Chung (✉)
Department of Business Administration, National Central University, No.300, Jhongda Road, Jhongli City, Taiwan (R.O.C.) 32001, Taoyuan County
e-mail: 984401019@cc.ncu.edu.tw

M. S. Cheng
Department of Industrial Engineering and Management, Ming Chi University of Technology, No.84, Gongzhuan Road, Taishan District, New Taipei City 24301, Taiwan (R.O.C)
e-mail: mscheng@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_51,

from the patent summary emerging words of a low-frequency nature, successfully filter out the fashion words, and accurately detect the future trends of emerging technologies from the patent documents.

Keywords Patent analysis · Text mining · Cross collection mixture model · Technology feature

1 Introduction

Due to the rapidly evolving technology, various types of products are continually changing and increasing in their complexity. Under such a fast change and short product life cycle, the technological innovation of the product has become the main source of corporate profits. Therefore, how to master the key technology has become the main weapon of today's enterprises to maintain their corporate competitiveness. By virtue of a unique industrial technology, the enterprise will be able to improve the corporate profits from its products, so the enterprise should attach more importance to the patent layout for its own unique technology. A complete patent layout for the enterprise is like a big umbrella that protects the corporate from being harmed by foreign competitors, and by expanding this patent umbrella enterprises can keep flourishing.

The quantitative prediction analysis of existing patents is aimed at historical data, while the research data columns are aimed at countries, inventors, patent classification, calculation of the growth of literature category, and technological growth and decline for predicting possible future developments, the predictive results are all the known research areas and cannot accurately tell what will be a potential area of . Therefore, knowledge mining by virtue of the combination of data mining and text-mining techniques to identify the possible potential knowledge from the semi-structured data, such as the summary and documentation of the patent, has also become an increasingly important analytical tool in recent patent analysis.

The keyword search was based on the keywords as defined by the knowledge of experts and therefore was often unable to uncover the implicit emerging technical documents or new words. So, it has been suggested that text-mining be used to find the keywords of the patent documents. This method of information retrieval is important because it can accurately find out the keywords representative of the patent documents and pinpoint this keyword using the growth curve to conduct analysis in the hopes of finding the emerging keywords. But usually the enterprise deliberately substitutes other words to prevent competitors retrieving this keyword, leading to the finding of keywords relating to already mature technology, which can cause great difficulties for the growth curve forecasts. Therefore to find out the emerging technology words from patent documents to help enterprises quickly cut into the possible technical development is the main objective of this study.

This study will pinpoint the content of summary of the unstructured patent documents to conduct trend analysis of words and identify possible potential new words in the hopes of finding words of a low-frequency nature in the past but under the changes in the time series will pop up in the future to become emerging words.

This study is structured as follow: Sect. 2 is the Literature that views this study's related patent predictive analysis and Cross Collection Mixture Model. Section 3 is System Processes for deriving the algorithm proposed in this study. Section 4 is the Empirical Analysis, which used the results of the research model to conduct the words trend analysis. Section 5 is the Conclusion, and the future research direction derived by this study.

2 Related Work

As the patent document has a time stamp, we hope to find the words and the change of theme under the time change, so that we can see the variations of the patent keyword. In 2004, Morinage and Yamanishi (Morinage and Yamanishi 2004) proposed the Finite Mixture Model for the real-time analysis of CRM (Customer Relationship Management), knowledge management, or Web monitoring. This model can use dynamic monitoring variation on the theme and use theme features to facilitate document clustering (Wu et al. 2010).

Correlations exist among the time, authors, or locations in documents. For example, at a press event the articles written by the same reporter will have the same style of coverage, or in the coverage of the tsunami event the theme reported in the time change will usually be different. In 2006, Mei and Zhai (Mei and Zhai 2006) proposed the contextual probabilistic latent semantic analysis (CPLSA) to improve the old probabilistic latent semantic analysis (PLSA). The new model introduces a new environment variable, such as spatiotemporal mining, author-topic analysis, temporal text-mining, etc. The documents have different underlying theme background time, place, and author (Porter et al. 1991; Perkiom et al. 2004; Chen et al. 2005). Zhai et al. (2004) adopted the Temporal Text-mining of Cross Collection Mixture Model (Fig. 1) to identify the life cycle changes of the tsunami news events and the intensity changes of the theme in each time of the news events. This study quoted the Cross Collection Mixture Model and by the background model removed the words that appeared too often. Meanwhile, the words collected by the common theme are specific words existing persistently in the documents in time, so they are popular and representative. The specific theme will only collect particular words appearing at certain times. The probability of these words standing out represents its intensity at the specific time. The purpose of using the specific theme is to see the frequency of these words in these times and observe which words have a sudden appearance and a high likelihood to continue its emergence in the future.

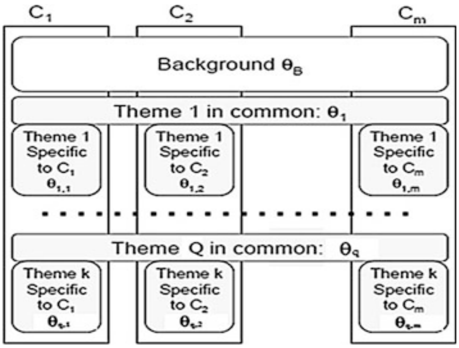


Fig. 1 Cross collection mixture model

3 System Design

The past patent analysis shows the patent analysis only focuses on the structured data (patent applicant, the technical category) to conduct the statistical analysis by aiming at the statistical model from a variety of different angles, such as the number of inventors, the amount of patent applications, and patent citations for quantitative analysis. But the problem often faced is that the structured data of patent cannot accurately represent the contents of the patent, only find out the titled keywords-related documents or specifically classified documents, but this search method requires many professionals to conduct the analysis and judgment to digest the large number of messages. Therefore, the use of computer-aid to effectively find out the valuable words of the patent document is an important subject we need to discuss. Our laboratory aims at WEBPAT Taiwan to provide the patent summary, emerging words strength across time, identification of keywords, and difference of emerging degree to identify possible future emerging technology areas, with the hope of increasing the predictive accuracy.

In this study, the algorithmic steps include:

1. Data collection and extraction.
2. Chinese word segmentation system processing/initial value setting.
3. Processing Cross-Collection Mixture Model-SQL.
4. Parameters Estimation with EM Algorithm.
5. Word analysis under specific theme.

Figure 2 Patent content documents collection $C = \{d_1, d_2, \ldots, d_k\}$, in order to extract a theme evolution, this study made the time of a year as a time interval. The documents were divided into m time intervals, i.e., $C = C_1 \cup C_2 \cup C_3 \cup C_m$, and the summary content of each document was composed of words from the collection $d = \left\{w_1, w_2, \ldots, w_{|V|}\right\}$.

Themes (θ) were to collect words with the conditional probability as the theme or sub-theme of semantic coherence. And the collection of the theme was done by the distribution of P(w|θ) with the probability of appearance of each word.

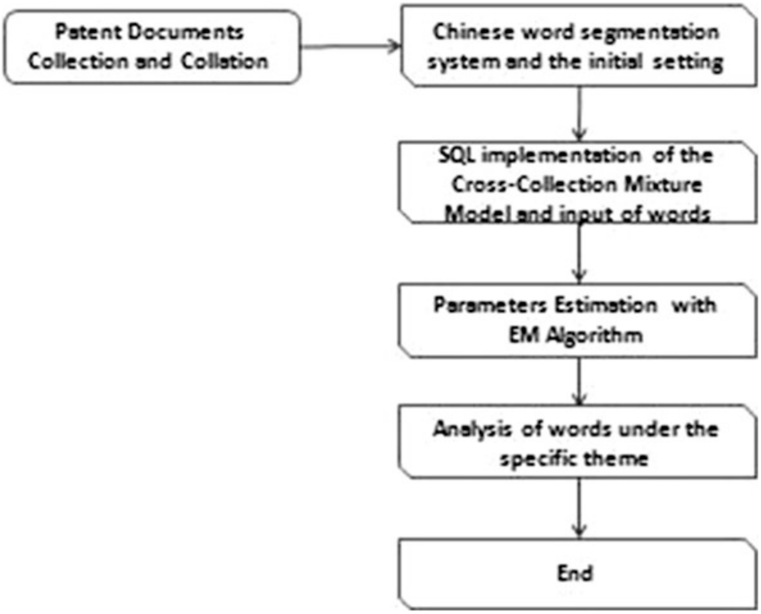


Fig. 2 System design flow

These words were sorted with probability, and the language model θ was composed of some words of higher $P(w|\theta)$ as a summary and definition of this theme. In which $\sum_{w \in v} P(w|\theta) = 1$, the extraction theme of this study makes use of the Cross Collection Mixture Model to divide the results of the conditional probability into the thematic cluster θ or background theme θ_B, common theme θ_i and specific theme θ_{ij}. Each patent document will be attributed to the Q theme group in the form of π_{ijd}

According to this study, as we hoped to find emerging words, we had to segment the words out of the patent documents. And in the natural language processing, the word is the most basic unit in processing, so we conducted the Chinese word processing for the collated summary. Through the Chinese word segmentation processing, the unstructured text can be collated into structured data to facilitate text-mining analysis.

Based on the source of information to set the value, the initial value may expressed as follows:

The initial value of $P^0(w|\theta_i)$ expressed as follows

$$P^0(w|\theta_i) = \lambda_c \times \frac{\sum_{j=1}^{m} \sum_{d \in c_j} \pi_{jdi} c(w,d)}{\sum_{j=1}^{m} \sum_{d \in c_j} \sum_{w' \in V} \pi_{jdi} c(w',d)} \tag{1}$$

The initial value of $P^0(w|\theta_{ij})$ expressed as follows

$$P^0\left(w|\theta_{ij}\right) = (1-\lambda_c) \times \frac{\sum_{d \in c_j} \pi_{jdi} c(w,d)}{\sum_{d \in c_j} \sum_{w' \in V} \pi_{jdi} c(w',d)} \tag{2}$$

This study uses the Cross-Collection Mixture Model and conditional probability distribution to collect words. There are Q common themes and Q × |C| specific themes and background model in this model. The probability distribution of the words collection operation is as follows:

$$p_{d,C_j}(w) = \lambda_B p(w/\theta_B) + (1-\lambda_B)\left(\sum_{\theta_i \in \Theta} \pi_{jdi}(1-\lambda_s)p(w/\theta_i) + \lambda_s p\left(w/\theta_{ij}\right)\right) \tag{3}$$

We express all word probability distributions as follows:

$$\begin{aligned} \log P\left(< C_1,..,C_m >\right) = \sum_{j=1}^{m} \sum_{d \in C_j} \sum_{w \in V} \Bigg\{ & c(w,d)k_{d,j} \log[\lambda_B p(w|\theta_B) \\ & + (1-\lambda_B)\left(\sum_{\theta_i \in \Theta} \pi_{jdi}((1-\lambda_s)p(w/\theta_i) + \lambda_s p\left(w/\theta_{ij}\right))\right)] \Bigg\} \end{aligned} \tag{4}$$

This study used the Expectation Maximization (EM) Algorithm to calculate the relative maximum probability value of each word falling into each theme, with the relative concept of probability to calculate the relative probability value of each sample falling into all the theme clusters.

The emerging term is defined in this study as the word that used to be of low-frequency in the past but has suddenly become a high-frequency word during this period. This study uses the Cross-Collection Mixture Model. After screening the words, those words collected from a specific theme in collection time. Based on strength of words, we look for the words of the top one percent strength in j period and analyze the words of low-frequency in the j-1 period. The words found will belong to the scope of our emerging words. And we will use the third period and the common theme to verify our results and see whether the emerging words continue to appear or have fallen into the common theme.

4 Empirical Analysis

In this study, first the patent documents of the WEBPAT Taiwan are collected based on IPC classification rules of patent documents to conduct research on the four categories of patent documents G06Q, H04B, H04L, and H04 N [8]. These four categories of patent documents classification are described as follows:

1. G06Q: The data processing systems or methods applies specifically to the purpose of administration, management, commerce, operation, supervision, or prediction; and the same not included in other categories.
2. H04L: Transmission of digital information, such as telegraph communications.
3. H04 N: Image communication, such as TV.
4. H04B: Transmission.

In this study, content of the patent documents was retrieved from the patent summary, a total of 1,562 patent contents were selected from patent documents released from 2003 to 2008, and patent documents per year were taken as a collection. 2003: 378 cases $(C_1 = \{d_1, d_2, \ldots, d_{378}\})$; 2004: 253 cases $(C_2 = \{d_{379}, d_{380}, \ldots, d_{631}\})$; 2005: 324 cases $(C_3 = \{d_{632}, d_{633}, \ldots, d_{955}\})$; 2006: 275 cases $(C_4 = \{d_{956}, d_{957}, \ldots, d_{1230}\})$; 2007: 265 cases $(C_5 = \{d_{1231}, d_{1232}, \ldots, d_{1495}\})$; In 2008 because of the open time limit for patent information that is publicly available, there are only 67 cases $(C_6 = \{d_{1496}, d_{1498}, \ldots, d_{1562}\})$.

Cases of patent document under each category: G06Q had 379 cases, H04L: 448 cases, H04N: 396 cases, and H04B: 337 cases. The information column name after filtration and collation are as follows: the patent document names; collecting data for six years; the patent summary.

Data of this 1,562 cases were fed to the Chinese word segmentation system to analyze the summary of the patent documents about the words and calculate the number of times c (w, d) the words appeared in each document. The resulting number of times the word appeared and the patent documents formed a two-dimensional matrix. This word segmentation system based on the corpus to conduct a contrast collected a total of 3,901 words. $\mathrm{V} = \{w_1, w_2, \ldots, w_{|\mathrm{V}|}\}$. The following analysis was then conducted.

Based on our study, the sources of patent documents collected had four categories, so we default the four themes. With a total of six years of data, making a total of 24 specific themes, the default cluster 1 was the patent documents H04B with a total 337 cases, cluster 2 H04L with 448 cases, cluster 3 H04N with 396 cases, and cluster 4 with G06Q 379 cases.

The Cross-Collection Mixture Model used a probability distribution for words collection, which consisted of four groups of θ_{i} (common theme) and θ_{B} (background model). Whereas it must first set value, the size of the parameter value is set by the researcher. This study set the model to gather words in θ_{B} with the proportion or weight as $\lambda_{\mathrm{B}} = 0.95$. As most of the data of the patent documents in this study were 300–500 words, with many words scattered, and the more frequent words were only concentrated in a few words, a larger λ_{B} value could be set. Because this study hopes to identify more specific themes, we set the λ_{C} value as $\lambda_{\mathrm{C}} = 0.4$ with the hope of making a specific theme value of a larger difference. In addition, we also set the other two sets of parameters. One set was $\lambda_{\mathrm{B}} = 0.95$, $\lambda_{\mathrm{C}} = 0.4$ and the other set was $\lambda_{\mathrm{B}} = 0.95$, $\lambda_{\mathrm{C}} = 0.6$ to contrast whether the results were subject to change when the parameter was different and to compare with our experimental results.

Table 1 Top ten key words of each theme

keyid	Common1	keyid	Common2
偏 振 片 (Polarizer)	0.037229	緩 衝 區 (Buffer)	0.024247
廣 視 角 (Wide Perspective)	0.01986	最 大 數 (Maximum Number)	0.013471
視 角 膜 (Perspective Film)	0.01986	合 會 (RCAs)	0.013344
靜 態 影 像 (Static Image)	0.013374	管 理 資 訊 (Management Information)	0.009685
替 代 性 (Alternative)	0.012145	界 線 (Boundary)	0.00899
占 卜 (Divination)	0.011866	薪 資 (Salary)	0.008648
圖 案 (Pattern)	0.01143	數 位 內 容 (Digital Content)	0.007228
管 理 中 心 (Management Center)	0.009016	通 行 碼 (Pass Code)	0.007136
安 全 模 組 (Security Module)	0.008354	光 罩 (Mask)	0.007071
色 度 (Chroma)	0.007779	記 憶 體 管 理 (Memory Management)	0.006225
keyid	**Common3**	**keyid**	**Common4**
運 動 (Movement)	0.103633	物 件 (Object)	0.191586
柱 形 (Columnar)	0.080316	串 流 (Streaming)	0.131786
字 體 (Font)	0.076037	像 素 (Pixels)	0.121299
積 分 器 (Integrator)	0.065446	媒 體 (Medium)	0.111169
端 面 (End)	0.055025	像 框 (Frame)	0.077681
預 測 值 (Predictive Value)	0.051258	參 數 (Parameter)	0.067922
凹 面 鏡 (Concave Mirror)	0.028581	相 機 (Camera)	0.065405
預 測 誤 差 (Prediction Error)	0.02445	區 段 (Section)	0.063112
集 成 (Integrated)	0.020575	序 列 (Sequence)	0.050709
射 角 (Angle)	0.017725	鏡 頭 (Shot)	0.046344

Table 1 shows $P(w|\theta_i)$ (i = 1, 2, 3, 4) of the top ten words. According to the original model common theme $P(w|\theta_i)$ can be used to describe the clustering of the themes, thereby locating the high strength words of the common theme to help describe the theme. The θ_1 keywords are the words related to the visual images, θ_2 are the words related to digital content management, θ_3 are the words for processing method for image perspective, and θ_4 are the words related to the digital content image data transmission method. All of these words continue to appear and have the power of identification. So we can based on the description of each theme filter out wanted keywords content

5 Conclusion and Future Research

From the study results, we can successfully find the emerging words of low-frequency in the past, which is different from the previous relevant studies with patent retrieval analysis focusing on the obvious and important words, while these obvious but important emerging words can help enterprises make accurate search to look for patent documents of emerging technologies or help enterprises by providing another possible direction for future research and development. We hope to take this approach to provide another keyword search method on the patent retrieval analysis. This method can help enterprises save a lot of labor costs in finding the answer they want from a large amount of patent documents content. The emerging words search is different from the past general data mining. The occurrences of emerging technologies are fast and rising rapidly so when carrying out trend analysis we should focus on words that first appeared but not obviously.

These keywords can help enterprises find the hidden patent documents of emerging technologies, which may also be where the enterprises' emerging technologies are located. Therefore, this study can help make more accurate results for the forecast of emerging technologies.

The literature of the technology gap mentions the use of the principal component analysis to reduce the dimension of the word. We hope the word search method of this study can be added to the empty hole diagram of the technology gap as discussed in the literature. This method can find the technology gap of the patent documents using the scatter diagram of the first principal component and the second principal component. We hope the word search will adopt the words of a common theme that continually appear. With a descriptive significance for the theme, the empty diagram can therefore be integrated to improve the shortcoming that the principal component analysis cannot effectively describe the field.

References

Chen CC, Chen MC, and Chen MS (2005) Liped: Hmm-based life profiles for adaptive event detection

Mei QZ, Zhai CX (2006) A mixture model for contextual text mining, ACM 1-59593-339-5/06/0008

Morinaga S, Yamanishi K (2004) Tracking dynamics of topic trends using a finite mixture model, ACM 1-58113-888-1/04/0008

Perkiom J, Buntine W, and Perttu S (2004) Exploring independent trends in a topic-based search engine

Porter AL, Roper AT, Mason TW et al (1991) Forecasting and management of technology. Wiley, New York

Wu YH, Ding YX, Wang XL et al (2010) Topic Detection by topic model induced distance using biased initiation. Advance in Computer Science and Information Technology

Zhai CX, Velivelli A, Yu B (2004) A cross-collection mixture model for comparative text mining, ACM 1-58113-888-1/04/0008

Making the MOST® Out of Economical Key-Tabbing Automation

P. A. Brenda Yap, S. L. Serene Choo and Thong Sze Yee

Abstract Industrial engineers observe and analyze movements and steps taken by a worker in completing a given task. The data obtained is defined and summed up through coded values to predetermine the motion time of process activities that occur within the production line. Although softwares have been developed to ease the recording and computation of such studies, they are expensive and require trainings to operate. The use of Maynard Operations Sequence Technique (MOST®) system has been recognized as one of the standards for predetermined time calculation. However, the sequential breakdown and movement analysis techniques of this system involving coded values can be complicated, time-consuming and tedious. This is worsened when the production line contains numerous activities with lengthy processes. The objective of this paper is thus to introduce an easy and cost-effective solution that uses simple Microsoft Excel macros key-in method which enables a trained analyst to record, determine and generate a MOST® time study within seconds. Case studies performed have shown that this method speeds up the calculation process at a 50–60 % rate faster than the ordinary individual code definition and tabulation recording method. As such, it has been proven to save time and eliminate the possibility of a miscalculation.

Keywords MOST · Time study · Industrial engineering · Cycle time · Work measurement · Predetermined time studies

P. A. B. Yap (✉) · S. L. S. Choo · T. S. Yee
A1 OPEX.No.25, JalanPuteri 11/8, Bandar PuteriPuchong 47100 Puchong, Malaysia
e-mail: brendayap@gmail.com

S. L. S. Choo
e-mail: slingchoo@hotmail.com

T. S. Yee
e-mail: g1240510789@studentmail.unimap.edu.my

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_52,

1 Introduction

Maynard Operations Sequence Technique (MOST®) is an index coded work measurement system where analyzed actions and processes are recorded down, code assigned and tabulated to provide a predetermined time study. It's a system designed to measure work through movement; an alternative method to using other systems such as MODAPTS (Modular Arrangement of Predetermined Time) or Methods-Time Measurement (MTM) Standards.Developed by H.B Maynard and Company,Maynard Operations Sequence Technique (MOST®) gained a wide reognition in Industrial Engineering practice since 1975 based on the fundamental statistical principles and work measurement data which evolved into a logical and natural way to measure work. Ithas since then, been applied in all sorts of industries ranging from production lines to offices, material handling and even finishing operations.

When basic MOST is applied into an analysis, the actions and movements are categorized according to 3 different sequence models. They are The General Move Sequence, The Controlled Move Sequence and the Tool Used Sequence Model. Each of these models has its sub activities broken down and represented by a series of alphabet indexes. A numbering value index will also be assigned to each alphabet depending on the steps and number of times a movement is repeated. Table 1 shows the basic MOST sequence models of the categorized activities.

2 Defining MOST

MOST uses time units that defined in TMU (Time Measurement Units) whereby 1 TMU is equivalent to 0.00001 h or 0.0006 min or 0.036 s. MOST® works by adding up the total index parameter values which an analyst will assign to the movement/actionand later adding it all up to get the predetermined time in Time Measurement Units (TMU). From there, the total TMU will be converted in order

Table 1 Basic MOST sequence models

Activity	Sequence model	Sub-activities
General move	ABG ABP A	A—action distance B—body motion C—gain control P—placement
Controlled move	ABG MXI A	M—move controlled X—process time I—alignment
Tool used	ABG ABP U ABP A	U—can be replaced with a specific action such as fasten, loosen, cut, surface treatment, measure, record and think.

to get the final time in either minutes or seconds. The index value assigned to each sub-activity has already been set in accordance to a prefixed MOST reference data card which classifies and categorizes the number and types of movements with the index value that an analyst will base on. For example, in a scenario where a skilled operator walks 5 steps to turn on a simple tact button switch by pressing and remain standing there; the MOST® code sequence will be classified as a controlled move with the parameters A B G M X I A. The index value assigned for the parameters are demonstrated in Table 2.

3 Problem Description

While MOST is known to be an efficient method of getting a predetermined time study, it is also complex and tedious in the compilation of data analysis. Thus, by having a handful of procedures, one will tend to make mistakes in observation, recording or even in the tabulation of data.Common human errors that are bound to influence or affect the accuracy of the recordings and most importantly affecting the summation of time values are:

- Fatigue and tiredness
- Loss of focus due to concentration on the video and process analysis
- Complicated processes that require more time and attention of the analyst
- A repeated sequence or action can confuse the analyst in making calculations
- Negligence in calculation

4 Collecting Data and Applying MOST

A certified MOST analyst is able to breakdown the entire process that is being observed and classifying it with parameters as well as assigning index values to each code sequence. The process is long, tedious and can be troublesome at times especially when the process involves complicated and sophisticated movements or activities. In many cases, a video of the entire process is captured and recorded first in order to playback and analyze with the MOST system. The video analysis

Table 2 MOST analysis sample

Activity sequence:	
Walk 5 steps to a machine and turn on the tact switch by pressing it and remain standing there. *Code defined:*	
A10 B0 G1 M1 X0 I0 A0	
$= 10 + 0 + 1 + 0 + 0 = 120$ TMU (1)	(1)
$= 120$ TMU $\times 0.036 = 4.32$ s	(1)

requires the analyst to playback the video in a reduced speed and may even have to repeat the video more than once to determine the significant action(s), eliminating non value added activities and even identifying steps that do not contribute to the efficiency of the process. However, the analyst has to weigh and ration between the identification of steps that are practical eventhough some of it may seem like a waste of time.In an experimental comparison of a certified analyst who used a manual recording method of MOST versus the usage of the MOST Excel sheet to analyze a 15 min video of a production operator at work, the application of the MOST Excel sheet used to produce the final cycle time result and tabulation was 60 % faster compared to the other manual tabulation analysis method.

4.1 Manual Versus Computerized Macros

The advantages of using MOST macros sheet is mainly speed, convenience and accuracy. It is clear that formanual pen-paper writing or individual key-in of parameters and a shortcut key generated parameter; the latter is a very much faster and efficient solution.With the Microsoft Excel macros sheet tabbing method, the shortcut keys assigned to generate the MOST parameter alphabets immediately allows the analyst to generate the string of action codes within seconds and only has to define the index code value to each alphabet. It is also cost-effective in terms of the need to purchase other work measurement software or licenses in the market that provides the same function of doing a time study. The comparisons between manual and macros recording methods these two are mapped out in Table 3 (Table 4).

Table 3 Comparison of MOST recording methods

Manual/single key in MOST	Macros MOST
• Analyst has to remember the alphabet codes to represent the correct action category and what it stands for.	• Sequence parameter alphabet codes are generated immediately by pressing two buttons. Saves time
• If written on paper, errors are harder to be corrected and checking back data will be difficult	• Analyst only requires to remember which shortcut generates which parameter
• Analyst is required to add up the time using a calculator and also make conversion for the unit of time measurement	• Computer generated data makes amendments and check backs easy
• Repeated processes or sequences can be confusing to the assigned analysis; sometimes affecting the tabulation accuracy	• The summation of time are added up and converted in different measurement units automatically
	• The number of a repeated action or sequence of an activity can be easily edited without having to make a recalculation of the data
	• Cost effective. No external/additional software or licensing is required

Table 4 Example of MOST parameters generated using macros sheet

PREDETERMINED TIME STUDY

Customer: | Standard Time (sec): 25.56 | Prepared By:

Product: | Assembly: | UPH: 140 | Date:

No	Method	L/R	MOST CODE	rf	TMU	cf	Total TMU	Time(sec)
1	Move Tray to workbench	R	A_3 B_0 G_1 A_3 B_0 P_1 A_0		80	1	80	2.88
2	Put screw to part	LR	A_1 B_0 G_1 A_1 B_0 P_1 A_0	2	60	1	60	2.16
3		L	A_0 B_0 G_1 A_0 B_0 P_0 A_0		10	1	10	0.36
4	Put Spring on fixture.	R	A_1 B_0 G_1 A_3 B_0 P_1 A_0		60	1	60	2.16
5	Fasten screw	R	A_1 B_0 G_1 A_1 B_0 P_1 A_0		40	1	40	1.44
6		LR	A_0 B_0 G_0 A_1 B_0 P_1 A_0		20	1	20	0.72
7		L	A_0 B_0 G_1 A_0 B_0 P_0 A_0		10	1	10	0.36
8		R	A_0 B_0 G_0 A_0 B_0 P_0 F_{27} A_1 B_0 P_2 A_0		300	1	300	10.80
9	Bend part	R	A_1 B_0 G_1 M_1 X_0 I_0 A_0		40	1	40	1.44
10		R	A_0 B_0 G_1 M_1 X_0 I_0 A_0		20	1	20	0.72
11		L	A_0 B_0 G_0 A_1 B_0 P_1 A_0		20	1	20	0.72
12	Place assembled part to bin	L	A_0 B_0 G_1 A_3 B_0 P_1 A_0		50	1	50	1.80

5 Macros Predetermined Time Sheet In Detail

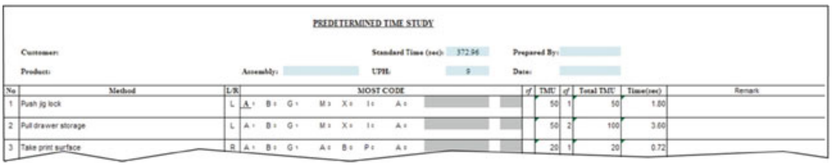
Microsoft Excel's Macros function allows the user to set certain functions as part of a 'pre-recorded' memory to be used so that the user does not have to retype the same data when needed over again. The key-tabbing shortcut method in Microsoft Excel's MOST sheet is programmed to generate a series of MOST parameter sequence according to the analyzed actions. It is a simple excel sheet that contains allocated columns for the recording of actions with assigned shortcut keys for the MOST parameter to be called out within seconds. After which, the user will key in the value codes for each alphabet and the total TMU and converted seconds will be automatically added up in another column respectively. In the event a particular alphabet is not used or does not have any value in its string of MOST alphabets sequence, the analyst may eliminate the inclusion of the alphabet just by keying in the assigned value as zero ('0'). The top part of the sheet contains indicators to fill in information such as the person in charge, customer, product, unit per hour (UPH), standard time, type of assembly and date. The second part of the sheet contains columns to be filled in with details and only the MOST code column preset with macros shortcut keys.

5.1 Colour Coded Indicator

Whenever a particular action or movement is repeated more than once; the analyst will key in the number of times an additional action is repeated below the alphabet code index and the value of the alphabet will automatically multiply itself with the additional number of times an action is made. The index colour will then turn yellow to indicate where the additional value is assigned from. This method also saves time for the analyst so that a repeated keying in of the whole action is not needed (Fig. 1).

5.2 *Macros Shortcut Keys*

The macros parameter shortcut keys that are assigned according to the appropriate parameters will generate in the MOST code column of the macros sheet by pressing two assigned keys at the same time. They are (Table 5):



Columns	Definition
No.	To fill in the step or procedure numbering
Method	The methods or actions that are being observed are recorded here
L/R	To record down whether left or right hand or both hands are used in this process
MOST	The parameter and index value codes are keyed and defined here
rf	Abbreviation for 'repeat frequency'. The number of times a specific action or movement is keyedin here to multiply the repeated action(s).
TMU	Time Measurement Unit.
cf	Abbreviation for 'cycle frequency'. The number of times a full cycle of a repeated action or sequence is keyed in here to multiply the a whole repeated cycle.
Total TMU	Total Time Measurement Unit (after the inclusion of '*cf*' or '*rf*')
Seconds	Conversion of total time from TMU to seconds
Remarks	Additional notes or comments can be recorded in this coloumn

Fig. 1 Macros MOST excel sheet columns

Table 5 Sequence shortcut keys

Shortcut Keys	Sequence parameter generated
Ctrl + d	General move
Ctrl + q	Tool use sequence
Ctrl + l	Controlled move sequence

6 Conclusion

With the utilization and application of macros MOST predetermined sheet method, the work of an industrial engineer for a predetermine time study recording is made convenient and simplified. Doing a time study analysis requires focus and concentration that only becomes accurate if broken down and analyzed properly. As human mistakes are bound to happen, using ways that can minimize the tendency of carelessness helps to produce effective results in a short amount of time. In addition, the MOST predetermined sheet method is a tool that can help to save cost without the need to use a pen and paper or the requirement to purchase an additional software and license to produce the same time study result.

Integer Program Modeling of Portfolio Optimization with Mental Accounts Using Simulated Tail Distribution

Kuo-Hwa Chang, Yi Shou Shu and Michael Nayat Young

Abstract Since Markowitz introduced mean–variance portfolio theory, there have been many portfolio selection problems proposed. One of them is the safety-first portfolio optimization considering the downside risk. From behavioral portfolio theory, investors may not consider their portfolios as a whole. Instead, they may consider their portfolios as collections of subportfolios over many mental accounts. In this study, we present a mixed-integer programming model of portfolio optimization considering mental accounts (MAs). In this study, varied MAs are described by different level of risk-aversion. We measure the risk as the probability of a return failing to reach a threshold level, called the downside risk. An investor in each MA specifies the threshold level of return and the probability of failing to reach this return. Usually the portfolio's returns are assumed as normally distributed, but this move may underestimate the downside risks. Accordingly, we estimate the downside risk by using models utilizing extreme-value theory and copula. We generate scenarios of the tail distribution based on this model, on which the mixed-integer program is applied. In the end, we use historical data to back test our model and the results are consistent with what they expected. These actions result in a better understanding of the relation between investor goals and portfolio production, and portfolio optimization.

Keywords Integer programming · Simulation model · Portfolio optimization · VaR

K.-H. Chang (✉) · Y. S. Shu · M. N. Young
Department of ISE, Chung Yuan Christian University, Chung Li, 302, Taiwan, ROC
e-mail: kuohwa@cycu.edu.tw

Y. S. Shu
e-mail: g10074035@cycu.edu.tw

M. N. Young
e-mail: g10174053@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_53,

1 Introduction

The behavior of people in terms of their investments has been a hot topic for research throughout the years. From the initial findings of Friedman and Savage (1948) Insurance-Lottery Framework to the (Das et al. 2010) Mental Accounting Framework (MA), investors tend to behave based on personal goals and aspirations (Friedman and Savage 1948). Insurance-Lottery Framework study started it all, they found out that certain people are risk seeking enough to buy lottery tickets for their financial aspiration and also risk averse enough to buy insurances for their financial security. Markowitz (1952) followed it with his Mean–Variance Theory (MVT) which is based from the expected utility theory and extended the Insurance-Lottery framework, wherein people who practice MVT don't buy lottery tickets as they are more risk averse. Shefrin and Statman (2000) followed suite with their goal based Behavioral Portfolio Theory (BPT), wherein investors divide their money into different mental layers with associated risk level tolerance within a portfolio. Each layer corresponds to a specific goal of the investor like retirement security, college education plans, and travel aspirations. Recently, Das et al. (2010) combined key aspects of MVT and the mental accounts of BPT to developed MA, but, similar to previous works, they assumed portfolio returns are normally distributed.

The foundation of BPT lies in (Lopes 1987) Safety First Portfolio Theory (SP/A Theory) and (Kahneman & Tversky 1979) Frame Dependence which are both developmental studies of the Insurance-Lottery Framework. SP/A Theory and Frame Dependence are all about how to deal with the risk threshold and framework of each investor to beat the inefficient market. These studies greatly impacted the Finance world in the 1990s which led to the formation of Behavioral Finance and BPT. In BPT, investors view their portfolio not as a whole but as a collection of several mental accounts that are associated with specific goals and varying risk attitude for each mental account. Investors can treat one mental account as their way to have protection from being poor, while other mental accounts as their tactic to have the opportunity to be rich.

In this study, we describe varied MAs by different level of risk-aversion. We measure the risk as the probability of a return failing to reach a threshold level, which is called the downside risk. An investor in each MA specifies the threshold level of return and the probability of failing to reach this return. Usually the portfolio's returns are assumed as normally distributed, but this move may underestimate the downside risks. Accordingly, we estimate the downside risk by using simulated tail distribution utilizing extreme value theory (EVT) and copula developed in (Chang and Wang 2012). We generate scenarios based on distribution, on which the mixed-integer program will be applied. In the end, we use historical data to back test our model.

2 Model Formulation

To further study BPT, we consider the following Telser's safety-first model model (Telser 1955):

$$\begin{aligned} & Max \quad E_h(W) \\ s.t. \quad & P(W < A) \le \alpha \end{aligned} \tag{1}$$

where $E_h(W)$ is the expected wealth under the transformed decumulative function which is mentioned in Lopes and Oden (1999), A is the minimum acceptable rate of return, and α is the risk threshold or the probability that the occurring return fall on the lower end of the acceptable risk.

In BPT, risk is measured as the probability of a return failing to reach a threshold level, called the downside risk. There are a lot of ways to estimate the probability. In this study, we are going to use the scenario data to estimate the risk based on a simulation model. Usually the portfolio's returns are assumed as normally distributed, but in practice, findings from past studies say that this is not the case. The rate of returns usually has heavy-tailed properties, so using normal distribution will underestimate the risk of incidence. Accordingly, to handle this problem, we adopt the model in Chang and Wang (2012), we consider heavy-tailed distribution by incorporating the EVT and the copula structure to the Monte Carlo Simulation to generate scenarios to be used as the focal point of this study.

There are $n$assets and $g$mental accounts. There are $m$generated scenarios. We define the variables as follows:

$w_{i,k}$	denote the percentage of wealth invested on asset i in mental account k, $i = 1, 2, \ldots, n$, $k = 1, 2, \ldots, g$
$r_{ij,k}$	denote the return of asset i in simulated scenario j in mental account k, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$, $k = 1, 2, \ldots, g$
$p_{j,k}$	denote the probability that simulated scenario j will occur in mental account k, $j = 1, 2, \ldots, m$, $k = 1, 2, \ldots, g$
$\overline{r}_i$	denote the mean return of asset i, $i = 1, 2, \ldots, n$
$R_{p,k} = \sum_{i=1}^{n} w_{i,k} r_{ij,k}$	denote the return of the portfolio in mental account k, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$, $k = 1, 2, \ldots, g$
$\overline{R}_{p,k} = \sum_{i=1}^{n} w_{i,k} \overline{r_i}$	denote the expected return of the portfolio in mental account k, $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$, $k = 1, 2, \ldots, g$
$R_{L,k}$	denote the tolerance level on return rate that investor desires in mental account k, $k = 1, 2, \ldots, g$
α_k	denote the acceptable probability of the return failing to reach the threshold level in mental account k, $k = 1, 2, \ldots, g$

For mental account k, the corresponding (1) is

$$\begin{aligned} & Max \quad \overline{R}_{p,k} \\ s.t. \quad & P(R_{p,k} < R_{L,k}) \le \alpha_k \end{aligned} \tag{2}$$

By Norkin and Boyko (2010), we can rewrite the constraints as follows:

$$\begin{aligned} & Max \quad \overline{R}_{p,k} \\ s.t. \quad & \sum\nolimits_{j=1}^{m} p_{j,k} z_{j,k} \le \alpha_k \end{aligned} \tag{3}$$

$$R_{L,k} - R_{p,k} \le (M + R_{L,k}) z_{j,k} \tag{4}$$

where $z_{j,k} \in \{0, 1\}$ and M is approaching to infinity.

To be more practical, the portfolio should be presented in the number of shares or units purchased on the assets. Let $x_{i,k}$ be the numbers of units of asset i purchased in portfolio in account k. If S_i is the initial price of asset i and we have initial capital b_k for account k, so the percentage of wealth on asset i in account k is

$$w_{i,k} = \frac{x_{i,k} \times S_i}{b_k} \tag{5}$$

We assume that the probabilities that simulated scenario j will occur, $p_{j,k}$, are equiprobable, so the constraint (3) can be written in

$$\sum\nolimits_{j=1}^{m} z_{j,k} \le \alpha_k \times m \tag{6}$$

where m is the total number of the simulated data.

In this setting, let $C_k = R_{L,k} \times b_k$ be the tolerance level on the loss from b_k. After writing $w_{i,k}$ in terms of $x_{i,k}$ and writing $R_{L,k}$ in term of C_k and adding the bounds on initial capital, our model is as follows.

$$\begin{aligned} & Max \quad \sum_{i=1}^{n} x_{i,k} \overline{r}_i S_i \\ s.t. \quad & \sum\nolimits_{j=1}^{m} z_{j,k} \le \alpha_k \times m \end{aligned} \tag{7}$$

$$C_k - \sum\nolimits_{i=1}^{n} x_{i,k} r_{ij,k} S_i \le (M + C_k) z_{j,k} \tag{8}$$

$$\sum\nolimits_{i=1}^{n} x_{i,k} S_i \le b_k \tag{9}$$

$$\sum\nolimits_{k=1}^{g} b_k \le B \tag{10}$$

$$x_{i,k} \ge 0, integer, \quad i = 1, 2, \ldots, n,\ k = 1, 2, \ldots, g$$

$$z_{j,k} \in \{0, 1\}, \quad j = 1, 2, \ldots, m,\ k = 1, 2, \ldots, g$$

where B is the total initial capital.

We then use this integer programming model to solve for the optimal portfolios.

3 Results and Analysis

We use the stocks of the MSCI Taiwan Index Top 20 largest constituents, and through the use of the Taiwan Economic Journal (TEJ) we get those stocks that falls after a week of the announcement of dividends. We calculate 102 portfolios from October 2010 to September 2012, and each portfolio uses 200 returns from the historical data. We use the data collected from November 2006 to September of 2012 to adjust and balanced the effect of the rate of returns. We then integrated the 200 original data to the pair-copula structure and simulated 20,000 scenarios. With reference to the EVT and the scenarios numerical distribution we were able to develop the model to solve for the optimal portfolios.

We consider that investors have 3 mental accounts with the parameters shown below :

"Weight" represents the proportion of wealth invested in the respective account. From the Table 1, Accounts 1 and 2 have the same risk threshold level but different return expectations, accounts 2 and 3 have different risk threshold levels but have similar return expectations. We then use different methods to study the investment returns.

First, we look at the accounts' means and standard deviations and at the same time compare them with the Market values as shown below :

In Table 2, we can see that account 1 has the least standard deviation and also outperforms the market. Similarly, Account 1 has the best mean return and outperforms the market. We can then observe the distribution of the returns in Fig. 1.

From Fig. 1, we can see that there is smaller volatility in Account 1 and Aggregate account. Then we can analyze the cumulative distribution of the returns through Fig. 2.

From Fig. 2, with the set of parameters in Table 1 it is clear that each account has a smaller probability of getting bad returns compared to the Market, especially in Account 1 and Aggregate account which gave the best performances.

Similar to the study in Chang and Wang (2012), we use following 3 cases (−,−), (+,−) and (−,+) to represent the returns of the accounts and the Market. (−,−) indicates that the account and market return rates are both negative. (+,−) indicates

Table 1 Parameter settings

	Account 1 (%)	Account 2 (%)	Account 3 (%)
R_L	−3	−5	−5
α	7.5	7.5	10
Weight	40	30	30

Table 2 Mean and standard deviation comparison

	Account 1	Account 2	Account 3	Aggregate	Market
Mean	0.002999	0.002412	0.00117	0.002273	−0.00017
Standard Deviation	0.018376	0.027671	0.02835	0.023487	0.025825

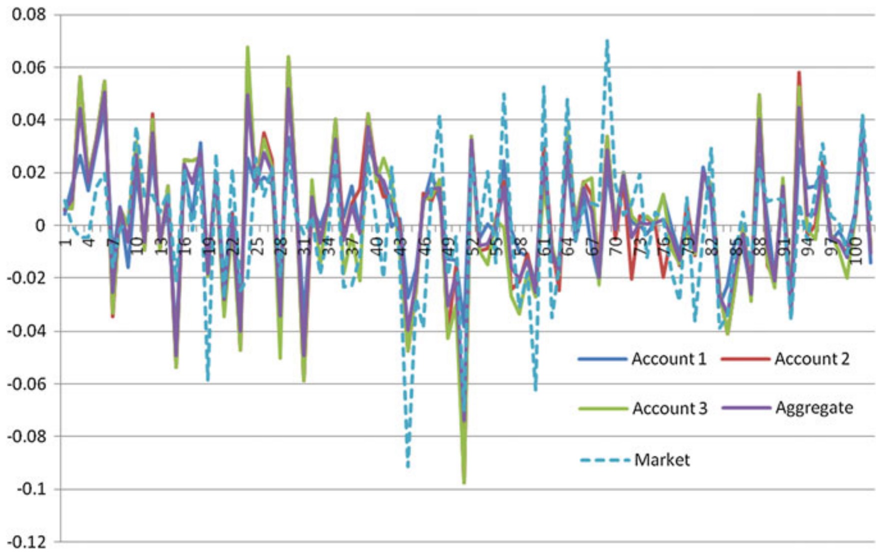


Fig. 1 Portfolio rate of return

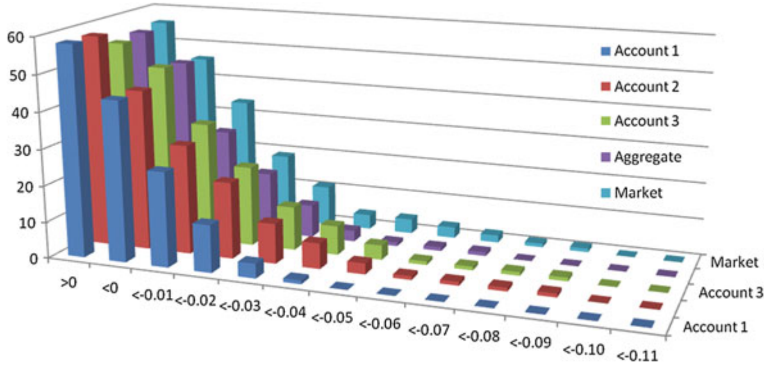


Fig. 2 Returns cumulative distribution map

that the account has positive returns, while the market has negative returns. (−,+) indicates that the account has negative returns, while the market has positive returns. The case (+,+) wherein both the market and the account have positive returns is not risky so it was excluded from the comparison. Using these 3 cases the summaries of the comparison are shown in Tables 3 and 4.

Finally we have geometric long term cumulative returns in Fig. 3:

From Fig. 3 it is clear that each account's rate of returns outperforms the Market and that each account has positive returns compared to the market with negative returns.

Table 3 Account 1 versus market & account 2 versus market

	Account 1	Market	Account 2	Market
(−,−)	25	8	17	15
(+.−)	13	0	14	0
(−, +)	0	11	0	12
Total	38	19	31	27

Table 4 Account 3 versus market & aggregate versus market

	Account 3	Market	Aggregate	Market
(−,−)	16	18	19	15
(+.−)	12	0	12	0
(−,+)	0	14	0	13
Total	28	32	31	28

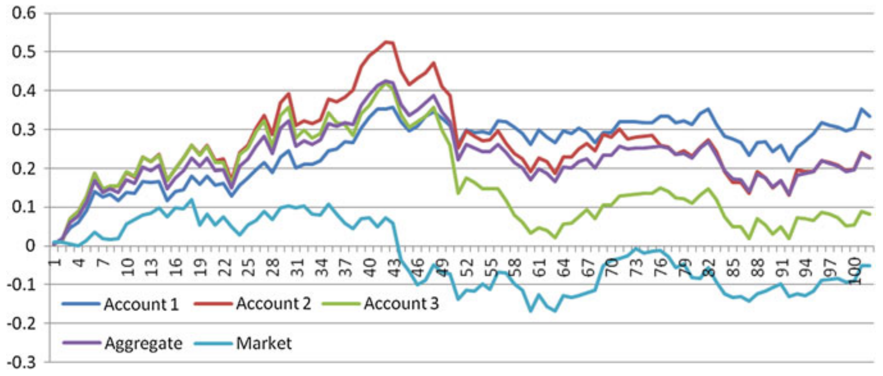


Fig. 3 Geometric long term cumulative returns

4 Conclusions

The main contribution of this study is to combine the mental accounting portfolio optimization with the safety-first model. We use mixed integer programming to find the optimal portfolios. Through the back test, it shows that the performances of the 3 accounts are within the pre-determined risk threshold and that the integrated portfolio performances are superior in all aspects of the market. These results supported our model in terms of obtaining optimal portfolios. To have a possibly more accurate portfolio, future studies should consider having varying occurrence probability for the returns and also allow short selling.

References

Chang KH, Wang ZJ (2012) Safety-first optimal portfolio with approximated bound on one-sided risk using simulated tail distribution. Working paper, Department of Industrial and Systems Engineering, Chung-Yuan Christian University

Das S, Markowitz H, Scheid J, Statman M (2010) Portfolio optimization with mental accounts. J Fin Quant Anal 45(2):311–334

Friedman M, Savage LJ (1948) The utility analysis of choices involving risk. J Polit Econ 56(4):279–304

Jiang CH, Ma YK, An YB (2013) International portfolio selection with exchange rate risk: a behavioral portfolio theory perspective. J Bank Finance 37:648–659

Kahneman D, Tversky A (1979) Prospect theory: an analysis of decision under risk. Econometrica 47(2):263–291

Lopes LL (1987) Between hope and fear: the psychology of risk. Adv Exp Soc Psychol 20:255–296

Lopes LL, Oden GC (1999) The role of aspiration level in risky choice: a comparison of cumulative prospect theory and SP/A theory. J Math Psychol 43:286–313

Markowitz H (1952) Portfolio selection. J Finance 7:77–91

Norkin V, Boyko S (2010) On the safety first portfolio selection. Working paper, Glushkov Institute of Cybernetics, National Academy of Science of Ukraine

Shefrin H, Statman M (2000) Behavioral portfolio theory. J Fin Quant Anal 35(2):127

Telser LG (1955) Safety-first and hedging. Rev Econ Stud 23:1–60

Simulated Annealing Algorithm for Berth Allocation Problems

Shih-Wei Line and Ching-Jung Ting

Abstract Maritime transport is the backbone of global supply chain. Around 80 % of global trade by volume is carried by sea and is handled by ports worldwide. The fierce competition among different ports forces the container port operators to improve the terminal operation efficiency and competitiveness. This research addresses the dynamic and discrete berth allocation problem (BAP) which is critical to the terminal operations. The objective is to minimize the total service times for vessels. To solve the NP-hard BAP problem, we develop a simulated annealing (SA) algorithm to obtain the near optimal solutions. Benchmark instances from the literature are tested for the effectiveness of the proposed SA and compared with other leading heuristics in the literature. Computational results show that our SA is competitive and find the optimal solutions in all instances.

Keywords Berth allocation problem · Simulated annealing · Container port

1 Introduction

Maritime transportation has been an important component of the international trade since the introduction of the container in the 1950s. There are more than 8.4 billion tons of goods carried by ships annually (UNCTAD 2011). Due to the growth of the ocean shipping demand, shippers and carriers would expect to speed

S.-W. Line (✉)
Department of Information Management, Chang Gung University, Kwei-Shan, Taoyuan, 33302, Taiwan, Republic of China
e-mail: swlin@mail.cgu.edu.tw

C.-J. Ting
Department of Industrial Engineering and Management, Yuan Ze University, Chung-Li, 32003, Taiwan, Republic of China
e-mail: ietingcj@saturn.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_54,

up their operations at the port stop. Thus, how to provide efficient and cost-effective services by using the limited port resources becomes an important issue for port authority. Among the port operations, berth allocation problem (BAP) that assign the berth positions to a set of vessels with the planning horizon to minimize the total service time catch both practical and academic attention.

The BAP has been tackled in both spatial and temporal variations: (1) discrete versus continuous; (2) static versus dynamic arrival times (Bierwirth and Meisel 2010). In the discrete case, the quay is divided into several berths and exactly one vessel can be served at a time in each berth. In the continuous case, there is no partition of the quay and vessels can moor at any position. A static BAP assumes that all vessels already in port before the berth allocation is planned, while the dynamic case allows vessels to arrive at any time during the planning horizon with known arrival information. The dynamic and discrete BAP that is known to be NP-hard (Cordeau et al. 2005) is the main focus of this paper. We propose a simulated algorithm to solve the dynamic and discrete BAP.

The remainder of the paper is organized as follows. Section 2 presents a brief literature review about the BAP. The proposed simulated annealing algorithm is presented in Sect. 3. In Sect. 4, computational experiments are performed and compared with the promised heuristics from the literature. Finally, our conclusion is summarized in Sect. 5.

2 Literature Review

Both the discrete and continuous BAP in various models have been proposed in the literature; however, most studies address the discrete BAP. Steenken et al. (2004), Stahlbock and Voß (2008) and Bierwirth and Meisel (2010) provided comprehensive overviews of application and optimization models in this field. In this paper, we will address the discrete BAP and only briefly review continuous BAP.

Imai et al. (1997) formulated a static BAP as a nonlinear integer programming model to minimize the weighted objectives which include berth performance and dissatisfaction. Imai et al. (2001) studied a dynamic BAP whose objective was to minimize the sum of waiting and handling times of all vessels. A Lagrangian relaxation based heuristic was proposed to solve the problem. Nishimura et al. (2001) extended the dynamic BAP with multi-water depth configuration. A genetic algorithm (GA) was developed to solve the problem. Imai et al. (2003) considered a dynamic BAP that vessels have different service priorities. The authors also proposed a GA to solve the problem.

Cordeau et al. (2005) addressed a dynamic BAP with time windows based on data from a terminal in the port of Gioia Tauro. The problem was formulated as a multiple depot vehicle routing problem with time windows (MDVRPTW), and solved by a tabu search algorithm. Imai et al. (2007) analyzed a two-objective BAP which minimizes service time and delay time. They proposed a Lagrangian relaxation with subgradient optimization and a GA to identify the non-inferior solutions. Hansen et al. (2008) extended Imai et al.'s (2003) model and developed a variable neighborhood search heuristic to solve it. Imai et al. (2008) studied a variant of the dynamic BAP in which an external terminal was available when the berth capacity is not enough.

Mauri et al. (2008) proposed a hybrid column generation algorithm to solve the MDVRPTW model in Cordeau et al. (2005). Barros et al. (2011) developed and analyzed a berth allocation model with tidal time windows, where vessels can only be served by berths during those time windows. Buhrkal et al. (2011) formulated the discrete BAP as a generalized set partitioning problem (GSPP). Their computational results provided the best optimal solutions for comparison in later research. de Oliveira et al. (2012b) applied a clustering search method with simulated annealing to solve the discrete BAP.

Lim (1998) was the first one to study the continuous BAP whose berths can be shared by different vessels. The problem was modeled as a restricted form of the 2-dimensional packing problem. Li et al. (1998) and Guan et al. (2002) modeled the continuous BAP as a machine scheduling problem with multiprocessor tasks. Park and Kim (2003) formulated a mixed integer programming model for the continuous to minimize the penalty cost associated with service delay and a non-preferred location. A Lagrangian relaxation with subgradient optimization method was developed to solve the problem. Kim and Moon (2003) formulated the continuous BAP as a mixed integer linear programming model and proposed a simulated annealing algorithm to solve it. Imai et al. (2005) enhanced their previous discrete BAP to a continuous BAP and proposed a heuristic for the problem. Wang and Lim (2007) proposed a stochastic beam search algorithm to solve the BAP in a multiple stage decision making procedure.

Tang et al. (2009) proposed two mathematical models and developed an improved Lagrangian relaxation algorithm to solve the continuous BAP at the raw material docks in an iron and steel complex. Lee et al. (2010) developed two greedy randomized adaptive search procedure (GRASP) heuristics for the continuous BAP. Seyedalizadeh Ganji et al. (2010) applied a GA to solve the problem proposed by Imai et al. (2005). Mauri et al. (2011) proposed a memetic algorithm to solve the continuous BAP. De Oliveira et al. (2012a) presented a clustering search method with simulated annealing heuristic to solve the continuous BAP.

3 Simulated Annealing Algorithm

The simulated annealing (SA) reaching a (near) global optimum during the search process mimics the crystallization cooling procedure (Metropolis et al. 1953; Kirkpatrick et al. 1983). SA first generates a random initial solution as an incumbent solution. The algorithm moves to a new solution from the predetermined neighborhood of the current solution. The objective function value of the new solution is compared to the current one to determine whether the new solution is better. If the objective function value of a new solution is better than that of the incumbent one, then the new solution is automatically accepted, and becomes the incumbent solution from which the search will continue. The procedure then continues with the next iteration. A worse objective function value for the new solution may also be accepted as the incumbent solution under certain conditions. By accepting a worse solution, the procedure may escape from the local optima.

A solution is represented by a string of numbers consisting of a permutation of n ships denoted by the set $\{1, 2, \ldots, n\}$ and $m - 1$ zeros for separating ships into m berths. The numbers between two zero are the sequence of the vessels that will be served by a berth. The completion time of each ship in the berth can be easily calculated according to its arrival time, the sequence in the berth, and the availability of the berth. If an infeasible solution is obtained, a penalty will be added to the objective function. We generate the initial solution based on first-come-first-serve of vessels' arrival times. Each ship is sequentially positioned to the berth which can provide the shortest completion time for the current assigned ship. After the initial solution X is obtained, a local search procedure is applied to improve X. The local search procedure applies swap moves and insertion moves to X sequentially.

To obtain a better solution, best-of-g-trial moves that choose the best solution among g neighborhood solutions as the next solution are also performed. At each iteration, a new solution Y is generated from the neighborhood of the current solution X, $N(X)$, and its objective function value is evaluated. Let $\Delta = \text{obj}(Y) - \text{obj}(X)$. If $\Delta \leq 0$, the probability of replacing X with Y is 1; otherwise it is based on another random generated probability and $T/(T^2 + \Delta^2)$, where T is the current temperature. T is reduced after running I_{iter} iterations from the previous decrease, according to the formula $T = \alpha T$, where $0 < \alpha < 1$. After each temperature reduction, a local search procedure is used to improve X_{best}, the best solution found so far. We use swap moves and insertion moves to X_{best} sequentially in the local search.

4 Computational Results

The proposed SA was implemented using the C language in Windows XP operating system, and run on a personal computer with an Intel Core 2 2.5 GHz CPU and 2G RAM. Each instance was solved using 10 runs of the proposed approach. The performance of the proposed SA_{RS} heuristic was compared with other existing algorithms for DBAP, namely tabu search (T^2S) (Cordeau et al. 2005), population training algorithm with linear programming (PTA/LP) (Mauri et al. 2008), clustering search (CS) approach (de Oliveira et al. 2012b). The benchmark instances of Cordeau et al. (2005) were used in this study. The instances were randomly generated based on data from the port of Gioia Tauro (Italy). The instances may be categorized as two sets, I2 and I3. The I2 set includes five instance sizes: 25 ships with 5, 7, and 10 berths; 35 ships with 7 and 10 berths and a set of 10 instances generated for each size. The I3 set includes 30 instances with 60 ships and 13 berths.

Table 1 Computational result for I2 problem set

Instance	GSPP		T^2S	SA		
	Opt.	Time	Best	Best	Avg.	Time
25 × 5_1	759	5.99	759	759	759.0	0.03
25 × 5_2	964	3.70	965	964	964.0	0.27
25 × 5_3	970	2.95	974	970	970.0	1.02
25 × 5_4	688	2.72	702	688	688.0	0.10
25 × 5_5	955	6.97	965	955	955.0	0.66
25 × 5_6	1,129	3.10	1,129	1,129	1,129.0	0.01
25 × 5_7	835	2.31	835	835	835.0	0.01
25 × 5_8	627	1.92	629	627	627.0	0.03
25 × 5_9	752	4.76	755	752	752.0	0.08
25 × 5_10	1,073	6.38	1,077	1,073	1,073.3	8.75
25 × 7_1	657	3.62	667	657	657.0	0.00
25 × 7_2	662	3.15	671	662	662.0	0.02
25 × 7_3	807	4.28	823	807	807.0	0.29
25 × 7_4	648	3.78	655	648	648.0	0.31
25 × 7_5	725	3.85	728	725	725.0	0.02
25 × 7_6	794	3.60	794	794	794.0	0.01
25 × 7_7	734	3.54	740	734	734.0	0.21
25 × 7_8	768	3.93	782	768	768.0	0.07
25 × 7_9	749	3.73	759	749	749.0	0.02
25 × 7_10	825	3.82	830	825	825.0	0.02
25 × 10_1	713	5.83	717	713	713.0	0.04
25 × 10_2	727	6.99	736	727	727.0	0.13
25 × 10_3	761	6.12	764	761	761.0	0.33
25 × 10_4	810	5.38	819	810	810.0	0.72
25 × 10_5	840	6.77	855	840	840.0	0.07
25 × 10_6	689	5.57	694	689	689.0	0.01
25 × 10_7	666	5.83	673	666	666.0	0.00
25 × 10_8	855	5.87	860	855	855.0	0.01
25 × 10_9	711	5.38	726	711	711.0	0.16
25 × 10_10	801	5.96	812	801	801.0	0.04
35 × 7_1	1,000	12.57	1,019	1,000	1,000.1	5.35
35 × 7_2	1,192	15.93	1,196	1,192	1,192.8	13.33
35 × 7_3	1,201	7.16	1,230	1,201	1,201.0	2.93
35 × 7_4	1,139	13.59	1,150	1,139	1,139.0	1.25
35 × 7_5	1,164	11.50	1,179	1,164	1,164.3	3.39
35 × 7_6	1,686	29.16	1,703	1,686	1,686.4	11.72
35 × 7_7	1,176	12.89	1,181	1,176	1,176.0	1.95
35 × 7_8	1,318	17.52	1330	1,318	1,318.1	4.44
35 × 7_9	1,245	8.41	1,245	1,245	1,245.0	0.76
35 × 7_10	1,109	14.39	1,130	1,109	1,109.1	4.00
35 × 10_1	1,124	19.98	1,128	1,124	1,124.0	0.33
35 × 10_2	1,189	11.37	1,197	1,189	1,189.0	5.64
35 × 10_3	938	8.97	953	938	938.0	0.13

(continued)

Table 1 (continued)

Instance	GSPP		T^2S	SA		
	Opt.	Time	Best	Best	Avg.	Time
35 × 10_4	1,226	10.28	1,239	1,226	1,227.1	16.21
35 × 10_5	1,349	22.31	1,372	1,349	1,349.0	0.95
35 × 10_6	1,188	10.92	1,221	1,188	1,188.0	0.39
35 × 10_7	1,051	9.74	1,052	1,051	1,051.0	0.33
35 × 10_8	1,194	9.39	1,219	1,194	1,194.0	0.08
35 × 10_9	1,311	29.45	1,315	1,311	1,311.0	2.30
35 × 10_10	1,189	14.28	1,198	1,189	1,189.0	0.05
Average	953.7	8.60	963.0	953.7	953.7	1.78

Table 2 Computational result for I3 problem set

Inst.	GSPP		T^2S	PTA/LP		CS		SA		
	Opt.	Time	Best	Best	Time	Best	Time	Best	Avg.	Time
i01	1,409	17.92	1,415	1,409	74.61	1,409	12.47	1,409	1,409.0	1.03
i02	1,261	15.77	1,263	1,261	60.75	1,261	12.59	1,261	1,261.0	0.05
i03	1,129	13.54	1,139	1,129	135.45	1,129	12.64	1,129	1,129.0	0.18
i04	1,302	14.48	1,303	1,302	110.17	1,302	12.59	1,302	1,302.0	0.09
i05	1,207	17.21	1,208	1,207	124.70	1,207	12.68	1,207	1,207.0	0.07
i06	1,261	13.85	1,262	1,261	78.34	1,261	12.56	1,261	1,261.0	0.00
i07	1,279	14.60	1,279	1,279	114.20	1,279	12.63	1,279	1,279.0	0.96
i08	1,299	14.21	1,299	1,299	57.06	1,299	12.57	1,299	1,299.0	0.30
i09	1,444	16.51	1,444	1,444	96.47	1,444	12.58	1,444	1,444.0	0.22
i10	1,213	14.16	1,213	1,213	99.41	1,213	12.61	1,213	1,213.0	0.11
i11	1,368	14.13	1,378	1,369	99.34	1,368	12.58	1,368	1,368.0	2.16
i12	1,325	15.60	1,325	1,325	80.69	1,325	12.56	1,325	1,325.0	2.51
i13	1,360	13.87	1,360	1,360	89.94	1,360	12.61	1,360	1,360.0	0.04
i14	1,233	15.60	1,233	1,233	73.95	1,233	12.67	1,233	1,233.0	0.05
i15	1,295	13.52	1,295	1,295	74.19	1,295	13.80	1,295	1,295.0	0.00
i16	1,364	13.68	1,375	1,365	170.36	1,364	14.46	1,364	1,364.0	3.15
i17	1,283	13.37	1,283	1,283	46.58	1,283	13.73	1,283	1,283.0	0.02
i18	1,345	13.51	1,346	1,345	84.02	1,345	12.72	1,345	1,345.0	0.00
i19	1,367	14.59	1,370	1,367	123.19	1,367	13.39	1,367	1,367.0	4.49
i20	1,328	16.64	1,328	1,328	82.30	1,328	12.82	1,328	1,328.0	3.31
i21	1,341	13.37	1,346	1,341	108.08	1,341	12.68	1,341	1,341.0	4.79
i22	1,326	15.24	1,332	1,326	105.38	1,326	12.62	1,326	1,326.0	1.16
i23	1,266	13.65	1,266	1,266	43.72	1,266	12.62	1,266	1,266.0	0.06
i24	1,260	15.58	1,261	1,260	78.91	1,260	12.64	1,260	1,260.0	0.07
i25	1,376	15.80	1,379	1,376	96.58	1,376	12.62	1,376	1,376.0	4.75
i26	1,318	15.38	1,330	1,318	101.11	1,318	12.62	1,318	1,318.0	0.46
i27	1,261	15.52	1,261	1,261	82.86	1,261	12.64	1,261	1,261.0	0.09
i28	1,359	16.22	1,365	1,360	52.91	1,359	12.71	1,359	1,359.4	13.53
i29	1,280	15.30	1,282	1,280	203.36	1,280	12.62	1,280	1,280.0	2.48
i30	1,344	16.52	1,351	1,344	71.02	1,344	12.58	1,344	1,344.0	3.80
Avg.	1,306.8	14.98	1,309.7	1,306.9	93.99	1,306.8	12.79	1,306.8	1,306.8	1.66

The computational results for both set of instances are presented in Tables 1 and 2, respectively. The optimal solution was provided by the GSPP model using CPLEX 11 (Buhrkal et al. 2011). The proposed SA is compared with T^2S for the I2 problem set as shown in Table 1. The first three columns show the instances, the optimal solution and the computational time. The results of T^2S and the best and average solution and CPU time of our SA are presented in columns 4–7. Our SA can obtain the optimal solutions in all I2 instances, while T^2S can only find five optimal solutions. Optimal solutions can be obtained in all 10 runs except for only nine instances in which the largest gap is 0.090 %.

Table 2 lists the results of T^2S, PTA/LP, CS and the proposed SA_{WRS} and SA_{RS} heuristics for the I3 problem set. The first three columns show the instances, the optimal solution and the computational time. The results of T^2S and the best and CPU time of PTA/LP and CS are presented in columns 4–8 followed by our SA results. The SA and CS obtain all optimal solutions, whereas PTA/LP cannot reach the optimal solutions in three instances.

5 Conclusions

In this paper we have studied the berth allocation problem with dynamic arrival times. We propose a simulated annealing (SA) heuristic to solve the problem and test our algorithm with two sets of instances. The results are also compared with the optimal and best known solutions from the literature. Computational results indicate that the proposed SA algorithm is fairly effective. Our SA algorithm is able to find all the optimal solutions of the BAP instances. In the future, we can apply the proposed SA algorithm to the continuous BAP in which vessels can berth anywhere along the quayside.

References

Barros VH, Costa TS, Oliveira ACM and Lorena LAN (2011) Model and heuristic for berth allocation in tidal bulk ports with stock level constraints. Comput Ind Eng 60:606–613

Bierwirth C and Meisel F (2010) A survey of berth allocation and quay crane scheduling problems in container terminals. Eur J Oper Res 202:615–627

Buhrkal K, Zuglian S, Ropke S, Larsen J, Lusby R (2011) Models for the discrete berth allocation problem: a computational comparison. Transp Res Part E 47:461–473

Cordeau JF, Laporte G, Legato P, Moccia L (2005) Models and tabu search heuristics for the berth-allocation problem. Transp Sci 39:526–538

de Oliveira RM, Mauri GR, Lorena LAN (2012a) Clustering search heuristics for solving a continuous berth allocation problem. Lect Notes Comput Sci 7245:49–62

de Oliveira RM, Mauri GR, Lorena LAN (2012b) Clustering search for the berth allocation problem. Expert Syst Appl 39:5499–5505

Guan Y, Xiao WQ, Cheung RK and Li CL (2002) A multiprocessor task scheduling model for berth allocation: heuristic and worst-case analysis. Oper Res Lett 30:343–350

Hansen P, Oğuz C, Mladenovic N (2008) Variable neighborhood search for minimum cost berth allocation. Eur J Oper Res 191:636–649

Imai A, Nagaiwa K, Chan WT (1997) Efficient planning of berth allocation for container terminals in Asia. J Adv Transp 31:75–94

Imai A, Nishimura E, Papadimitriou S (2001) The dynamic berth allocation problem for a container port. Transp Res Part B 35:401–417

Imai A, Nishimura E, Papadimitriou S (2003) Berth allocation with service priority. Transp Res Part B 37:437–457

Imai A, Nishimura E, Papadimitriou S (2008) Berthing ships at a multi-user container terminal with a limited quay capacity. Transp Res Part E 44:136–151

Imai A, Sun X, Nishimura E, Papadimitriou S (2005) Berth allocation in a container port: using a continuous location space approach. Transp Res Part B 39:199–221

Imai A, Zhang JT, Nishimura E and Papadimitriou S (2007) The berth allocation problem with service time and delay time objectives. Marit Econ Logistics 9:269–290

Kim KH and Moon KC (2003) Berth scheduling by simulated annealing. Transp Res Part B 37:541–560

Kirkpatrick S, Gelatt CD and Vecch MP (1983) Optimization by simulated annealing. Science 220:671–680

Lee DH, Chen JH and Cao JX (2010) The continuous berth allocation problem: A greedy randomized adaptive search solution. Transp Res Part E 46:101–1029

Li CL, Cai X and Lee CY (1998) Scheduling with multiple-job-on-one-processor pattern. IIE Trans 30:433–445

Lim A (1998) The berth planning problem. Oper Res Lett 22:105–110

Mauri GR, Oliveira ACM and Lorena LAN (2008) A hybrid column generation approach for the berth allocation problem. Lect Notes Comput Sci 4972:110–122

Mauri GR, Andrade LN and Lorena LAN (2011) A memetic algorithm for a continuous case of the berth allocation problem. 2011 International conference on evolutionary computation theory and applications, Paris, France

Metropolis N, Rosenbluth A, Rosenbluth M, Teller A and Teller E (1953) Equation of state calculations by fast computing machines. J Chem Phys 21:1087–1090

Nishimura E, Imai A, Papadimitriou S (2001) Berth allocation planning in the public berth system by genetic algorithms. Eur J Oper Res 131:282–292

Park YM, Kim KH (2003) A scheduling method for berth and quay cranes. OR Spectrum 25:1–23

Stahlbock R and Voß S (2008) Operations research at container terminals: a literature update. OR Spectrum 30:1–52

Steenken D, Voß S, Stahlbock R (2004) Container terminal operation and operations research a classification and literature review. OR Spectrum 26:3–49

Seyedalizadeh Ganji SR, Babazadeh A and Arabshahi N (2010) Analysis of the continuous berth allocation problem in container ports using a genetic algorithm. J Mar Sci Technol 15:408–416

Tang L, Li S, Liu J (2009) Dynamically scheduling ships to multiple continuous berth spaces in an iron and steel complex. Int Trans Oper Res 16:87–107

UNCTAD (2011) Review of maritime transportation. United Nations Conference on Trade and Development

Wang F, Lim A (2007) A stochastic beam search for the berth allocation problem. Decis Support Syst 42:2186–2196

Using Hyperbolic Tangent Function for Nonlinear Profile Monitoring

Shu-Kai S. Fan and Tzu-Yi Lee

Abstract For most of the Statistical process control (SPC) applications, the quality of a process or product is measured by one or multiple quality characteristics. In some particular circumstances, quality characteristics depend on the relationship between the response variable and one and/or explanatory variables. Therefore, such a quality characteristic is represented by a function or a curve, which is called a ‘profile’. In this paper, a new method of using the hyperbolic tangent function will be addressed for modeling the vacuum heat treatment process data. The hyperbolic tangent function approach is compared to the smoothing spline approach when modeling the nonlinear profiles. The vector of parameter estimates is monitored by using the Hotelling’s T^2 for the parametric approach and by the metrics method for the nonparametric approach. In Phase I, the proposed hyperbolic tangent approach is able to correctly identify the outlying profiles.

Keywords Nonlinear profile · Hyperbolic tangent function · Smoothing spline · Hotelling’s T^2

1 Introduction

Statistical process control (SPC) has been widely recognized for quality and productivity improvement in many domains, especially in manufacturing industries. It was pioneered by Walter A. Shewhart in the early 1920s. For most SPC

S.-K. S. Fan (✉) · T.-Y. Lee
Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei City 10608, Taiwan, Republic of China
e-mail: morrisfan@ntut.edu.tw

T.-Y. Lee
e-mail: ritatzu1007@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_55,

applications, the quality of a process or product is measured by one or more quality characteristics. However, in some practical circumstances, the quality characteristic is better characterized by a curve. Such a functional relationship is called a profile. A new economic age is beginning in which the demand for quality is rapidly increasing, with a resulting global competition of companies striving to provide quality products or services. In practice, the aluminum alloy heat treatments are quite difficult to link to an SPC program. Due to its nonlinear data type, some researchers attempted to develop thermal monitoring hardware and SPC software that makes it possible to automatically gather data on the thermal portions on the heat treatment of the aluminum alloy rim process in real time. In this kind of applications, profile monitoring intends to keep watch on the relationship between the response variable and the explanatory variables and then draw inferences about the profile of quality characteristics. There are two distinct phases in profile monitoring. The purpose of phase I analysis is to evaluate the stability of a process, to find and remove any outliers attributed to some potential assignable cause, and to estimate the in-control values of the process parameters. Based on the parameter estimates obtained from phase I, the goal of phase II is to monitor the online data in order to quickly detect any change in the process parameter as possible. To date, the majority of profile monitoring works focus on phase II analysis.

A wide variety of literature has appeared in recent years, demonstrating a growing popularity in profile monitoring. Woodall et al. (2004) gave an excellent overview of the SPC literature regarding profile monitoring. For further discussions on linear profiles, interested readers can be referred to this article. A few references have directly addressed the issues of nonlinear profiles. Basically, nonlinear profile monitoring approaches can be classified two categories: parametric and nonparametric. For example, the parametric approaches include that Williams et al. (2007) addressed the monitoring of nonlinear profiles by considering a parametric nonlinear regression model. Jensen and Birch (2009) proposed a nonlinear mixed model to monitor nonlinear profiles to account for the correlation structure. Fan et al. (2011) proposed a piecewise linear approximation approach to model nonlinear profile data. Chen and Nembhard (2011) used the adaptive Neyman test and the discrete Fourier transform to develop a monitoring procedure for linear and nonlinear profile data. For the nonparametric approaches, Ding et al. (2006) utilized several types of reduction techniques for nonlinear profile data. Moguerza et al. (2007) used support vector machines to monitor the fitted curves instead of monitoring the parameters of models that fit the curves. Zou et al. (2007) discussed profile monitoring via nonparametric regression methods. Qiu et al. (2010) proposed a novel control chart for phase II analysis, which incorporates a local linear kernel smoothing technique into the exponentially weighted moving average (EWMA) control scheme when within-profile data are correlated.

The SPC problem with a nonlinear profile is particularly challenging by nature. Unlike the linear profile, the nonlinear models are different from one case to another. Different models can be used to fit different nonlinear profiles. Jin and Shi (1999) proposed monitoring the tonnage stamping profile by the use of dimension reduction techniques. Ding et al. (2006) proposed using nonparametric procedures

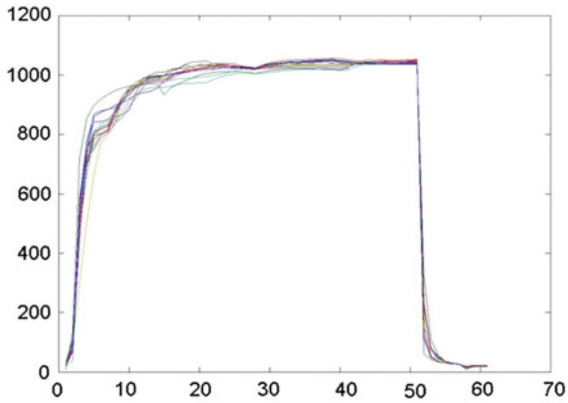


Fig. 1 A typical aluminum alloy rim heat treatment profile

to perform phase I analysis for multivariate nonlinear profiles. They adopted data reduction components that projected the original data onto a subspace of lower dimension while preserving the original data clustering structure. The main goal of this paper is to monitor the heat treatment of aluminum alloy rim process. A set of profile data is obtained from an industrial company in Taiwan. As demonstrated in Fig. 1, the sample data depicts nicely the typical thermal profile graph. It should be set up to monitor oven stability and to identify any process change before it affects product quality. In the first part, the temperature of the data is recorded by the thermal barrier through the production line, then analytical tool gains essential information that allows the process engineer to collect statistics and perform the monitoring.

In this paper, the hyperbolic tangent function is proposed to model this nonlinear profile data set. We evaluate the effectiveness of the proposed approach by comparing it with the smoothing spline approach. In phase I, the Hotelling T^2 and metric charts will be used for the outlier detection and the estimation of the in-control parameters. The rest of the article is organized as follows. The definitions of the hyperbolic tangent function and the parameters used in the function are explained in Sect. 2. Phase I analysis is performed in Sect. 3. Conclusions are drawn in Sect. 4.

2 Hyperbolic Tangent Function

The proposed approach in this article is to monitor nonlinear aluminum alloy heat treatment profiles which are fitted using the "modified" hyperbolic tangent function in comparison to the smoothing spline approach based on a model-building viewpoint. The first step in monitoring nonlinear profiles is to fit a parametric model that characterizes the relationship between the response variables and the explanatory variables. In essence, various modeling approaches should be tried in order to achieve the best fitting result. Here, we use the small sample Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) for model selection. The aluminum alloy heat treatment data is used to illustrate the proposed approach.

The hyperbolic tangent function is the major model-building approach investigated in this paper. It is adopted for periodic functions and is a linear combination that consists of the hyperbolic tangent function with constant multipliers. With the hyperbolic tangent function, a single profile can be represented by.

$$y_j = \sum_{i=1}^{s} a_i\left(x_j - b_i\right)\tanh\left(\frac{x_j - b_i}{w_i}\right) + \varepsilon_j, \qquad i = 1, \ldots, s; \quad j = 1, \ldots, n, \tag{1}$$

where a_i is the strength of curve, b_i is the transition time position for going into/leaving the state, w_i is the width at each tangent wave term, s is the number of terms in the series, and n is the number of observations in the profile. The parameters are estimated through the nonlinear least squares estimation method. In this paper, the Marguardt's algorithm is utilized. The error term is assumed to have a zero mean and a constant variance and to be uncorrelated with each other. The hyperbolic tangent function also takes into account the variation among the different points of the data. The criterion of minimizing the squared errors is opted to decide the most appropriate model. Typically, the coefficient of determination should be high enough to indicate a good fitting result. According to Kang and Albin (2000), profile data consist of a set of measurements with a response variable y and one or more explanatory variables $(x's)$, which are used to evaluate the quality of manufactured items. Assume in this paper that n observations in the i-th random sample (i.e., profile) collected over time are available, indicated by $\left(x_{ij}, y_{ij}\right)$ for $j = 1, \ldots, n$ and $i = 1, \ldots, m$. If the case of $s = 2$ is considered, the relationship between the paired observations as the process is in statistical control can be expressed by

$$f\left(x_{ij}\right) = a_{1j}\left(x_{ij} - b_{1j}\right)\tanh\left(\frac{x_{ij} - b_{1j}}{w_{1j}}\right) + a_{2j}\left(x_{ij} - b_{2j}\right)\tanh\left(\frac{x_{ij} - b_{2j}}{w_{2j}}\right) + \varepsilon_{ij}. \tag{2}$$

Without losing generality, adding the intercept to Eq. (2) gives

$$f\left(x_{ij}\right) = a_{0j} + a_{1j}\left(x_{ij} - b_{1j}\right)\tanh\left(\frac{x_{ij} - b_{1j}}{w_{1j}}\right) + a_{2j}\left(x_{ij} - b_{2j}\right)\tanh\left(\frac{x_{ij} - b_{2j}}{w_{2j}}\right) + \varepsilon_{ij}. \tag{3}$$

where the fitted profiles can be constructed via the estimation of the unknown parameters $\beta_j = \left(a_{0j}, a_{1j}, a_{2j}, b_{1j}, b_{2j}, w_{1j}, w_{2j}\right)'$.

3 Phase I Analysis

Akaike information criterion (AIC) is a statistical indicator for the selection of several models that can best explain the data. This criterion not only considers the fitting result but also considers the number of parameters. As the parameters increase, the model would become more complex accordingly and then affecting the effectiveness of fitting result. Akaike information criterion mainly consists of accurate fitting result and the parameters number. A minimum AIC value is desirable.

At the Fig. 2 shows that the modeling function using hyperbolic triple tangent functions exhibits a better fit than hyperbolic double tangent functions. $\overline{AIC}$ is used to decide the best hyperbolic tangent function. We developed double, triple, and quadruple hyperbolic tangent function by hyperbolic tangent function. Table 1 shows that using hyperbolic triple tangent function yields is the smallest $\overline{AIC}$, so the choice of the hyperbolic triple tangent function is chosen for this case study of the vacuum heat treatment data.

In order to find the model near that best fits profiles, extending to hyperbolic triple and quadruple tangent functions are attempted. The hyperbolic triple tangent function can be described by

$$f(X_{ij}, \beta_i) = a_{0i} + a_{1i}(x_{ij} - b_{1i}) \tanh\left(\frac{x_{ij} - b_{1i}}{w_1}\right) + a_{2i}(x_{ij} - b_{2i}) \tanh\left(\frac{x_{ij} - b_{2i}}{w_2}\right) + a_{3i}(x_{ij} - b_{3i}) \tanh\left(\frac{x_{ij} - b_{3i}}{w_3}\right) + \varepsilon_j, \quad (7)$$

Figure 3 shows the T^2 control charts by using the hyperbolic double tangent function method from the control chart shows the 9th profile appears to be an outlier as its parameter estimates are quite different from those of remaining profiles.

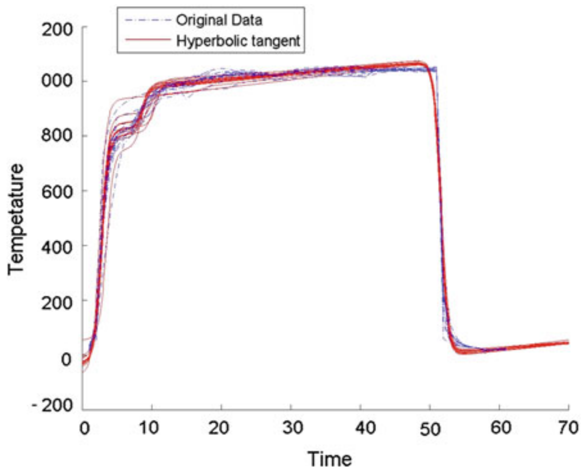


Fig. 2 Profile fitting by hyperbolic triple tangent

Table 1 The fitting results for the hyperbolic tangent functions

Knots	Double	Triple	Quadruple
$\overline{R^2}$	0.9841	0.99197	0.992097
$\overline{R^2_{adj}}$	0.9823	0.98521	0.990121
$\overline{AIC}$	25.8799	**23.7199**	29.7199

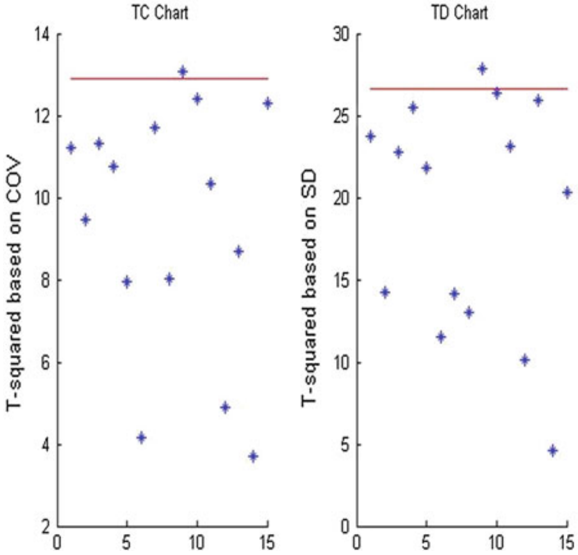


Fig. 3 T^2 control charts for 15 profiles data

4 Conclusion

The field of SPC is becoming more and more promising as the modern technology advances. As products and process become more competitive and complex, there is an increasing demand for the development of statistical methodologies to meet these needs. This objective of this paper is to develop a new approach that can properly characterize the aluminum alloy vacuum heat treatment process data and also provide competitive phase I monitoring performances. The specific shape of the profile addressed in this thesis is nonlinear. In Phase I, we propose using the modified hyperbolic tangent function to fit the aluminum alloy heat treatment process data. The proposed approach provides a good fit to the studied data. By means of the two T^2 statistics, the outlying profiles can be correctly identified through this monitoring framework.

Studying the fundamental of manufacturing processes could always be an interesting area in SPC. It helps understand whether the profiles are being over-fitted or under-fitted. Also, a comparison study of proposed approach to the other nonparametric methods, appearing in literature may be a good idea for further study. Building upon the research of the aluminum vacuum heat treatment process monitoring, how to create an effective combination of non-parametric charts in phase I analysis also deserves a future study.

References

Chen S, Nembhard HB (2011) A high-dimensional control chart for profile monitoring. Qual Reliab Eng Int 27(4):451–464

Ding Y, Zeng L, Zhou S (2006) Phase I analysis for monitoring nonlinear profiles in manufacturing processes. J Qual Technol 38(3):199–216

Fan SKS, Yao NC, Chang YJ, Jen CH (2011) Statistical monitoring of nonlinear profiles by using piecewise linear approximation. J Process Control 21:1217–1229

Jensen AJ, Birch JB (2009) Profile monitoring via nonlinear mixed models. J Qual Technol 41(4):18–34

Jin J, Shi J (1999) Feature-preserving data compression of stamping tonnage information using wavelets. Technometrics 41(4):327–339

Kang L, Albin SL (2000) On-line monitoring when the process yields a linear profile. J Qual Technol 32(4):418–426

Moguerza JM, Munoz A, Psarakis S (2007) Monitoring nonlinear profiles using support vector machines. Lecture notes in computer science 4789, Springer, Berlin, pp 574–583

Qiu P, Zou C, Wang Z (2010) Nonparametric profile monitoring by mixed effects modeling. Technometrics 52(3):265–293

Williams JD, Woodall WH, Birch JB (2007) Statistical monitoring of nonlinear product and process quality profiles. Qual Reliab Eng Int 23(8):925–941

Woodall WH, Spitzner DJ, Montgomery DC, Gutpa S (2004) Using control charts to monitor process and product quality profiles. J Qual Technol 36:309–320

Zou C, Tsung F, Wang Z (2007) Monitoring profiles based on nonparametric regression models. Technometrics 49:395–408

Full Fault Detection for Semiconductor Processes Using Independent Component Analysis

Shu-Kai S. Fan and Shih-Han Huang

Abstract Nowadays, semiconductor industry has been marching toward an increasingly automated, ubiquitous data gathering production system that is full of manufacturing complexity and environmental uncertainty. Hence, developing an effective fault detection system is virtually essential for the semiconductor camp. This paper focuses on the physical vapor deposition (PVD) process. In order to rectify the aforementioned difficulties that could realistically take place, an independent component analysis approach is proposed that decomposes every process parameter of interest into the basis data. A fault detection method is presented to identify the faults of the process and construct a process monitoring model by means of the obtained basis data.

Keywords Process monitoring · Independent component analysis (ICA) · Semiconductor manufacturing · Fault detection

1 Introduction

Due to the high complexity of semiconductor manufacturing, monitoring and diagnosis are gaining importance in manufacturing system. In semiconductor process, the common process variations can be due to process disturbances such as process mean shift, drift, autocorrelation, etc. For variance reduction, the critical source of process variation needs to be first identified. The effective fault detection

S.-K. S. Fan (✉) · S.-H. Huang
Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei 10608, Taiwan, Republic of China
e-mail: morrisfan@ntut.edu.tw

S.-H. Huang
e-mail: e2813260@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_56,

techniques can help semiconductors reduce scrap, increase equipment uptime, and reduce the usage of test wafers. In semiconductor industry, a massive amount of trace or machine data is generated and recorded. Traditional univariate statistical process control charts have long been used for fault detection, such as the Shewhart, CUSUM (cumulative sum), and EWMA (exponentially weighted moving average) charts have long been applied to reducing process variablility. Although univariate statistical techniques are easy to implement, they often lead to a significant number of false alarms on multivariate processes where the sensor measurements are highly correlated because of physical and chemical principles governing the process operation, such as mass and energy balances. Multivariate statistical fault detection methods such principal component analysis (PCA) and partial least squares (PLS) have drawn increasing interest in semiconductor manufacturing industry recently. PCA and PLS-based methods have been tremendously successful in continuous process applications such as petrochemical processes and its application to traditional chemical batch processes has been extensively studied in the last decade.

2 Independent Component Analysis

To rigorously define ICA (Hyvärinen et al. 2001), a statistical "latent variables" model is considered. Assume that we observe n linear mixtures $x_1, \ldots, x_n$ of n independent components, as expressed by

$$x_j = a_{j1}s_1 + a_{j2}s_2 + \cdots + a_{jn}s_n. \tag{1}$$

In the ICA model, we assume that each mixture $\mathbf{x}$ as well as each independent component s_n is a random variable. It is convenient to use vector-matrix notation instead of the sums as in equation. Let us denote by $\mathbf{x}$ the random vector whose elements are the mixtures $x_1, \ldots, x_n$, and likewise, by s the random vector with elements $s_1, \ldots, s_n$. Let us also denote by $\mathbf{A}$ the mixing matrix with elements a_{ij}. In terms of vector–matrix notation, the above mixing model becomes

$$\mathbf{X}_{m\times k} = \mathbf{A}_{m\times n} \cdot \mathbf{S}_{n\times k}. \tag{2}$$

The statistical model in equation is called independent component analysis, or ICA model. The ICA model is a generative model, implying that it describes how the observed data are generated by a process of mixing the component $\mathbf{S}$. The independent components are termed latent variables, meaning that they cannot be directly observed. Thus, the mixing matrix is assumed to be unknown. The ICA aims to find a demixing matrix $\mathbf{S}$ by means of the random vector $\mathbf{x}$, such that

$$\mathbf{Y}_{n\times k} = \hat{\mathbf{S}}_{n\times k} = \mathbf{W}_{n\times m} \cdot \mathbf{X}_{m\times k}. \tag{3}$$

The fundamental restriction imposed on ICA is that the independent components are assumed statically independent and they must have non-Gaussian distributions. These two conditions are also critical techniques that make ICA different from any other methods.

3 Proposed Fault Detection Method

We use the Independent Component Analysis (ICA) method to perform the fault detection in the process variable and information that are obtained from the sensor. Wu have proposed an ICA method that will be borrowed for use in Wu (2011). In his thesis, they use the ICA method to detect the defects of solar cells/modules in electroluminescence images. Here, we utilize their ICA method to design our fault detection procedure in semiconductor process and we find the ICA method can easily help us to make distinction between the normal data and abnormal data in the process. Here, we focus on the sputter deposition that is a physical vapor deposition (PVD) method of depositing thin films by sputtering. Sputter deposition is a physical vapor deposition (PVD) method of depositing thin films by sputtering. Resputtering is re-emission of the deposited material during the deposition process by ion or atom bombardment. Sputtered atoms ejected from the target have a wide energy distribution, typically up to tens of eV (100,000 K). The sputtered ions can ballistically fly from the target in straight lines and impact energetically on the substrates or vacuum chamber (causing resputtering).

In what follows, the proposed fault detection method will be described. We have to firstly choose the normal data to be trained by using the ICA and then we can obtain the basis data. Therefore, using the linear combination of the basis data to reconstruct each testing data.

Step 1: Choose several normal data from the sensor to be the training data.

X is the matrix of the training data. Each normal data is in each column then the sample matrix is shown below:

$$\mathbf{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ x_{21} & x_{22} & \cdots & x_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{M1} & x_{M2} & \cdots & x_{MN} \end{bmatrix}. \tag{4}$$

M Number of the normal data
N Number of observations in each normal data

Step 2: Obtain the source matrix by using the FastICA to train the training data.

In this step, we can take the input data (**X**) into FastICA process, and then we can obtain the basis data **U**. The size of **U** is $M \times N$. ICA model is as below:

$$\mathbf{U} = \mathbf{W} \cdot \mathrm{X}, \tag{5}$$

where **W** is the demixing data that is obtained by using FastICA, and the size of **W** is $H \times H$. The basic data **U** ($\mathbf{U} = [u_1, u_2, \cdots, u_H]^{\mathrm{T}}$) is the source matrix that stands for the linear combination of basis data. Due to the page limitation, for the procedure of reconstructing the test data, interested readers can be referred to Huang.

4 Experimental Results

We will discuss the experimental results of ICA for each process parameters (see Fig. 1) and we will find the key step for each process parameter. Because we focus on the sputter deposition, then we have four important process parameters to be investigated that include Gas2, Gas3, PRESSURE and PWR. Gas2 and Gas3 are the reactive gas, PRESSURE is the pressure measured inside in the chamber and PWR is the pressure of the Ar. We collect 227 parameters that are known as normal data serving as the training data. There are 68 observations in Gas2, 69 observations in Gas3, 64 observations in PRESSURE and 68 observations in PWR. We have 20 test data that include 10 normal data (good wafers) and 10 abnormal data (bad wafers). We collect 20 sets of the testing data. Here we use FastICA

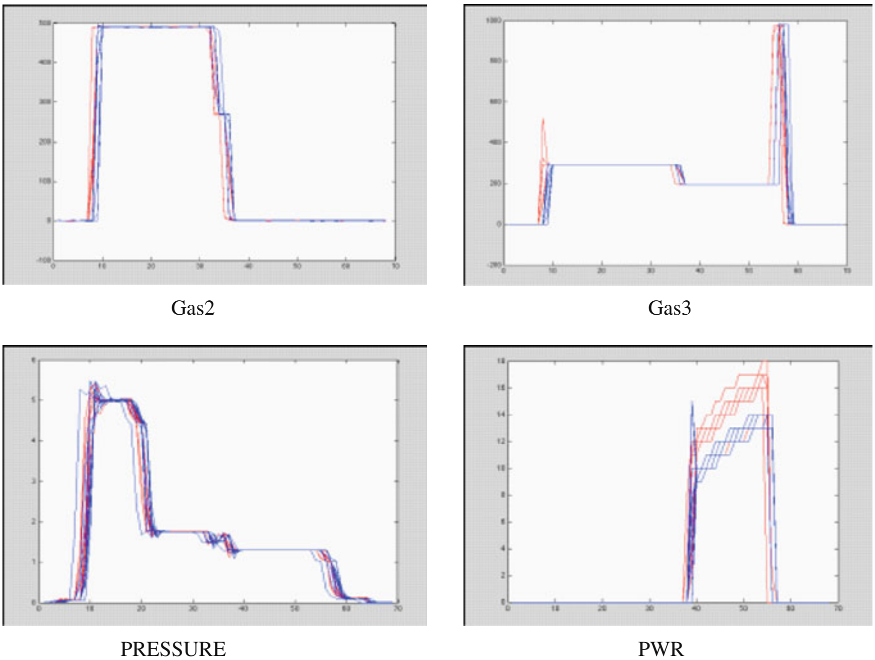


Fig..1 Process parameter

algorithm to retrieve the basis data from the training data in each process parameters. The flow of FastICA algorithm has been described in Sect. 3.3.3.1. By using FasICA algorithm we obtained 67 basis data from Gas2, 68 basis data from Gas3, 63 basis data from PRESSURE and 23 basis data from PWR.

When we use ICA to analyze the data, we have to set up the threshold for each process parameter to help us to distinguish the good and bad wafers in the testing data. Therefore, we consider the empirical rule to find the suitable threshold after we analyze the testing data by using ICA via a comprehensive preliminary test. The thresholds for each parameter are in Table 1.

After we set up the empirical rule for the threshold, then we can start to detect the faults of the data that has been analyzed (i.e., the distance between the testing data and reconstructed data has been calculated). The success rate along with its standard deviation for each process parameter are displayed in Table 2.

In order to further investigate the accuracy rate, then we compute the type I error and type II error for each parameter. Here, the type I error indicates the rate of the normal data that is mistakenly identified as the abnormal data; the type II error indicates the rate of the abnormal data that is not correctly identified as abnormal data. The results of the type I error and type II error are in Tables 3 and 4.

Table 1 Threshold of each process parameter

Threshold	Gas2	Gas3	PRESSURE	PWR
Model 1	1,555	1,620	13.95	28
Model 2	1,648	1,760	15.3	29

Table 2 Experimental results of each parameter monitored

Threshold (Std)	Gas2	Gas3	PRESSURE	PWR
Model 1	57 % (9.5026)	55 % (10.083)	62 % (9.5867)	77 % (6.0886)
Model 2	56 % (4.3457)	61 % (4.759)	65 % (12.3886)	70 % (9.0238)

Table 3 Type I error

Type I error	Gas2 (%)	Gas3 (%)	PRESSURE (%)	PWR (%)
Model 1	44	49	43	31
Model 2	47	41	36	26

Table 4 Type II error

Type II error	Gas2 (%)	Gas3 (%)	PRESSURE (%)	PWR (%)
Model 1	52	53	41	33
Model 2	39	28	32	24

5 Conclusions

In this study of sputter deposition, the observations for each process parameter in the semiconductor process can be always divided to steps 0–10. We take steps 0–10 for each observations in each process parameter to perform the simulation by using the ICA method. For experimental results of ICA model1, the success rates of Gas2, Gas3, PRESSURE and PWR are 57, 55, 62 and 77 %, respectively. However, if we only take the key (step 2–7 in Gas2, step 1–4 in Gas3, step 0–2 in PRESSURE and step 8–9 in PWR) to perform the simulation in experimental result of ICA model 1, the success rates of Gas2, Gas3, PRESSURE and PWR are 64, 62, 68 and 79 %, respectively. From these experimental results, we can obviously see that the success rate of only considering the key step is completely higher than taking steps 0–10. It means that if we take steps 0–10 to perform ICA analysis, there will produce much useless information that could influence the efficiency of ICA in the observations. Therefore, in order to reduce the influence of this useless information, we can only take the key step to perform ICA. For time delay and missing values, we have several methods to deal with these problems. For time delay data, after we correct the time delay data according to the difference in time, we find that using no insert data is a suitable method from the experimental results. For missing values, using a half standard deviation control chart is suitable method to deal this problem.

References

Hyvärinen A, Karhunen J, Oja E (2001) Independent component analysis. Wiley, New York

Wu SH (2011) Machine vision-based defect detection of solar cells/modules in electroluminescence images, Master thesis. Yuan-Ze university. Department of Industrial Engineering, Taoyuan County, Taiwan

Multi-Objective Optimal Placement of Automatic Line Switches in Power Distribution Networks

Diego Orlando Logrono, Wen-Fang Wu and Yi-An Lu

Abstract The installation of automatic line switches in distribution networks provides major benefits to the reliability of power distribution systems. However, it involves an increased investment cost. For distribution utilities, obtaining a high level of reliability while minimizing investment costs constitutes an optimization problem. In order to solve this problem, the present paper introduces a computational procedure based on Non-dominated Sorting Genetic Algorithm (NSGA-II). The proposed methodology is able to obtain a set of optimal trade-off solutions identifying the number and placement of automatic switches in distribution networks for which we can obtain the most reliability benefit out of the utility investment. To determine the effectiveness of the procedure, an actual power distribution system was considered as an example. The system belongs to Taiwan Power Company, and it was selected to drive comparisons with a previous study. The result indicates improvements in system reliability indices due to the addition of automatic switching devices in a distribution network, and demonstrates the present methodology satisfies the system requirements in a better way than the mentioned previous study.

Keywords Automatic line switches · Genetic algorithm · Power distribution networks · Multi-objective optimization

D. O. Logrono (✉)
Graduate Institute of Industrial Engineering, National Taiwan University,
Taipei 10617, Taiwan, Republic of China
e-mail: r99546042@ntu.edu.tw

W.-F. Wu
Graduate Institute of Industrial Engineering and Department of Mechanical Engineering,
National Taiwan University, Taipei 10617, Taiwan, Republic of China
e-mail: wfwu@ntu.edu.tw

Y.-A. Lu
Department of Mechanical Engineering, National Taiwan University, Taipei 10617,
Taiwan, Republic of China
e-mail: Skippy_lu11@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_57,

1 Introduction

For modern power distribution utilities, service quality and continuity are the two most important demands. To attend to this demand, distribution automation is used for improving the system response in the event of outages. On distribution automation projects, the biggest challenge is how to achieve the most possible benefit while minimizing the investment costs (Abiri-Jahromi et al. 2012). The optimal placement and number of automatic line switches in distribution networks is essential for utilities in order to reduce power outages. However this optimization is a combinatorial constrained problem described by nonlinear and nondifferential objective functions and their solution can be challenging to solve (Tippachonl and Rerkpreedapong 2009). Many studies provided insight on the subject, for example, Abiri-Jahromi et al. (2012) and Chen et al. (2006). In papers such as Conti et al. (2011), different versions of NSGA-II have been applied for the allocation of protective and switching devices. This paper proposes the development of a computational algorithm to address the optimal placement of automatic line switches in distribution networks that simultaneously minimizes cost expenditures and maximizes system reliability. A version of NSGA-II is employed.

2 Problem Formulation

2.1 Multi-objective Optimization

The multi-objective optimization problem (MOOP), in its general form, can be expressed using the following structure (Deb 2001):

$$
\begin{aligned}
\text{Minimize/Maximize } f_m(\mathbf{x}), &\quad m = 1, 2, \ldots, M; \\
\text{subject to } g_i(\mathbf{x}) \geq 0, &\quad j = 1, 2, \ldots, J; \\
h_k(\mathbf{x}) \geq 0, &\quad k = 1, 2, \ldots, K; \\
x_i^{Lower} \leq x_i \leq x_i^{Upper}, &\quad i = 1, 2, \ldots, n.
\end{aligned}
\tag{1}
$$

where $f_m(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}), \ldots, f_M(\mathbf{x}))^T$ is a vector of M objective functions to be optimized. A solution $\mathbf{x}$ is a vector of n decision variables $\mathbf{x} = (x_1, x_2, \ldots, x_n)^T$. When a solution $\mathbf{x}$ satisfies all the $(J + K)$ constraints and is allocated within the $2n$ variable bounds, it is known as a feasible solution for the optimization problem and can be mapped into the M objective functions to obtain the objective space. We can perform all possible pair-comparisons for a finite set of solutions, and find which solutions dominate. The solution set of a multi-objective optimization consists of all non-dominated solutions, and it is known as Pareto-optimal set or Pareto-optimal front.

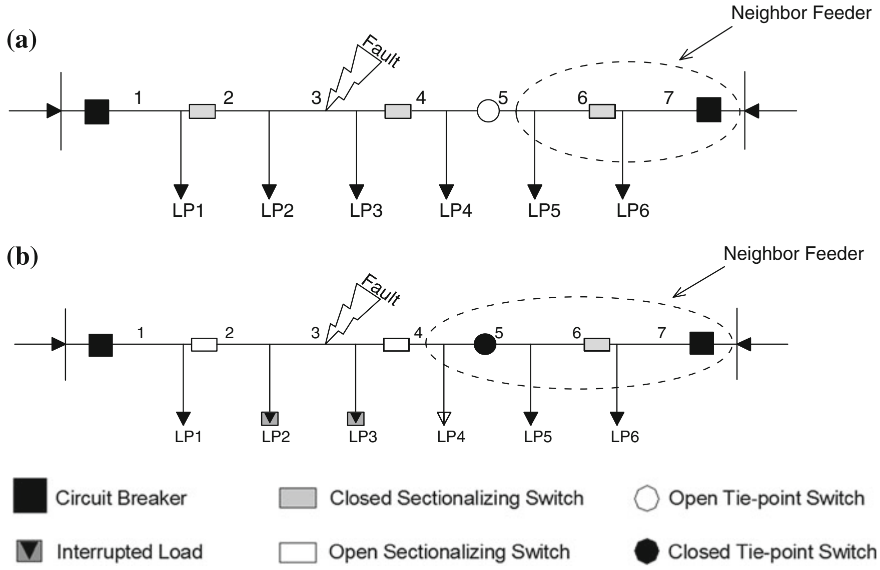


Fig. 1 Automatic sectionalizing and tie-point switches in distribution networks

2.2 Distribution Feeder Model

An illustration of a radial feeder of a distribution system is presented in Fig. 1. There are two types of line switches normally installed along distribution feeders: sectionalizing switch (D) and tie-point switch (TP). For Fig. 1a, the sets of switching devices can be expressed as: D = {1,4,6} and TP = {5}.

When a failure occurs in Sect. 3, the configuration becomes as that of Fig. 1b. Customers in load point LP1 and LP4 will experience an interruption equal to the switching time of the devices, while loads between the two automatic switches (LP2 and LP3) will experience longer outage duration equal to the repair time of feeder Sect. 3.

2.3 Objective Functions

We select three objectives to be minimized simultaneously: System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI) and TCOST (total investment cost). We use a method based on a modification of the study performed by Tippachonl and Rerkpreedapong (2009), defined as follows:

- *SAIFI*, $f_1(\mathbf{x})$: system average interruption frequency index.

$$SAIFI = \frac{\sum_{i=1}^{n} \left(\sum_{s=1}^{m} \lambda_{is} \right) N_i}{\sum_{i=1}^{n} N_i} \text{ (int./cust. - year)} \tag{2}$$

where N_i is the number of customers at load point i, n identifies the number of load points and m the number of sections. λ_{is} is the permanent failure rate of load point i due to failure in section s.

- SAIDI, $f_2(\mathbf{x})$: system average interruption duration index. It is referred to as the average time that a customer is interrupted per year.

$$SAIDI = \frac{\sum_{i=1}^{n} \left(\sum_{s=1}^{m} \lambda_{is} r_{is} \right) N_i}{\sum_{i=1}^{n} N_i} \text{ (min/cust. - year)} \tag{3}$$

where r_{is} is the average time per interruption of load point i due to outages in section s.

- *TCOST*, $f_3(\mathbf{x})$: total cost.

$$TCOST = Num_D \times C_D + Num_{TP} \times C_{TP} \text{ (US\$ - year)} \tag{4}$$

where Num_D accounts for the number of sectionalizing switches and Num_{TP} for the number of tie-point switches to be installed. C_D and C_{TP} are the total costs including purchase and installation of sectionalizing and tie-points, respectively. For this task, a decision variable will be associated to every section for computation purposes and its value represents the cases in which: 0—no device, 1—sectionalizing switch, or 2—a tie-point switch.

2.4 Constraints

The following operation constraints are considered in this study:

- Each decision variable can only take integer values 0, 1 or 2.
- Only one automatic tie-point switch can connect two neighbor feeders.
- When performing the load transfer for service restoration, no overloading should be introduced to the power transformers.

3 Proposed Integer Version of NSGA-II

Genetic Algorithms (GAs) handle a population of solutions that is modified over the course of a number of generations using genetic operators and are able to work with a wide range of types and number of objective functions making them suitable for our multi-objective optimization problem. A modified version of NSGA-II was selected as the search mechanism for the optimal solutions to the proposed problem.

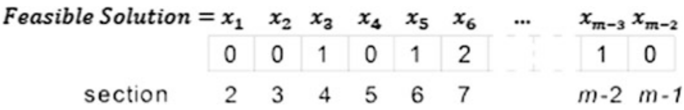


Fig. 2 Chromosomal representation for a feasible solution

3.1 Solution Codification

The optimal placement of automatic line switches in distribution networks can be considered as an integer optimization problem (integer phenotype). In this paper, integer-coding is used.

A decision variable has been associated to every section of the distribution feeder where a switch can be allocated (0 → no switch, 1 → auto sectionalizing switch, 2 → auto tie-point switch). An illustration of the chromosomal representation for this feeder is shown in Fig. 2.

3.2 Algorithm Procedure

The optimal solution searching process performed by the proposed NSGA-II follows the procedures shown in the Fig. 3. The steps are presented as follows: (1) *Generate the Initial Population;* (2) *Fitness Assignment;* (3) *Elitist Selection;* (4) *Tournament Selection;* (5) *Crossover;* (6) *Mutation*.

4 Numerical Results

An actual distribution system has been considered for comparison. The system is part of Taiwan Power Company and it is located in the Fengshan area. The system is described in Chen et al. (2006).

The NSGA-II settings for both case studies are determined in Table 1. Other data have been retrieved from Chen et al. (2006) in Table 2. For this case study, we run the proposed NSGA-II using a population size and number of generations of 100 and 500, respectively, with a total of 50,000 computational evaluations. The scatter of the non-dominated solutions and the Pareto-optimal solutions for the switch placement optimization problem is found as that of Fig. 4.

In this study, a max–min approach has been used to select a final solution for the multi-objective problem. Each solution in the nondominated set is first normalized and then a max–min operator is applied to them using the following expression as in Tippachonl and Rerkpreedapong (2009):

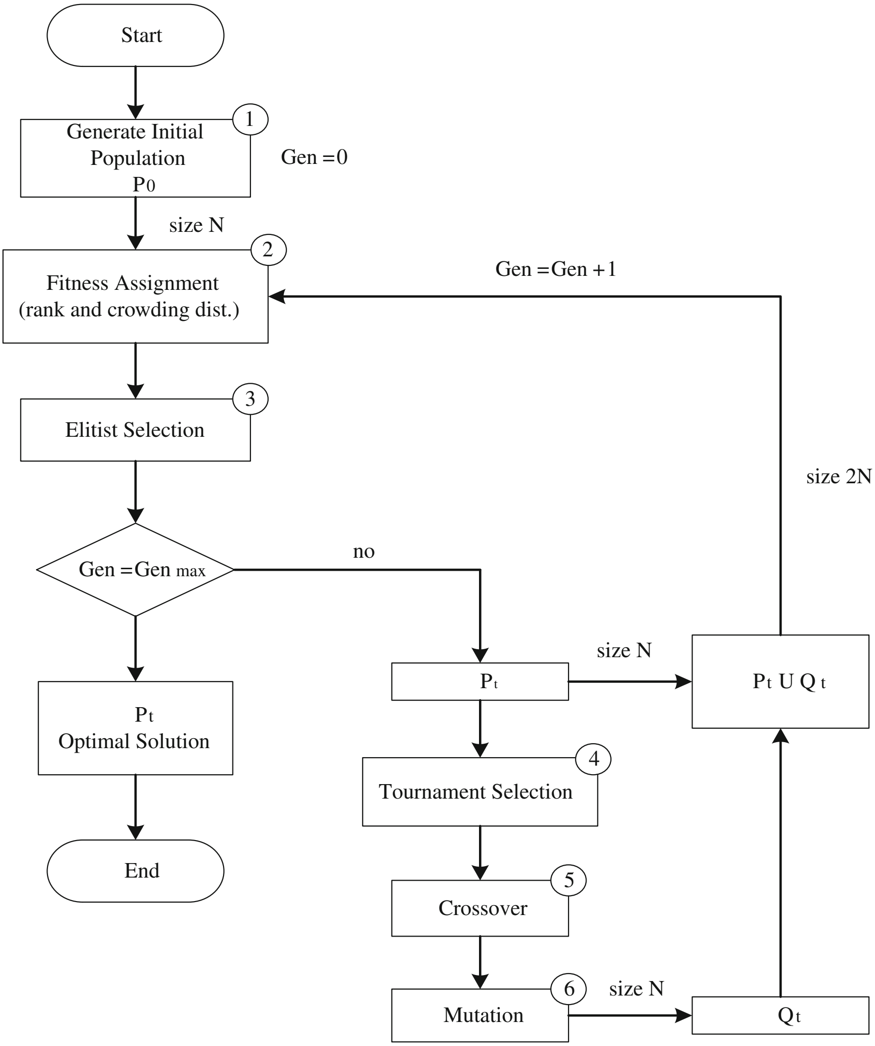


Fig. 3 Procedure performed in the proposed NSGA-II

$$\max\left[\min\left(\frac{SAIFI_{\max} - SAIFI_i}{SAIFI_{\max} - SAIFI_{\min}}, \frac{SAIDI_{\max} - SAIDI_i}{SAIDI_{\max} - SAIDI_{\min}}, \frac{TCOST_{\max} - TCOST_i}{TCOST_{\max} - TCOST_{\min}}\right)\right]. \tag{5}$$

In Table 3, we present a comparison of the reliability indexes in the original system; after the partial automation study; and finally our proposed study for the optimal placement of automatic line switches.

Table 1 NSGA-II parameter settings

	Parameter	Value
Crossover	Crossover fraction	0.9
	Ratio	0.1
Mutation	Mutation fraction	0.4
	Scale	0.5
	Shrink	0

Table 2 Distribution feeder parameters

Parameter		Rate/Duration time
Average permanent failure rate, λ_s		0.132 failures/year-km
Average repair time, r_{rs}		240 min.
Switching time, r_{sw}	Upstream the failure	5 min
(automatic switches)	Downstream the failure	0.33 min

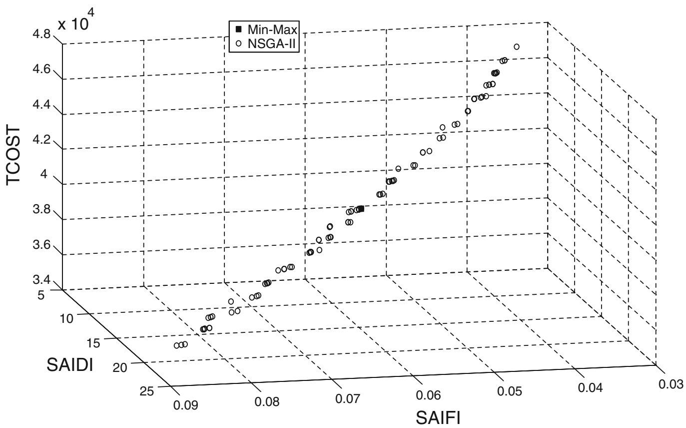


Fig. 4 Pareto-optimal solutions and max–min solution for the case study

The solution obtained by the max–min approach represents an improvement of 62 % in SAIFI and 32 % in SAIDI, when compared to the previous study. Consequently, SAIFI has been reduced from 0.157 to 0.059 int./cust. – year, and SAIDI from 20.872 to 14.212 (min./cust. – year) An investment 2.8 times higher than the later study is required for gaining the above mentioned reliability benefit.

Despite the higher TCOST, the max–min solution not only excels in providing a remarkable reduction in the current reliability indices, but also the reliability values obtained by its possible implementation can be still useful in the future since Taipower Company has now set a new goal of 15.5 min./cust. – year for SAIDI by the year 2030 (Runte 2012).

Table 3 Results of the proposed study

	Original system manual switching	Previous study partial automation	Our proposed solution fully automated
SAIFI (**int**./**cust**. − **yr**.)	0.231	0.157	0.059
SAIDI (**min**./**cust**. − **yr**.)	32.233	20.872	14.212
TCOST (**US$** − **yr**.)	–	14,326	40,516.9

5 Conclusion

This paper provides a methodology to solve the multi-objective optimal placement of automatic line switches in distribution networks. The proposed integer version of NSGA-II has showed that this methodology guarantees a very good approximation to the true Pareto-front. The decision maker can select a final solution from the Pareto-optimal according to his/her professional experience. However, a selection approach has also been presented in this study in order to choose the final solution based on Max–min method. The methodology was tested using an actual distribution system. The proposed solution for the system allows obtaining notable improvements for reliability indices but involves higher investment cost for the utility.

References

Abiri-Jahrom A, Fotuhi-Firuzabad M, Parvania M, Mosleh M (2012) Optimized sectionalizing switch placement strategy in distribution systems. Power Delivery, IEEE Trans 99:1–7

Chen CS, Lin CH, Chuang HJ, Li CS, Huang MY, Huang CW (2006) Optimal placement of line switches for distribution automation systems using immune algorithm. Power Syst, IEEE Trans 21(3):1209–1217

Conti S, Nicolosi R, Rizzo SA (2011) Optimal investment assessment for distribution reliability through a multi-objective evolutionary algorithm. Paper presented at 2011 International conference on clean electrical power (ICCEP)

Deb K. (2001) Multi-objective optimization using evolutionary algorithms. Chichester New York Weinheim [etc.]: J. Wiley

Runte G (2012) Taiwan power: quietly getting the smart grid, Power Generation

Tippachon W, Rerkpreedapong D (2009) Multiobjective optimal placement of switches and protective devices in electric power distribution systems using ant colony optimization. Electr Power Syst Res 79(7):1171–1178. doi:10.1016/j.epsr.2009.02.006

The Design of Combing Hair Assistive Device to Increase the Upper Limb Activities for Female Hemiplegia

Jo-Han Chang

Abstract Many researches show that the progress of the upper limb function of patients with more than one year apoplexy appears to be Learned Nonuse. This research takes concepts of the Constraint-induced Movement Therapy and User-Centered Design and develops the combing hair assistive device to increase the upper limb activities for female Hemiplegia. We adopt the AD-TOWS (Assistive Devices-Threats, Opportunities, Weaknesses, and Strengths) matrix to develop 33 design concepts among which 4 concepts are screened to make models, and then invite 5 participators in the experiment. By analyzing the results of upper limb lifting angle, the upper limb movement angle forced by the "Joint Adjustable Device" is the biggest, which is followed by the "Comb Convertible Device", and then is the "Comb Convertible Lengthening Device". The upper limb average angle of operating the above mentioned three assistive devices are bigger than that of operating the existing devices. By the result of the part unable to be combed, we find that the most difficult action to users who use the existing long-handled comb is to comb their sutural bone and occipital bone, however, the "Double-Handled Device" is good at improving the action unable to be done.

Keywords Activities · Constraint-induced movement therapy · Hemiplegia · Upper limb · User-centered design

1 Introduction

For the patients with cerebral apoplexy, besides suffering from physical dysfunction, they also suffer from great psychological impact (Qiu 2008; Mitchell and Moore 2004). Patients will have Body Image Disturbance, and even hold a

J.-H. Chang (✉)
Department of Industrial Design, National Taipei University of Technology, 1, Section 3, Chung-hsiao E. Road, Taipei 10608, Taiwan, Republic of China
e-mail: johan@ntut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_58,

negative attitude towards the disease. Many researches show that the upper limb function of the patients with more than one year history of cerebral apoplexy gradually present the symptom of Learned Nonuse (Taub et al. 1994).

In recent years, Constraint-Induced Movement Therapy (CIMT) has been used clinically, called Forced Use. Many researches also certified that the limb function of the affected side of 50 % patients is significantly improved after a lot of appropriate training (Liepert et al. 1998).

The proportions of items in which the female has difficulties in self-care are higher than those of male, and the proportion of complete loss of self-care ability in walking up and down stairs, washing hair and outdoor walking for female is over 5 % higher than that for male (Census and Statistics Department of Ministry of the Inferior 2006). For many females, it is very important that they can tidy personal appearance and hygiene independently. The goal of medical team devoted is to help the patients live independently and restore their self-esteem. This paper proposes an assumption that if we can design an assistive device based on the concept of CIMT by the love of beauty in female's nature, and the assistive device can not only help the patients live independently, but also can promote their synchronous motion, so as to help the patients achieve the purpose of rehabilitation at an early date, even return to normal life.

2 Literature Review

The biggest difference between disabled people and general users is the physiological function of the disabled people is divided into normal side and affected side, and the conditions of normal side and affected size are different, as a result, when they use an assistive device, it can bring opportunities to achieve the purpose, but also may cause danger due to inapplicability. Ma et al. (2007) proposed AD-SWOT (Assistive Devices-Strength, Weakness, Opportunity, Threat), imported the Business Management Strategy and Method-SWOT (Strength, Weakness, Opportunity, Threat) into the design procedure of assistive devices, analyzed the physiological condition of users by AD-SWOT, and developed the design of assistive devices according to the AD-SWOT analysis results. Then, Wu et al. (2009) developed the assistive devices using the method of AD-TOWS (Assistive Devices-Threat, Opportunity, Weakness, Strength) matrix to take full advantage of patients' physiological conditions, therefore both the affected side and normal can be moved during the process of using assistive devices.

The purpose of this paper is to develop an assistive device which can promote movements. This paper try to develop the assistive devices based on the concept of CIMT and develop a new assistive device through AD-SWOT and AD-TOWS procedures, so as to make good use of patients' limbs to help the patients complete tasks with their own strength, and they can also make limb movement in the process.

3 New Assistive Devices Design

In this stage, a participator was invited to have a hemiplegia condition analysis, so as to design new assistive devices according to the research results.

3.1 Physiological Condition Analysis of Female Hemiplegia

3.1.1 Ability Measurement of Participator

To learn about the consciousness, cognitive function, communication condition, motor coordination ability and motor function of the participator.

1. Consciousness, cognitive function and communication condition: Diagnosed by doctor, the participator was a left hemiplegia apoplexy patient caused by right cerebral artery occlusion, whose consciousness, cognitive function and communication condition were normal.
2. Motor coordination ability: The participator had left upper limb hemiplegia, myasthenia and poor upward activity of shoulder joint.
3. Motor function: The participator can overcome the basic synergistic effects and easily perform actions such as Hand to Sacrum, Raise Arm Forward to Horizontal, Pronation (Elbow Flexed) and Supination (Elbow Flexed).

3.1.2 AD-SWOT of Participator

AD-SWOT of the participator was summarized and analyzed according to the observation on actions and activity of upper limbs (Table 1).

3.2 Combing Hair Assistive Device Design for Female Hemiplegia

In this stage, the assistive device design was developed according to the steps of AD-SWOT and AD-TOWS, and AD-WO developed 9 concepts, AD-SO and AD-ST developed 12 concepts respectively. In order to screen the best design, 19 evaluation items containing W (Weakness) of user and T (Threat) of assistive device as well as WT (Weakness/Threat) were proposed to screen the best design from the 33 design concepts. Four design concepts with the highest score are shown in Table 2, named as Comb Convertible Device, Joint Adjust-able Device, Double-Handled Device and Comb Convertible Lengthening Device.

Table 1 AD-SWOT of participator

SWOT	Description
Strength	1 The shoulder joint of left upper limb can bend forward and lift to the height of shoulder
	2 The ROM and myodynamia of forward bending the right upper limb shoulder joint are complete
	3 The shoulder joint of right upper limb can lift to the height of shoulder
	4 The ROM and myodynamia of the elbow, wrist and fingers of right upper limb are complete
	5 Shoulder joints of right and left upper limbs can rotate inward and outward
Weakness	1 The shoulder joint of left upper limb can't bend forward, lift and abduct beyond the shoulder
	2 Myodynamia of moving the shoulder, elbow, wrist and finger of left upper limb are insufficient
	3 The shoulder joint of right upper limb can't lift and abduct beyond ear, and without insufficient myodynamia
	4 Myodynamia of the shoulder joint of right upper limb to rotate inward and outward is insufficient
Opportunity	1 The user can complete the whole task using assistive devices
	2 The user's physiological functions can be induced by using the assistive devices and the users utilize their own abilities
	3 The assistive devices can help rehabilitation
Threat	1 The operational motion makes the user lose balance
	2 The pain and change of blood flow volume are caused when the user exerts strength suddenly and violently
	3 Bad compensatory postures cause other pains

4 Research Methods

In order to evaluate whether the assistive devices developed by AD-SWOT and AD-TOWS meet the concept of CIMT, this program used mock-up to perform experiment of testing and evaluation. In the evaluation, 5 left hemiplegia patients were invited to actually operate the combing hair assistive devices to learn their level of enforcement; the existing combing hair assistive devices (long-handled comb) and the four assistive devices in this program were given to participators; instead of being asked to perform typical tasks, the participators were allowed to operate assistive devices freely to test the applicability of the assistive devices. The content of evaluation contained two aspects:

4.1 Combing Completion

Parts able to be combed were analyzed, including parietal bone, right parietal bone, left parietal bone, sutural bone, occipital bone, right temporal bone and left temporal bone.

Table 2 New combing hair devices for female hemiplegia

Assistive device	Picture	Design description
Comb convertible device		1. The area of comb bed is increased 2. The contact point of comb bed and handle is arranged with a rotational joint, so that the comb bed can rotate to different angles so as to help the users with myodynamia insufficiency 3. The handle can be pressed and the surface of handle is granular, which can stimulate user's sensation of touch
Joint adjustable device		1. The area of comb bed is increased 2. The contact point of comb bed and handle is arranged with a rotational joint, so that the comb bed can rotate to different angles and adjust its length to help the users with myodynamia insufficiency as well as those who are unable to lift up upper limbs 3. The handle can be pressed and the surface of handle is granular, which can stimulate user's sensation of touch
Double-handled device		1. With two handles and the handles are rotatable (All of the four joints can rotate smoothly) 2. The comb bed appears to be curved 3. The comb bed is widened
Comb convertible lengthening device		1. The comb bed is rotatable (The joint can rotate smoothly) 2. The handle is lengthened 3. The comb bed is widened

4.2 Angle of Upper Limb Activity

Observing and measuring the upper limb movement angle of operating the assistive devices, so as to learn whether the new assistive devices are effective on improving upper limb activity; recording the maximum lifting angle and analyzing the average lifting angle respectively.

5 Results

Table 3 is combing completion in the experimental. Table 4 is the angle of upper limb activity in the experimental.

By analyzing the combing completion, we found that it was more difficult for participators to comb sutural bone and occipital the combing completion pital bone by using the existing long-handled comb. As for the four new type assistive devices, the parts unable to be combed of the participators were different; the Double-Handled Device could best improve the action unable to be done. Moreover, two participators could complete the whole combing task by using the Comb Convertible Device and Double-Handled Device.

By analyzing the average angle of upper limb activity, we found that the upper limb movement angle forced by Joint Adjustable Device was the biggest, followed by "Comb Convertible Device", and after that is "Comb Convertible Lengthening Device"; and the upper limb average angle of operating the mentioned three assistive devices was bigger than that of operating the existing devices.

By analyzing the maximum lifting angle of upper limb activity, we found that, both the existing and new combs could promote the upper limb lifting when users comb the parietal bone, while the Double-Handled Device can lift two upper limbs up to the sutural bone. In addition, two participators could lift upper limbs when combing the left and right temporal bones with Comb Convertible Device; and another two participators lifted upper limbs when combing the left temporal bone with Joint Adjustable Device.

Table 3 The combing completion in the experimental

Assistive devices	Left parietal bone	Parietal bone	Right parietal bone	Occipital bone	Sutural bone	Left temporal bone	Right temporal bone	Total
Long-handled comb	0	0	0	4/5	4/5	0	1/5	1 4/5
Comb convertible device	0	1/5	0	3/5	4/5	0	0	1 3/5
Comb convertible lengthening device	2/5	0	1/5	3/5	3/5	4/5	1/5	2 4/5
Joint adjustable device	2/5	2/5	2/5	4/5	2/5	2/5	1/5	3
Double-handled device	0	0	0	1/5	0	1/5	1/5	3/5
Total	4/5	3/5	3/5	3	2 3/5	1 2/5	4/5	

Table 4 The angle of upper limb activity in the experimental

Assistive devices	Maximum angle	Minimal angle	Average angle	Standard deviation
Long-handled comb	105	15	46	35.1
Comb convertible device	25	125	66	37.5
Comb convertible lengthening device	15	110	53	36.8
Joint adjustable device	20	165	83	56.0
Double-handled device	40	15	28	17.7

6 Discussion

This experiment shows that the new combing hair assistive devices for female hemiplegia can improve the upper limb activity of the users. The Double-Handled Device can best improve the action unable to be done, and it can help users to lift bilateral upper limbs to sutural bone so as to achieve the purpose of forcing the movement of the affected part. The products developed by AD-SWOT and AD-TOWS can utilize the user's limbs, so as to successfully promote the movement of the affected part.

By analyzing the experimental record, we found that when the comb bed was perpendicular to the handle, the contact area of comb bed and hair was reduced, so that the participators must lift their upper limbs to complete the task. The results showed that the upper limb lifting can be promoted by reducing the contact area of comb bed and hair, which can serve as a reference for future design.

Previous researches showed that for the patients with more than one year history of cerebral apoplexy, if we limit their the upper limb activity of normal side for 2 weeks and give enough appropriate training on the affected side, about 50 % patients will obviously improve their motor function of the affected upper limb (Liepert et al. 1998); and this improvement can be continued and obviously observed during the application of the affected upper limb in daily life. In this research, the assistive device design evaluation was mainly focused on the promotion of upper limb activity and validity of using the products. In the future, we will continue to observe whether this Double-Handled Device can achieve rehabilitation effects.

Acknowledgments Special thanks to National Science Council (NSC 98-2218-E-033-005-) for its support for this study.

References

Census and Statistics Department of Ministry of the Inferior (2006) The report of people with disabilities living needs. Census and Statistics Department of Ministry of the Inferior, Taipei

Liepert J, Miltner WH, Bauder H, Sommer M, Dettmers C, Taub E, Weiller C (1998) Motor cortex plasticity during constraint-induced movement therapy in stroke patients. Neurosci Lett 250(1):5–8

Ma MY, Wu FG, Chang RH (2007) A new design approach of user-centered design on a personal assistive bathing device for hemiplegia. Disabil Rehabil 29(14):1077–1089

Mitchell E, Moore K (2004) Stroke: holistic care and management. Nursing Standard 33(18):43–52

Qiu HY (2008) The current status of stroke and epidemiological characteristics. Nao Zhong Feng Hui Xun 15(3):2–4

Taub E, Crago JE, Burgio LD, Groomes TE, Cook EW, DeLuca SC (1994) An operant approach to rehabilitation medicine: overcoming learned nonuse by shaping. J Exp Anal Behav 61:281–293

Wu FG, Ma MY, Chang RH (2009) A new design approach of user-centered design on hair washing assistive device design for users with shoulder restriction. Appl Ergon 40(5):878–886

Surgical Suites Scheduling with Integrating Upstream and Downstream Operations

Huang Kwei-Long, Lin Yu-Chien and Chen Hao-Huai

Abstract Surgical operations are a critical function for hospitals because they are responsible for almost two-thirds of all profits. Hence, medical resources associated with surgical operations and operation rooms (OR) should be utilized efficiently. Conducting an overall plan for the allocation of medical resources and capacities used in surgical operations is complicated because numerous types of resources are involved in an OR scheduling problem. Furthermore, the upstream and downstream operations of a surgery, such as the number of beds for preoperative examination and intensive care unit, also significantly affect OR schedule performance. The objective of OR scheduling is to minimize the overtime cost of surgical operations and the idle cost of ORs. Using the concept of OR suites and modes, we construct a mixed integer linear programming model by considering surgical resources and the corresponding upstream and downstream operations. A five-stage heuristic method is proposed to solve large-scale problems effectively and efficiently. A numerical study is conducted, and the results show that the proposed method can reduce the total cost of managing operation rooms and improve the quality of surgical services.

Keywords Operation room · Scheduling · Resource capacity constraint · Heuristic algorithm

H. Kwei-Long (✉) · L. Yu-Chien · C. Hao-Huai
Institute of Industrial Engineering College of Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, Taiwan, Republic of China
e-mail: craighuang@ntu.edu.tw

L. Yu-Chien
e-mail: r99546044@ntu.edu.tw

C. Hao-Huai
e-mail: r01546025@ntu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_59,

1 Introduction

The managerial aspect of providing health services to hospital patients is becoming increasingly important. Among all hospital operations, surgery is one of the most critical because the revenue derived from surgeries is about two-thirds of the total income of the hospital (Jackson 2002). Denton et al. (2010) indicated that operating rooms (ORs) constitute about 40 % of a hospital's total expenses. ORs are therefore simultaneously the most expensive center and the greatest source of revenue for most hospitals. To lower the cost of ORs and run ORs efficiently, OR scheduling must be implemented. If the schedule is too tight, ORs will be less flexible in handling emergencies. Conversely, if the schedule is too loose, ORs may become idle. Thus, methods on how to improve the efficiency of OR scheduling have received considerable attention in recent years.

So far, most OR scheduling problems only consider how surgeries can be scheduled to increase the performance of ORs. However, to improve the efficiency of ORs, the periods when the OR is available should be considered along with the coordination of other resources. Weinbroum et al. (2003) showed that the better coordinated the upstream and downstream resources, the higher the efficiency of ORs in operation room scheduling. Pham and Klinkert (2008) indicated that a complete surgery is divided into three stages: preoperative, perioperative, and postoperative. They also proposed the concept of the OR suite to illustrate that considering other support facilities when scheduling surgeries is important. In the present study, we considered the simultaneous limitation of upstream and downstream OR resources and used the concept of the OR suite to integrate and plan resources. This method prevents ORs from becoming idle or occupied by a surgery for an extended period, which causes a lack of resources upstream and downstream. We propose a mixed integer linear programming (MILP) model to produce a multi-day OR schedule. The resulting model can help hospital managers decide the required number of ORs, how to assign surgeries to the OR, and the time each medical team should conduct operations.

The remainder of this article is organized as follows. The next section gives a brief review of related literature. In Sect. 3, we describe the problem and definitions. Section 4 proposes a heuristic algorithm and shows the numerical results of algorithm. In the final section, we summarize our main conclusions.

2 Literature Review

Pham and Klinkert (2008) indicated that scheduling priority for different cases and predictability should be considered separately in the scheduling problems of surgical cases. They also divided surgical cases into four types: emergency, urgent, elective, and add-elective cases.

In a hospital, the proper functioning of an OR depends upon the doctors, the number of operating and recovery rooms, anesthesiologists, and nurses. Moreover, the crucial points of different factors should be focused for generating an effective OR schedule, which can improve healthcare quality and reduce costs in numerous restrictions. Denton et al. (2007) divided OR scheduling into two systems: the block system and the open system. The open system is designed to arrange the patients to be served during the scheduled period. The surgery team will apply for an appointment to use the OR after a surgery case is held, then the supervisor will schedule the time when the ORs may be used. By contrast, Patterson simplified the open system into a first-come, first-served policy. Furthermore, Dexter et al. (2003) defined the "any workday strategy," in which the surgical team is free to make an appointment for a surgery date and an OR. Gable indicated that the open system is rarely utilized and that surgery cases are often cancelled because surgery teams prefer to complete surgery cases during fixed days. However, the open system forces them to complete all surgery cases in a day or a separated group of days, thereby reducing the satisfaction of the surgery team. In practice, the open system is rarely adopted in hospitals.

In the OR scheduling problem, upstream and downstream resource capacity constraints, including caregivers, surgery teams, ORs, and equipment, must be considered. Insufficient capacity may result in surgical delays and OR/personnel scheduling changes, leading to additional healthcare costs and reduced patient satisfaction. Jonnalagadda et al. (2005) showed that 15 % of surgery cases in hospitals are cancelled because of the lack of available recovery beds. About 24 % of appointed surgery cases are refused because of a full intensive care unit (ICU); moreover, the patients' length of stay in the ICU and the number of ICU beds significantly affect surgery scheduling (Sobolev et al. 2005; Kim 2000).

3 Problem Description and Definition

We consider an OR scheduling problem with the limited upstream and downstream capacities and integrate the demand of resources, including staff and facilities in every stage of surgery. The objective is to reduce the total overtime cost and total idle cost of ORs. Moreover, a stable schedule can reduce the number of delayed or cancelled surgeries and the extra costs caused by schedule adjustments.

Our problem is a scheduling problem without a buffer. Using the OR suite concept, we define a surgery as a job that can be separated into three stages: preoperative, perioperative, and postoperative. In each stage, resources are needed when conducting the operation, including human resources (anesthesiologists, nurses, and surgeons) and facilities (OR, recovery room, and other medical equipment). The combination of resources in every stage is called a mode. Different operations require different modes. Therefore, for any job, two concurrent operations will never use the same resource. In this study, different modes may process the same operation. Some assumptions for the mode are given as follows:

- The available mode for any operation is known. The number of available modes is limited by the capacity of the hospital.
- When a mode is chosen for an operation, all the resources of that mode are occupied for that period of time, which consists of processing time, setup time, and cleanup time.
- Other modes that include the same resources as the chosen mode cannot provide services when the chosen mode is in progress.
- The lengths of various modes are slightly different. Every mode has an available time limit, and the available time interval of every mode is decided at the beginning of a problem setting.

In the early stages of planning, we will verify the modes available to process every stage of every job and to indicate that the available path of every job is different and known. If we consider the mode of every stage as different functions of a machine, we can turn the scheduling problem of each stage into a flexible scheduling model for the unrelated parallel machine scheduling problem and formulate a mixed integer linear programming model (MILP).

4 Heuristic Algorithm and Numerical Analysis

4.1 Heuristics

This study investigates the scheduling problem with the flexible unrelated parallel machine, which is an NP-hard problem. Therefore, we need to develop a heuristic algorithm to solve large-scale problems. This heuristic algorithm is divided into five steps to obtain a near optimal solution in a short period.

Initial step: Dividing surgical cases into three types

The first type of surgical case is the critical surgical case. It has the highest priority in scheduling. Next, the second type of surgical case has a higher priority than the third type because it requires more time to be accomplished.

Step 1: Planning critical surgical cases

Planning the perioperative and postoperative stages and scheduling OR suites are the main objective of this step. In addition, the first type of case that requires downstream resources is a high priority for planning. To avoid the chance of overtime and overtime costs and increase the efficiency of scheduling surgical cases, a preliminary plan for the order of processing for the first type of cases and OR suites is created in this step.

Step 2: Calculating the adjustment factor and deciding the adjustment range

Fig. 1 Maximum possible idling gap

If the first type of cases occupied downstream resources for a long period, then other cases must wait for the release of downstream resources, causing other surgery cases to become blocked and upstream resources to become idle. The blocking of the critical surgical case with the longest time on ICU and the surgical case with the shortest processing time result in the maximum possible idling gap (denoted as $G_{\max}$) as shown in Fig. 1.

In this study, we can derive an adjustment factor from the maximum possible idling gap, idle costs, and overtime costs of the OR suites to decide the maximum possible adjustment range by this factor. When considering placing surgical cases into the maximum possible idling gap, if the processing time of the surgical case is less than the maximum possible idling gap, the surgical case can be placed into the time interval. Conversely, it will result in overtime costs for the OR suite.

We define the unit cost of the processing time of the mode r as C_r^p and the unit overtime cost of the mode r as C_o^r. P_r is the processing time of the surgical case, which is most likely to be scheduled into the maximum possible idling gap. The idle time cost is C_{idle}. If we want to use another mode r' to deal with this surgical case, the unit cost of time and processing time are defined as $C_{r'}^p$ and $P_{r'}$. If the processing and overtime costs of the mode r are less than or equal to the processing cost of the mode r' and the idle cost of $G_{\max}$, then placing this surgical case into the maximum possible idling gap can reduce the total cost. Moreover, the critical value can be derived from Eqs. (1) and (2):

$$C_r^p \times P_r + C_o^r \times (P_r - G_{\max}) = C_{r'}^p \times P_{r'} + G_{\max} \times C_{idle}. \quad (1)$$

$$P_r = \frac{C_{r'}^p \times P_{r'} + G_{\max} \times \left(C_{idle} + C_o^r\right)}{C_o^r + C_r^p}. \quad (2)$$

More critical surgical cases require the use of the ICU and are usually operated by an experienced medical team. The processing and overtime costs of the combination of resources are therefore almost the same. We can simplify Eq. (2) by assuming $C_r^p \cong C_{r'}^p$ and $P_r \cong P_{r'}$ to derive Eq. (3):

$$P_r = \frac{G_{\max} \times \left(C_{idle} + C_o^r\right)}{C_o^r}. \quad (3)$$

If the processing time of the surgical case exceeds the critical value, placing the surgical case into the maximum possible idling gap is not advisable.

Step 3: Planning the surgical case not within the adjustment range

After finding the maximum adjustment range in Eq. (3), a small- or medium-sized surgical case with a processing time larger than the adjustment range will be planned first. The processing time of these surgical cases is relatively longer than that of other cases; in addition, these cases are expected to use more downstream resources which may also result in the idling gap. Therefore, these surgical cases should be given higher priority in planning than other cases.

Step 4: Adjusting the upper and lower bounds of the start time of planned surgeries

To improve the idle situation caused by system congestion, small and medium-sized surgical cases can be placed into the idle time interval in this step. However, not all idle time intervals can accommodate small and medium-sized surgical cases. Thus, we aim to place very small cases into the interval by a slight adjustment of the start time or end time of planned cases to increase the utilization of the OR. Given the processing time of unplanned surgical cases, an adjustment threshold (G_{adjust}) can be derived as Eq. (4).

$$G_{\text{adjust}} = \frac{C_o^r \times P_r}{\left(C_{idle}^k + C_o^r\right)}. \tag{4}$$

Step 5: Planning all surgeries

The start time and end time of surgical cases planned in Steps 1 and 3 are adjusted based on G_{adjust} and considered as constraints for planning these surgical cases. Further, the resource modes for these planned surgical cases are recorded as the input data. Because of the reduction of the problem size, all surgical cases and resource allocations are scheduled by the mixed integer linear programming model.

4.2 Parameter Analysis and Comparison

The objective of this study is to minimize the total fixed costs, overtime costs, and total cost of idle ORs. In the parameter analysis, we compared the example with five types of surgical cases and three ORs with 13 combinations of resources within a 3-day planning period solved by an MILP model and the proposed heuristic algorithm. Three factors are studied: overtime cost, idle time cost, and ability represented by O, I, and A, respectively. These factors are set to high and low standards, which are represented by subscripts H and L, respectively. Therefore, eight scenarios are studies and the results are summarized in Table 1.

Table 1 Comparison of MILP and Heuristic results

Scenario	MILP result				Heuristic result			
	Total cost	Overtime cost	Idle time cost	OR utility (%)	Total cost	Overtime cost	Idle time cost	OR utility (%)
$1(O_H, I_H, A_H)$	\$161,632	\$9,142	\$1,200	96.30	\$169,115	\$22,855	\$2,800	96.30
$2(O_H, I_H, A_L)$	\$192,216	\$54,976	\$800	97.04	\$203,347	\$45,207	\$100	99.63
$3(O_H, I_L, A_H)$	\$166,230	\$0	\$360	90.48	\$172,680	\$2,150	\$360	90.48
$4(O_H, I_L, A_L)$	\$187,380	\$13,060	\$620	83.60	\$197,070	\$0	\$960	78.24
$5(O_L, I_H, A_H)$	\$163,400	\$32,000	\$0	100	\$164,650	\$33,250	\$0	100
$6(O_L, I_H, A_L)$	\$164,270	\$18,500	\$1,500	94.44	\$169,280	\$24,050	\$1,500	100.00
$7(O_L, I_L, A_H)$	\$139,780	\$19,000	\$0	100	\$143,030	\$22,250	\$0	100
$8(O_L, I_L, A_L)$	\$151,160	\$29,300	\$0	100	\$151,160	\$29,300	\$0	100

Figure 2 shows that the total medical cost has roughly the same pattern as the fixed costs and that the fixed costs of opening or not opening OR suites significantly affect the total cost of the hospital. The difference between the total medical cost and the fixed cost in Scenario 2 is slightly large because the overtime work involved in the situation is more serious than the others, thereby leading to higher overtime costs.

Although the result of MILP is similar to that of the heuristic algorithm, they differ in overtime costs. The total cost in the heuristic algorithm is higher than the approximate optimal solution by only about 3.2 % in average, but the time required by the MILP to reach a solution is about 443 times longer than that by the heuristic algorithm. Therefore, we suggest using the heuristic algorithm to save time.

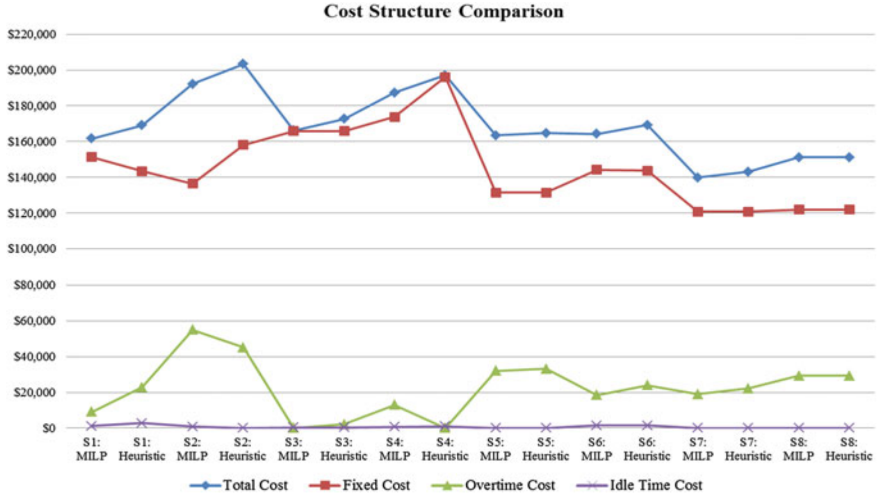


Fig. 2 Costs comparison for each scenario

5 Conclusion

In this study, we integrate resources and plan the schedule using the concept of the OR suite while considering constraints of upstream and downstream resources of ORs in a hospital to avoid ORs being occupied or idle because of a lack of upstream and downstream capacities. Using the OR scheduling method proposed in this study, the forced cancellation or delay of surgeries for the maintenance of the quality of medical and surgical services can be avoided. Hence, the satisfaction of staff and patients is also improved.

This problem can be formulated as an MILP model, and the objective is to minimize the fixed costs, overtime costs, and idle costs of ORs. Given the high degree of complexity of this problem, we propose a five-step heuristic algorithm to increase the efficiency of solving this large-scale problem. We also compare and discuss the results of MILP and the heuristic algorithm to identify the applicable conditions for the problems faced by the different scenarios.

In conclusion, the differences in total costs between MILP and the heuristic algorithm when solving the different scenarios are within 6 %. However, the heuristic algorithm is more efficient, and it can be used to solve not only different scenarios within this problem but also large-scale practical problems.

Acknowledgments This research was supported by National Science Council of Taiwan (NSC 99-2221-E-002-155-MY3).

References

Denton B, Viapiano J, Vogl A (2007) Optimization of surgery sequencing and scheduling decisions under uncertainty. Health Care Manage Sci 10(1):13–24

Denton BT, Miller AJ, Balasubramanian HJ, Huschka TR (2010) Optimal allocation of surgery blocks to operating rooms under uncertainty. Oper Res 58(41):802–816

Dexter F, Traub RD, Macario A (2003) How the release allocated operating room time to increase efficiency: predicting which surgical service will have the most underutilized operating room time. Anesth Analg 96:507–512

Jackson RL (2002) The business of surgery: managing the OR as a profit center requires more than just IT. It requires a profit-making mindset, too. Oper Room Inf Syst, Health Manage Technol

Jonnalagadda R, Walrond ER, Hariharan S, Walrond M, Prasad C (2005) Evaluation of the reasons for cancellation and delays of surgical procedures in a developing country. Int J Clin Pract 59(6):716–720

Kim SC (2000) Flexible bed allocation and performance in the intensive care unit. J Oper Manage 18:427–443

Pham DN, Klinkert A (2008) Surgical case scheduling as a generalized job shop scheduling problem. Eur J Oper Res 185:1011–1025

Sobolev BG, Brown PM, Zelt D, FitzGerald M (2005) Priority waiting lists: is there a clinically ordered queue? J Eval Clin Pract 11(4):408–410

Weinbroum AA, Ekstein P, Ezri T (2003) Efficiency of the operating room suite. Am J Surg 185:244–250

Research on Culture Supply Chain Intension and Its Operation Models

Xiaojing Li and Qian Zhang

Abstract In recent years, China has become the cultural industry toward highly centralized, with the rapid development of international direction. Between the competitions of the 21st century, not a business enterprise competition, but competition in the supply chain and supply chain, supply chain is the development trend of industry chain as the value chain of cultural products. Supply chain functions, like integration, and optimization, are gradually reflected in the cultural industries. The cultural characteristics of the supply chain are proposed in this paper. From the perspective of the cultural industry and supply chain's intension, several cultural supply chain operating models are given in this paper. From the angle of the supply chain finance and capital flow, the supply chain operation mechanism is presented for how to promoting the culture of the supply chain, which is provided a reference for increasing the cultural development of the supply chain.

Keywords Culture industry · Culture supply chain · Operation mode · Supply chain finance · Operating mechanism

In 2010, the overall size of Chinese cultural industry market total transactions amount reached to 169.4 billion, an increase of 41 % from 2009. In 2011, Chinese cultural industry market transactions amount reached to 210.8 billion. In 2012, the first time China surpassed United States to become the world's largest art market; Chinese cultural industry output value is expected to exceed 4 trillion Yuan, make further enhance the proportion of GDP. These series growth dates indicated that cultural industry market as a special market have tremendous development potential and cultural industry is gradually mature in china.

X. Li (✉) · Q. Zhang
School of Economics and Finance, Huaqiao University, Quanzhou, Fujian 362021, People's Republic of China
e-mail: 1017126988@qq.com

Q. Zhang
e-mail: zhangyl@hqu.edu.cn

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_60,

1 The Connotation of Cultural Supply Chain

What is “culture”? In 1871 American anthropologist Edward Taylor put forward to a concept, the cultural is defined as “a completed system including knowledge, faith, art, morality, custom, and all the abilities and habitats from which a social member would acquire”. Cultural products are created by a person or department, and cultural or artistic as the main content, which the goals are meet the needs of the human spirit, reflect the social ideology and become mass entertainment culture carrier. UNESCO United Nations defined cultural industry is “According to industry standards, cultural industry includes production, reproduction, storage, and distribution of cultural products and a series of activities.” Cultural industry market is different from other material economy markets. When mining existing cultural resources to create a new cultural products or services, instead of bring consumption and loss of original cultural resources; we will increase the content of the original cultural resources. Supply chain is building around the core business, starting from the procurement of raw materials, intermediate products and final products, then deliver to consumers by sales network, through control information flow, logistics, capital flow, together suppliers, manufacturers, distributors, retailers, until end-user into an overall functional network chain structure. Now Chinese cultural industry is constantly maturity, development, and gradually forms a complete industrial chain. Putting supply chain theory into cultural industry, using supply chain basic ideas to achieve these goals that include integrate the cultural industry, achieve efficient operation of cultural industry, create time value, place value, and other value-added; achieve cultural industry restructuring, optimize the industrial structure, improve the functional organization of urban land use, improve the investment environment, the protection of the urban environment and bring about other important social functions. Through anglicizing and combing the concept of cultural product and supply chain, this paper present cultural connotation of product supply chain and it unlike other material goods supply chain, put forward to the definition of cultural products supply chain and features that differ from other products. Taking the market as the orientation, Cultural supply chain is based on leading enterprises, linked with interest, put the cultural product creation, production, processed, sales, as a whole, be integrated with flow of material, information and capital, finally form a network structure with industrial chain. The cultural flow chart of the supply chain as follows in Fig. 1.

2 Basic Characteristics of Cultural Supply Chain

The key to form a complete supply chain is to increase the added value of cultural industry chain. If you do not use supply chain theory to optimize logistics, information, capital on the whole industry chain flow, to reduce unnecessary links, the china is just a cultural industry chain, not a cultural industry supply chain.

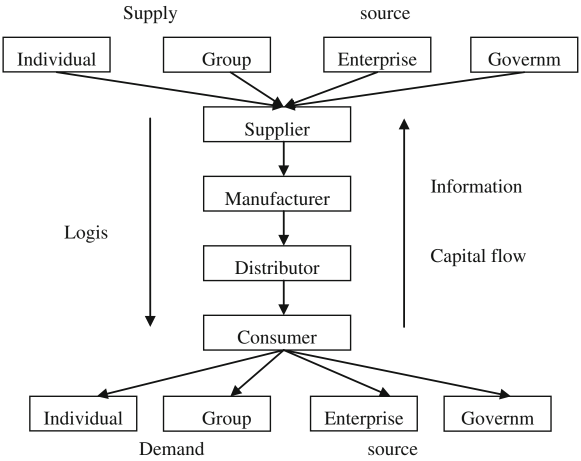


Fig. 1 The cultural supply chain flow chart

In the cultural industry, around the core enterprise, optimize the characteristics of cultural products and supply chain management, control the logistics flow, information flow, capital flow, to form a supply chain network structure from the creative source to the final consumers. According to the analysis of cultural industry and supply chain, cultural industry supply chain has characteristics of general industry supply chain, also has its own characteristics. The cultural supply chain basic characteristics are as follows:

1. Higher complexity. Compare with other products, Cultural products supply chain more complexity, this kind of complexity is composed of several aspects. First, the supply chain upstream—cultural product creation, cultural product features: symbolic, invisible, ideology and so on, determine the diversity of cultural product types, and sources of product creators. The product creators including individuals, social groups, enterprises and government. Cultural upstream supply chain show its complexity, so that we should pay attention to upstream supply chain. Second, compare with other general products, the manufacturing process of cultural product become more complexity, cultural manufacture process is not a one-time processing, but through industrial chain, take advantage of cultural resources, put in-depth development to repeatedly output on the content, including offer rich additional market value for related industries. This special complexity is determined by cultural features like the eternal value and advanced. Finally, the last thing is cultural product sales, because of cultural product consumption has a lot of uncertainty, compared with the general sales, cultural products become more complexity. These uncertainties are directly or indirectly connect with the policy changes, the demand of social media, and not simplify for supply and demand theory determine the entire marketing process. At the same time, cultural products consumers may also be new cultural product creators, therefore cultural products of service object may become to cultural products provider.

2. Better agility. Compared with general industry, the ideology and intangibility of cultural products represent cultural products in constant spread, demand is also constantly changing, so better agility of whole cultural supply chain to be required. As a creative of cultural industry, cultural industry supply chain need dynamic more, so its agility requires higher. The agility of cultural supply chain is mainly reflected in three aspects: Firstly, source of cultural supply chain—cultural products suppliers, Cultural product innovation and mining maximum cultural value directly affects entire cultural industry supply chain from source of manufacture to sales. Secondly, manufacturing process of cultural product, because of culture features: innovative frequent, the entire manufacturing operation require to make quick response to meet supply chain requirements, to shorten the operating cycle, to reduce unnecessary work link, can be reflect to supply chain upstream in time. Finally, cultural products marketing process, that is to maximize product speed which is transferred to the consumer market, shorten the operating cycle of cultural products.
3. More network nodes. Cultural supply chain is a network structure which consists of core business of supplier, the supplier's suppliers and users, end-users. Because of the special attributes of cultural products, suppliers, intermediaries and users of cultural supply chain appear diversification, while government and special assessment agencies are also involved in the whole cultural product supply chain process. Compare with other products, network nodes of cultural supply chain with more hierarchical, more integration use to entire cultural supply chain. A reasonable network node has a vital role to improve entire cultural products supply chain efficiency and integration.

3 Cultural Supply Chain Operation Modes

Supply chain theory in the application of cultural industry are mainly reflected in two aspects: **Integrated Supply Chain (ISC).** The use of ISC in cultural industry mainly centres on product-orientation, geographical area, various enterprises and Industry internal and external systems etc. In general, ISC deem supply chain as integration which include integration of supply demand relations, integration of logistics, information and management. **Green Chain.** Green Chain is that considering environmental factors and regeneration influence factors on the industrial chain integration. In the development of cultural industries, it contains Green Chain idea. For example, ecological park is a kind of green tourism, green is an important factor to consider in the development of park, need to ensure minimum damage to the environment, to realize the green supply chain operation, reduce unnecessary waste. Again for instance, recovery based on knowledge of culture product, also embodies the idea of Green Chain. Nowadays the competition between enterprises is the competition between supply chains. Through analysis the characteristics and connotation of cultural supply chain, combined with the actual situation of China's cultural industry development, according to the development of cultural industry relying on the land space needs, gradually formed two types of supply chain development models: one is the entity of the industrial park and industrial integration mode, second is the virtual network level mode.

3.1 Physical Space: The Cultural Industry Cluster Supply Chain Operation Mode

At present, innovation is an important role in cultural industry development, innovation make all-round, large-scale influence on cultural industry development. According to innovation and degree of dependence on tangible resources, mainly have the following several kinds of supply chain development path: (1) Relying on resources mode. (2) Creative guidance modes. (3) Non inheritance innovation mode.

3.2 Virtual: Network Level Cultural Supply Chain Operations Mode

With the development of international information, Science and technology, e-commerce in various industries have achieved a certain degree of development. Cultural supply chain network modes consist of Cultural Assets and Equity Exchange, namely establish a network platform that realize seamless connectivity between service providers and customers, reduce unnecessary operational flow. This mode has the following features:

1. Supply chain management functions. Through integrated information, technology to the entire operation platform, controlled logistics, information, capital flow from suppliers and customers, reduced unnecessary operation process, such as suppliers, etc., to achieve the whole chain integration and optimization.
2. Integration of capital flows. From the view point of capital flow, currently chinese cultural property rights exchange mainly to solve cultural products pricing, settlement, delivery, financing and other capital flows problems. Because cultural property trading platform can put individual, group, government, corporate and other participants together, take advantage of information technology as soon as possible to achieve circulation of entire supply chain flow and to get rid of the unnecessary capital flows operation, to achieve capital flow integration of entire supply chain and value-added of industrial chain, to achieve integration of capital flow operation (Fig. 2).

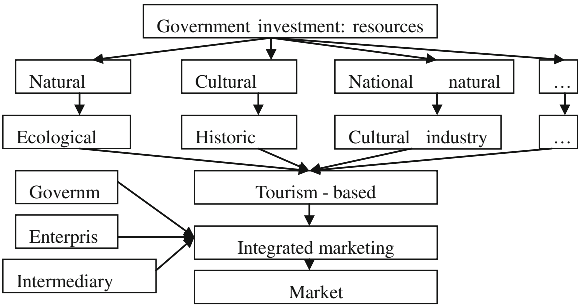


Fig. 2 Resources type culture industry supply chain mode of operation

4 Cultural Supply Chain Operation Mechanism

Cultural supply chain operating mechanism is use to optimize and integrate cultural industry in logistics, information and capital flow. Logistics: cultural supply chain logistics related to cultural products such as procurement, production, inventory, package, transportation, sales process. Information flow: through information sharing, cultural supply chain information flow mainly realize seamless connectivity to reduce the bullwhip effect, achieve to fast response and entire supply chain agility. Capital flow: cultural supply chain capital flow mainly is reflected in financing activities, settlement payment, procurement activities and risk control.

Supply chain finance embedded industrial clusters can get more new resources "blood" to promote cultural industry cluster rapid development. Industrial clusters also can make supply chain finance more widely used, and then provide a good credit environment to improve income levels and reduce the risk for financial institutions. From point view of supply chain finance, optimizing integration of cultural supply chain we can from following aspects:

1. Establish clear cultural industry supply chain finance subject. Depending on the supply chain model, subjects have following categories: (1) government, macro managers. As planners and investors of Chinese cultural industry parks, ecological parks and other gathering place, in the early stages development of cultural supply chain government is a very important finance body. (2) Core enterprises. As cultural supply chain dominant enterprises, core enterprises open up cultural supply chain upstream and downstream financing needs to stabilize entire supply chain cash flow and to promote supply chain integration and flexible development. (3) Other enterprises. As other supply chain node enterprise, be able to reduce capital flow pressure, to some extent, promoting supply chain stable and orderly development. (4) other organizations. Other organizations such as bank play an important payment and settlement role which affecting whole cultural supply chain capital flow. Making a clear cultural supply chain financial body category, and then proposing different financial strategies for financial body have significant significance.

2. Coordination mechanisms. From point view of core enterprise capital flow, Supply chain finance collaborative management is base on collaborative theory. At strategic, motivation, business level, through financing, procurement, payment, we wish settlement and risk control activities can achieve whole cultural supply chain financial body coordination, achieve cultural supply chain capital flow integration, shorten current cycle of cultural products, improve the operating efficiency of entire supply chain, achieve whole culture supply chain coordination, agility and flexibility.
3. Establish partnership. Supply chain partnership is the node enterprises for the common goal to establish a benefit-sharing, risk-sharing partnership in the supply chain. Cultural supply chain operations have certain risks, such as credit risk. Establishing partnerships is an effective means to avoid credit risk, help to improve the reputation of the business-to-business, to reduce unnecessary approval operational aspects, to control supply chain finance risks, to achieve a higher level of integration of supply chain, to improve the operation of the entire supply chain finance.

Acknowledgments This paper was supported in part by National Natural Science Foundation of China under grant number 71040009, in part by Program for New Century Excellent Talents in University under grant number NCET-10-0118, in part by Youth Foundation of Chinese Education by Huo Ying-dong under grant number 104009.

References

Fang Z, Zhang X (2010) Cluster-based supply chain study of cultural creative industry. In: E-business and information system security (EBISS)

Sheng W (2008) Cultural industry supply chain, industrial chain and value chain—in order to Dafen Industrial Park as an example of cultural characteristics. Urban Probl 12:2008

Song H (2012) Relationship of supply chain finance and the development of industrial clusters. North Finance 01:2012

Wu Z (2008) Cluster-based supply chain, the development of cultural industry garden path. J Nanjing Univ Finance and Econ 05:2008

Yu P (2013) Chinese cultural innovation report. Social Science Culture Press, Beijing

Zang X, You T (2011) Cultural product: further understanding of the characteristics and attributes. Exploration No. 05 2011

Zhu Z, Zhang S (2012) Cultural creative industry concept and form analysis. Northeastern University News No.01 2012

Power System by Variable Scaling Hybrid Differential Evolution

Ji-Pyng Chiou, Chong-Wei Lo and Chung-Fu Chang

Abstract In this paper, the variable scaling hybrid differential evolution (VSHDE) used to solve the large-scale static economic dispatch problem. Different from the hybrid differential evolution (HDE), the concept of a variable scaling factor is used in the VSHDE method. The variable scaling factor based on the 1/5 success rule of evolution strategies (ESs) is embedded in the original HDE to accelerate the search for the global solution. The use of the variable scaling factor in the VSHDE can overcome the drawback of the fixed and random scaling factor used in HDE. To alleviate the drawback of the penalty method for equality constraints, the repair method is proposed. One 40-unit practical static economic dispatch (SED) system of Taiwan Power Company is used to compare the performance of the proposed method with HDE. Numerical results show that the performance of the proposed method combining with the repair method is better than the other methods.

Keywords VSHDE · Economic dispatch · Repair method

J.-P. Chiou (✉) · C.-W. Lo
Department of Electrical Engineering, Ming Chi University of Technology, New Taipei, Taiwan
e-mail: jipyng@mail.mcut.edu.tw

C.-W. Lo
e-mail: milk_tea666666@hotmail.com

C.-F. Chang
Department of Electrical Engineering, WuFeng University, Chiayi, Taiwan
e-mail: cfchang@wfc.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_61,

1 Introduction

The aim of the economic dispatch (ED) is to obtain the great benefits in power system. So, many mathematic programming methods have been researched for ED problems. Su and Chiou (1995) applied Hopfield network approach to solve the economic dispatch problems. However, the Hopfield network method requires two phase computations. Sewtohul et al. (2004) proposed genetic algorithms (GAs) to solve the economic dispatch problem. Gaing (2003) proposed a practical swarm optimization (PSO) method for solving the economic dispatch problems in power systems. The population size is set to 10 × b, where b, is the number of decision parameters. In so doing, much more computation time is required to evaluate the fitness function. Sinha et al. (2003) used an evolutionary programming (EP) method to solve economic dispatch problems.

Hybrid differential evolution (HDE) (Chiou and Wang 1999, 2001) is a stochastic search and optimization method. The fittest of an offspring competes one by one with that of the corresponding parent. This competition implies that the parent is replaced by its offspring if the fitness of the offspring is better than that of its parent. On the other hand, the parent is retained in the next generation if the fitness of the offspring is worse than that of its parent. This one by one competition gives rise to a faster convergence rate. However, this faster convergence also leads to a higher probability of obtaining a local optimum because the diversity of the population descends faster during the solution process. To overcome this drawback, migrating operator and accelerated operator act as a trade-off operator for the diversity of population and convergence property in HDE. However, a fixed scaling factor is used in HDE. Using a smaller scaling factor, HDE becomes increasingly robust. However, much computational time should be expanded to evaluate the objective function. HDE with a larger scaling factor generally produces a local solution or misconvergence. Lin et al. (2000) used a random number that its value is between zero and one as a scaling factor. However, a random scaling factor could not guarantee the fast convergence.

In this study, a variable scaling hybrid differential evolution (VSHDE) (Chiou et al. 2005) for solving the large-scale economic dispatch problems is proposed. Different from the HDE, the scaling factor based on the 1/5 success rule of evolution strategies (ESs) (Back and Schwefel 1991, 1993) is used in VSHDE method to accelerate searching out the global solution. The repair method is used to alleviate the drawback of the penalty method for equality constraints. To illustrate the convergence property of the proposed method, one 40-unit economic dispatch system of Taiwan power system is used to compare the performance of the proposed method with HDE.

2 Problem Formulation

The economic dispatch problem can be mathematically described as follows:

$$min \sum\nolimits_{i \in \boldsymbol{\Psi}} \mathrm{P}_i = \mathrm{P}_D + \mathrm{P}_L \tag{1}$$

where i is index of dispatchable units, P_i is power generation of unit i, $\boldsymbol{\Psi}$ is a set of all dispatchable units. Subject to the following constraints:

1. Power balance constraint

$$\sum\nolimits_{i \in \boldsymbol{\Psi}} \mathrm{P}_i = \mathrm{P}_D + \mathrm{P}_L \tag{2}$$

$$\mathrm{P}_L = \sum_i \sum_j \mathrm{B}_{ij} \mathrm{P}_i \mathrm{P}_j \tag{3}$$

where P_D is total load demand, P_L is power losses and B_{ij} is power loss coefficient.

2. Generation limits of units

$$\mathrm{P}_{i\ min} \leq \mathrm{P}_i \leq \mathrm{P}_{i\ max} \tag{4}$$

where $\boldsymbol{P_{i\ min}}$ and $\boldsymbol{P_{i\ max}}$ are the minimum and maximum of unit i, respectively.

3 VSHDE Method

The VSHDE method is briefly described in the following.

Step 1: Initialization

The initial population is chosen randomly in an attempt to cover the entire parameter space uniformly as (5).

$$Z_i^0 = Z_{i,min} + \left(\sigma_i \cdot \left(Z_{i,max} - Z_{i,min}\right)\right), \quad i = 1, 2, \ldots, N_p \tag{5}$$

where $\sigma_i \in (0, 1]$ is a random number. The initial process can produce N_P individuals of Z_i^0 randomly.

Step 2: Mutation operation

The essential ingredient in the mutation operation is the difference vector. Each individual pair in a population at the G-th generation defines a difference vector D_{jk} as

$$D_{jk} = Z_j^G - Z_k^G \tag{6}$$

The mutation process at the G-th generation begins by randomly selecting either two or four population individuals Z_j^G, Z_k^G, Z_j^G and Z_m^G for any j, k, l and m. These four individuals are then combined to form a difference vector D_{jklm} as

$$D_{jklm} = D_{jk} + D_{lm} = \left(Z_j^G - Z_k^G\right) + \left(Z_l^G - Z_m^G\right) \tag{7}$$

A mutant vector is then generated based on the present individual in the mutation process by

$$\hat{Z}_i^{G+1} = Z_p^G + \left(F \cdot D_{jklm}\right), \quad i = 1, 2, \ldots, N_p \tag{8}$$

where F is the scaling factor. Further more, j, k, l and m are randomly selected.

Step 3: Crossover operation

The perturbed individual of $\hat{Z}_i^{G+1}$ and the present individual of Z_i^G are chosen by a binomial distribution to progress the crossover operation to generate the offspring. Each gene of i-th individual is reproduced from the mutant vectors $\hat{Z}_i^{G+1} = \left[\hat{Z}_{1i}^{G+1}, \hat{Z}_{2i}^{G+1}, \ldots, \hat{Z}_{ni}^{G+1}\right]$ and the present individual $Z_i^G = \left[Z_{1i}^G, Z_{2i}^G, \ldots, Z_{ni}^G\right]$. That

$$\hat{Z}_i^{G+1} = \begin{cases} Z_{gi}^G & \text{if a random number} > C_r \\ \hat{Z}_{gi}^{G+1} & \text{otherwise} \end{cases} \tag{9}$$

where $i = 1, \ldots, N_p; g = 1, \ldots, n$; and the crossover factor $C_r \in [0, 1]$ is assigned by the user.

Step 4: Estimation and selection

The evaluation function of a child is one-to-one competed to that of its parent. This competition means that the parent is replaced by its child if the fitness of the child is better than that of its parent. On the other hand, the parent is retained in the next generation if the fitness of the child is worse than that of its parent, i.e.

$$Z_i^{G+1} = \arg\ min\left\{\mathrm{f}\left(Z_i^G\right), \mathrm{f}\left(\hat{Z}_i^{G+1}\right)\right\} \tag{10}$$

$$Z_b^{G+1} = \arg\ min\left\{\mathrm{f}\left(Z_i^G\right)\right\} \tag{11}$$

where *arg min* means the argument of the minimum.

Step 5: Migrating operation if necessary

In order to effectively enhance the investigation of the search space and reduce the choice pressure of a small population, a migration phase is introduced to regenerate a new diverse population of individuals. The new population is yielded based on the best individual Z_b^{G+1}. The g-th gene of the i-th individual is as follows:

$$Z_{ig}^{G+1} = \begin{cases} Z_{bg}^{G+1} + \left(\sigma_i \cdot \left(Z_{g\,min} - Z_{bg}^{G+1}\right)\right), & \text{if } \delta \frac{Z_{bg}^{G+1} - Z_{g\,min}}{Z_{g\,max} - Z_{g\,min}} \\ Z_{bg}^{G+1} + \left(\sigma_i \cdot \left(Z_{g\,max} - Z_{bg}^{G+1}\right)\right), & \text{otherwise} \\ i = 1, 2, \ldots, N_p; \quad g = 1, 2, \ldots, n \end{cases} \tag{12}$$

where σ_i and δ are randomly generated numbers uniformly distributed in the range of [0,1]; $i = 1, \ldots, N_p$; and $g = 1, \ldots, n$.

The migrating operation is executed only if a measure fails to match the desired tolerance of population diversity. The measure is defined as follows:

$$\varepsilon = \sum_{\substack{i=1 \\ i \neq b}}^{N_p} \sum_{g=1}^{n} \frac{\eta_z}{\left(n \cdot \left(N_p - 1\right)\right)} < \varepsilon_1 \tag{13}$$

where

$$\eta_z = \begin{cases} 0, & \text{if } \varepsilon_2 < \left\| \frac{Z_{gi}^{G+1} - Z_{bi}^{G+1}}{Z_{bi}^{G+1}} \right\| \\ 1, & \text{otherwise} \end{cases} \tag{14}$$

Parameter $\varepsilon_1, \varepsilon_2 \in [0, 1]$ expresses the desired tolerance for the population diversity and the gene diversity with respect to the best individual.

Step 6: Accelerated operation if necessary

When the best individual at the present generation is not improved any longer by the mutation and crossover operations. A decent method is then employed to push the present best individual toward attaining a better point. Thus, the accelerated phase is expressed as follows

$$Z_b^{G+1} = \begin{cases} Z_b^{G+1}, & \text{if } f\left(Z_b^{G+1}\right) < f\left(Z_b^G\right) \\ Z_b^{G+1} - \alpha \nabla f, & \text{otherwise} \end{cases} \tag{15}$$

where Z_b^G denotes the best individual, as obtained from Eq. (15). The step size $\alpha \in (0, 1]$ in (15) is determined by the descent property. Initially, α is set to one to obtain the new individual.

Step 7: Updating the scaling factor if necessary

The scaling factor should be updated in every q iterations as follow:

$$F^{t+1} = \begin{cases} c_d \times F^t & \text{if } p_s^t < \frac{1}{5} \\ c_j \times F^t & \text{if } p_s^t > \frac{1}{5} \\ F^t & \text{if } p_s^t = \frac{1}{5} \end{cases} \tag{16}$$

where p_s^t is the frequency of successful mutations measured. The initial value of the scaling factor, F, is set to 2 (Storn and Price 1996; Price 1997). The factors of $c_d = 0.82$ and $c_j = 1/0.82$ (Michalewicz 1999) are used for adjustment, which should be taken place for every q iterations.

When the migrating operation performed or the scaling factor is too small to find the better solution, the scaling factor is reset as follow:

$$F = 1 - \frac{iter}{itermax} \tag{17}$$

where $iter$ and $itermax$ are the number of current iteration and the maximum iteration, respectively.

Step 8: Repeat step 2 to step 7 until the maximum iteration quantity or the desired fitness is accomplished.

4 Example

To investigate the convergence property of the VSHDE, a 40-unit practical ED system of Taiwan Power Company (TPC) is employed as an example. The power loss is released in this example. The total demand is 10,500 MW. The penalty method and repair method are used for the equality constraints, respectively. To compare the performance of the VSHDE and HDE methods, this system is repeated 20 independent trials. The best convergence property among this 20 runs of the HDE and VSHDE methods are lists in Fig. 1. From the Fig. 1, the convergence property of the VSHDE combining the repair method is better than the other methods. The largest and smallest values among the best solutions of the 20

Fig. 1 The best convergence property of the HDE and VSHDE methods

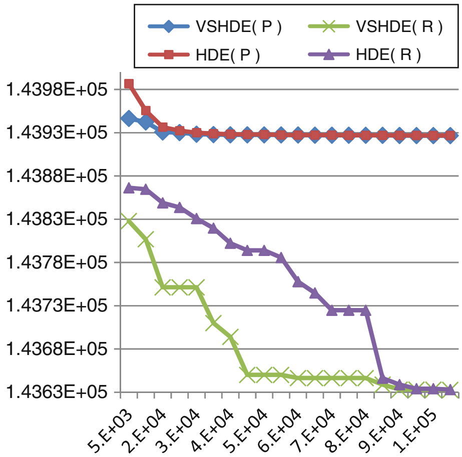


Table 1 Computational result for 20 runs of example

	Penalty method		Repair method	
	VSHDE	HDE	VSHDE	HDE
STD	0.1598983	0.1673993	41.9851067	58.0260301
MAX. ($)	143926.9138	143927.2861	143778.2017	143831.3298
MIN. ($)	143926.4272	143926.7005	143632.7084	143633.0706
AVE. ($)	143926.6289	143927.0029	143724.7618	143757.7223

runs are, respectively, expressed in Table 1. The average for the best solutions of the 20 runs and the standard deviation with respect to the average are also shown in this table. A smaller standard deviation implies that almost all the best solutions are close to the average best solution. The standard deviation for the VSHDE method is smaller than the HDE method. From the above discussion, the convergence property of the VSHDE method is better than the HDE method.

5 Conclusion

This paper uses the VSHDE and HDE methods is solved the large-scale economic dispatch systems, respectively. The VSHDE method utilized the 1/5 success rule of the evolution strategies (ESs) to adjust the scaling factor to accelerate searching out the global solution. The variable scaling factor is used to overcome the drawback of fixed and random scaling factor used in HDE. To alleviate the drawback of the penalty method for the equality constraints, the repair method is used in this paper. The computational results obtained of solving one 40-unit practical ED system of Taiwan Power Company are investigated. From the computation results, the VSHDE method combing the repair method is better than the other methods.

Acknowledgments Financial research support from the National Science Council of the R. O. C. under grant NSC 100-2632-E-131-001-MY3 2/3 is greatly appreciated.

References

Back T, Schwefel HP (1993) An overview of evolutionary algorithms for parameter optimization. Evol Comput 1:1–23

Chiou JP, Wang FS (1999) Hybrid method of evolutionary algorithms for static and dynamic optimization problems with application to fed-batch fermentation process. Comput Chem Eng 23:1277–1291

Chiou JP, Wang FS (2001) Estimation of monod parameters by hybrid differential evolution. Bioprocess Biosyst Eng 24(2):109–113

Chiou JP, Chang CF, Su CT (2005) Variable scaling hybrid differential evolution for solving network reconfiguration of distribution systems. IEEE Trans Power Syst 20(2):668–674

Gaing ZL (2003) Particle swarm optimization to solving the economic dispatch considering the generator constraints. IEEE Trans Power Syst 8(3):1187–1195

Lin YC, Hwang KS, Wang FS (2000) Plant scheduling and planning using mixed-integer hybrid differential evolution with multiplier updating. Congr Evol Comput 1:593–600

Michalewicz Z (1999) Genetic algorithms + data structures = evolution programs, 3rd edn. Springer, New York

Price KV (1997) Differential evolution vs. functions of the 2nd ICEC. IEEE Conf Evol Comput 1:153–157

Sewtohul LG, Ah K, Rufhooputh HCS (2004) Genetic algorithms for economic dispatch with valve point effect. IEEE Int Conf Network, Sens Control 2:1358–1363

Sinha N, Chakrabarti R, Chattopadhyay PK (2003) Evolutionary programming techniques for economic load dispatch. IEEE Trans Evol Comput 7(1):83–94

Storn R, Price KV (1996) Minimizing the real functions of the ICEC'96 contest by differential evolution. IEEE Conference on Evolutionary Computation pp 842–844

Su CT, Chiou GJ (1995) Hopfield network approach to economic dispatch with prohibited operating zones. In: Proceedings of IEEE on energy management and power delivery conference, pp 382–387

Investigating the Replenishment Policy for Retail Industries Under VMI Strategic Alliance Using Simulation

Ping-Yu Chang

Abstract Recently, retail industries are booming rapidly because of the convenience and low price. However, as the competition increases, inventory shortage becomes a serious problem for both retailer and supplier. Therefore, developing a suitable inventory management for retailer and supplier has been a pertinent area of study in recent years. Some strategies such as Quick Response (QP), Continuous replenishment (CR), and Vendor Managed Inventory (VMI) have been proven to have impact on retailer-supplier inventory. However, only qualitative research are devoted in these strategies which might not provide detailed insights of the usefulness for using these strategies. Therefore, this paper investigates VMI strategies using simulation models and develops the replenishment policy for implementing VMI. Furthermore, this research uses Automatic Pipeline Inventory Order Based Production Control System (APIOBPCS) to identify the factors of using VMI in retailer-supplier inventory management and a simulation model based on these factors is developed to achieve the replenishment policy. The results show that total cost will be reduced and inventory turnover can be increased using this replenishment policy in VMI.

Keywords Retailer · VMI · Strategic alliance · Replenishment policy

1 Introduction

Recently, retail industries are booming rapidly because of the convenience and low price. The major function of retailers is being the middleman between suppliers and customers. For the suppliers, retailers provide exihibition place for their

P.-Y. Chang (✉)
Department of Industrial Engineering and Management, Ming Chi University of Technology, #84 Gungjuan Rd, Taishan District, New Taipei City 243, Taiwan
e-mail: pchang@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_62,

product while retailers maintain various product and reduce transaction cost for customers. Simchi-Levi et al. (2001) pointed out the reason of bullwhip effect and showed that reducing uncertainty and constructingstrategic alliance will reduce the bullwhip effect. For strategic alliance, Quick Response (QR), Continuous Replenishment (CR), and Vendor Management Inventory (VMI) are usually implemented and discussed. All the strategic alliances are proved to reduce inventory and lead time while increasing efficiency. Furthermore, Tyan and Wee (2003) analyzed VMI and demonstrated that VMI can solve the problem of inventory shortage. VMI is realized to have the most significant effect on reducing inventory and lead time than QR and CR. However, its effectiveness will be different among various strategies executions. To realize the impact, further analysis should be performed with appropriate measurements. Computer simulation has become a very popular tool in the analysis and design of manufacturing systems and has been done for a variety of purposes from assessing the flexibility of the system to comparing different system designs. Therefore, this research investigates the effect of implementing VMI into industries using simulation.

2 Literature Reviews

VMI is known as the suppliers (vendors) control the quantity and the date of the shipment so that inventory levels of suppliers and retailers can be reduced. Alberto compared the situations of traditional supply chain and VMI supply chain when orders occur. His research proved that VMI can be effective for inventory control because of the just-in-time information flow between suppliers and retailers. Tyan and Wee (2003) investigated the impact of implementing VMI in retail industries in Taiwan. The results showed that great advantages can be achieved using VMI in inventory control for retail industries. The results also indicated that VMI can be applied in electronic industries to reduce inventory level and lead time. Disney and Towill (2003a, b) described VMI as the special collaborative strategy between manufacturers and distributors based on literatures. Distributors will collect and pass customers' purchasing information to manufacturers and suppliers so that forecast estimation accuracy and reorder point can be improved. Furthermore, Disney and Towill (2003a, b) proved that VMI can solve bullwhip effect within traditional supply chain while inventory cost was reduced and inventory turnover is increased. Disney et al. (2004) also evaluated the impact of using VMI in different echelons of supply chain and concluded that VMI was appropriate for dynamic supply chain. Hong (2002) used IOBPCS (Inventory and Order Based Production Control System) to present the problems within the production systems and provided strategies to solve the proposed problems. IOBPCS was first mentioned by Coyle in 1977 and strengthened by Naim and Towill in 1993. IOBPCS represents the simplify model of the relations within the real production system and was introduced based on observation of British industries. Berry discussed the variables that were appropriate for IOBPCS. These variables are production completion rate, inventory level, lead time, and fill rate.

John introduced WIP (work in progress) into IOBPCS to enhanced the stability of the system and proposed APIOBPCS(Automatic Pipeline Inventory and Order Based Production Control System,APIOBPCS) for modeling the production system. Disney and Towill (2002a, b, c) then applied APIOBPCS to increase the stability of VMI supply chain and the results showed that the production system can be more stable with WIP as the performance measurement.

3 Methodology and Results

This research develops an APIOBPCS model of VMI for retailers and suppliers based on the IPBPCS model created by Disney. The proposed model can be applied to evaluate the impact of implementing VMI into the relationship of suppliers and retailers. Figure 1 demonstrates the developed APIOBPCS model of suppliers and retailers. In Fig. 1, the direction with a positive sign represents the decision making process will add value to the supply chain. For example, a positive sign existed on the direction from warehousing to suppliers safety stock. The reason of positive sign is that inventory is moved from warehouse to suppliers to reduce the total inventory level of the supply chain. The negative sign represents the decision making process will deduct the value to the supply chain. The reason

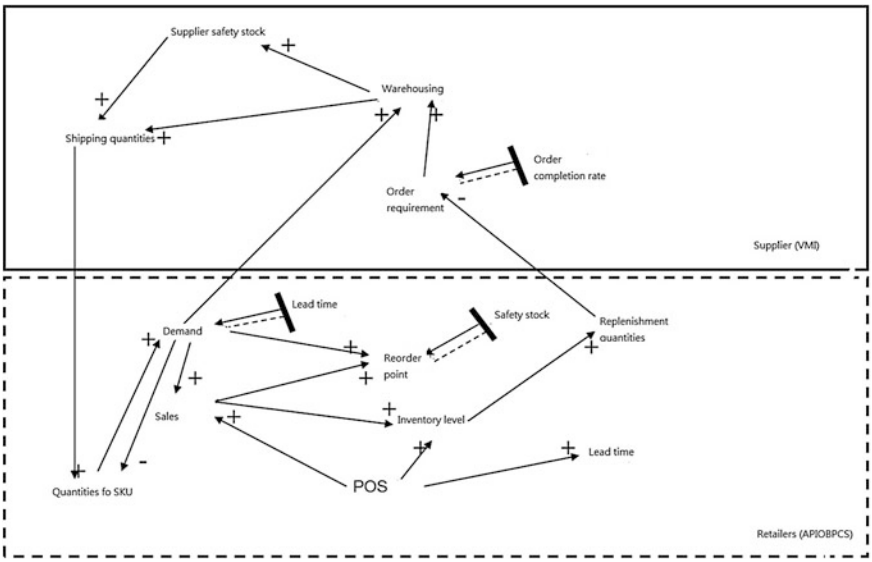


Fig. 1 Retailer and supplier APIOBPCS

of a negative sign between replenishment quantities and order requirement is that the order requirement will have negative impact on the replenishment quantities.

In the VMI supply chain, suppliers will obtain demand information from retailer's database using information technology. The suppliers will determine shipping quantities and time to deliver product to retailers. Through APIOBPCS, the flow of information and the value of the decision making process are evaluated. Based on APIOBPCS, decisions that can provide positive value to the supply chain are mentioned. To realize the significance effect of using VMI and APIOBPCS, simulation models are constructed and factors with different levels are tested in the simulation models.

3.1 Simulation Results

The simulation models are developed using ARENA with order processing time and supplier replenishing time as the performance measurements. Table 1 shows the factors and levels of the simulation experiments. In Table 1, three factors, product variety, inventory levels, and replenishment quantities are determined based on literatures for the simulation experiments.

Table 2 demonstrates the results of order processing time using simulation for VMI supply chain and traditional supply chain. The average order processing time of VMI is significant shorter than the average order processing time of traditional supply chain. The decrement of the order processing time indicates the reduction of the lead time. The most significant reduction is when inventory level is low and replenishment quantities is high. The average processing time for traditional supply chain and VMI are 105.098 and 73.843, respectively. Furthermore, the variances of traditional supply chain and VMI in this experiment are 126.817 and 23.953, respectively. This result indicates that implementing VMI not only reduce the average order processing time but stabilize the system performance.

Table 3 demonstrates the replenishing time for the traditional supply chain and VMI. It takes more time for the traditional supply chain to replenish inventory than the time for VMI. The product varieties do not have significant effect on the average replenishing time. However, the variances of the replenishing time between traditional supply chain and VMI do not have significant difference.

Based on the results showed in Tables 2 and 3, VMI is a better supply chain strategy than the traditional supply chain with the performance measures of order processing time, order waiting time, and replenishing time. The variance of order

Table 1 Factors and levels

Factors	Levels
Product variety	Uniform (10, 20), Uniform (20, 40)
Inventory levels	50, 60
Replenishment quantities	50, 70, 80

Table 2 Order processing time

	Product variety	Inventory level	Replenishment quantities	Average	Variance
Traditional	Uniform (20, 40)	60	50	85.175	58.457
			70	94.725	106.84
			80	98.292	97.904
		50	50	88.342	76.864
			70	96.256	86.626
			80	105.098	126.817
	Uniform (10, 20)	60	50	42.435	12.239
			70	47.104	24.716
			80	49.720	23.973
		50	50	44.987	11.364
			70	50.004	15.408
			80	52.486	19.133
VMI	Uniform (20, 40)	60	50	74.004	21.124
			70	73.638	27.918
			80	73.843	23.953
		50	50	74.004	21.124
			70	73.638	27.918
			80	73.843	23.953
	Uniform (10, 20)	60	50	37.677	4.061
			70	37.629	2.550
			80	37.428	1.992
		50	50	37.916	5.706
			70	37.536	5.190
			80	39.265	19.507

processing time and order waiting time for VMI outperform traditional supply chain. However, no difference of the variance of replenishing time between VMI and the traditional supply chain is found.

4 Conclusions

This research uses simulation to prove the advantages of adapting VMI into supply chain. Three factors, product varieties, inventory levels, and replenishment quantities with different levels are tested in the models to realize the impact of using VMI in the supply chain. The results of the simulation show that VMI can be implemented to shorten order processing time, order waiting time, and replenishing time. With the reduction in these three categories, order lead time can be decreased. Furthermore, VMI outperform the traditional supply chain in different experiments. The results also indicate that VMI can be extended to be implemented in retailers-suppliers supply chain. Although strengths of using VMI are addressed in this research, more topics can be discussed as future research. Topics

Table 3 Replenishing time

	Product variety	Inventory level	Replenishment quantities	Average	Variance
Traditional	Uniform (20, 40)	60	50	379.272	446.817
			70	396.646	681.108
			80	409.999	1098.48
		50	50	382.717	482.991
			70	389.307	1291.476
			80	404.483	997.099
	Uniform (10, 20)	60	50	375.289	626.856
			70	399.523	953.422
			80	412.295	1038.913
		50	50	381.951	464.437
			70	407.785	1002.174
			80	411.624	776.065
VMI	Uniform (20, 40)	60	50	287.896	542.757
			70	266.594	534.132
			80	272.476	1422.782
		50	50	287.896	542.757
			70	266.594	534.132
			80	272.476	1422.782
	Uniform (10, 20)	60	50	311.294	459.662
			70	274.125	772.330
			80	272.476	1422.782
		50	50	313.158	332.286
			70	285.631	663.091
			80	288.429	768.464

such as safety stocks, adapting optimized retailer-supplier relations in the supply chain, and determining optimal levels for the factors can be discuss further to identify the advantages of using VMI.

References

Disney SM, Naim MM, Potter A (2004) Assessing the impact of E-business on supply chain dynamics. Inter J prod Econ 89(2):109–118

Disney SM, Towill DR (2002a) A procedure for the optimization of the dynamic response of a vendor managed inventory system. Com Ind Eng 43(1–2):27–58

Disney SM, Towill DR (2003a) The effect of vendor managed inventory(VMI) dynamics on the bullwhip effect in supply chains. Inter J Prod Econ 85(2):199–215

Disney SM, Towill DR (2002b) A discrete transfer function model to determine the dynamic stability of a vendor managed inventory supply chain. Inter J Prod Res 40(1):179–204

Disney SM, Towill DR (2003b) On the bullwhip and inventory variance produced by an ordering policy. Omega: The Inter J Manage Sci 31(3):157–167

Disney SM, Towill DR (2002c) A robust and stable analytical solution to the production and inventory control problem via a z-transform approach. Logistics Systems Dynamics Group,

Cardiff Business School, Cardiff University. Retrieved Feb 2007, from http://www.ipe.liu.se/rwg/igls/igls2002/Paper039.pdf
Hong-Ming S (2002) Re-engineering the UK private house building supply chain. University of Wales, U.K., degree of Doctor of Philosophy
Simchi-Levi D, Kaminsky P, Simchi-Levi E (2001) Designing and managing the supply chain: concepts, strategies, and case studies. Irwin/McGraw-Hill, Boston
Tyan J, Wee HM (2003) Vendor managed inventory : a survey of the taiwanese grocery industry. J Purchasing Sup Manage 9(1):11–18

Applying RFID in Picker's Positioning in a Warehouse

Kai Ying Chen, Mei Xiu Wu and Shih Min Chen

Abstract As the RFID technology gradually matures, the research on the RFID technology-based positioning system has attracted more attention. The RFID technology applied to positioning can be used for orientation recognition, tracking moving trajectories, and optimal path analysis, as well as information related to the picker's position. According to previous literatures, warehousing management consumes high cost and time in business operation, more specifically; picking is one of the most costly operations in warehousing management, which accounts for 55 % of total warehousing cost. Therefore, this study constructed an actual picking environment based on the RFID technology. This system uses the back-propagation network method to analyze the received signal strength indicator (RSSI), so as to obtain the position of the picker. In addition, this study applied this locating device to picking activities, and discussed the effects of the positioning device on different picking situations.

Keywords RFID · Back-propagation network · Positioning · Warehouse management

K. Y. Chen (✉) · M. X. Wu · S. M. Chen
Department of Industrial Engineering and Management, National Taipei University of Technology, No. 1, Chunghsiao East Road, Sec 3, Taipei, Taiwan, Republic of China
e-mail: kychen@ntut.edu.tw

M. X. Wu
e-mail: fly6616@gmail.com

S. M. Chen
e-mail: teaorme555@msn.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_63,

1 Introduction

In recent years, the vigorous development and continuous improvement of wireless communications technology have been promoting the gradual growth of RFID technology. From 2000 onward, RFID has been widely applied in transportation management, logistics management, livestock management and personal ID recognition. With increasingly maturing RFID technology, studies on RFID technology-based positioning system are gaining more and more attention. The application of RFID technology in positioning can provide direction recognition, movement tracking and optimal route analysis as well as information relating to the user location. To reduce the redundant labor cost in picking and maximize the benefits, this study uses RFID technology to build a real application environment and judge the location of the order picking personnel in real time with the help of the RSSI reading results. Moreover, this study also applies the positioning device in order picking activities to explore the overall effectiveness of the positioning devices in order picking activities to reduce unnecessary paperwork and respond quickly to temporary orders or changes.

2 Literature Review

2.1 Introduction to RFID

RFID is mainly originated in the technology for military purpose of identifying the friend or foe aircraft in WWII in 1940. The one gives rise to the wave of RFID application is the largest chain store of the United States, the Wal-Mart. In a retailer exhibition held in Chicago in 2003, it announced to request the top 100 suppliers to place RFID tags on the pallets and packaging cartons before 2005 (Glover and Bhatt 2006).

RFID is a "non-contact" automatic identification technology, mainly consisting of transponder, reader and middleware system. Its automatic identification technology can complete management operations without manual labor by mainly using the wireless wave to transmit the identification data. The fixed or hand-held reader then automatically receives the identification data contained in the tag chip to realize the purpose of identity recognition. The received data will then be filtered in real time and sent back to the back end application systems to generate data with added-value after summarization. RFID can be integrated with production, logistics, marketing and financial management information for combined applications (Lahiri 2006).

2.2 Discussions on Positioning Approaches

The principle of triangulation is mainly to use the known geometric relationship of lengths or angles of three points in the space as the reference for positioning to calculate the object position. With distance as the reference basis, it mainly measures the relative distances in between three fixed points of known locations. With the distances between fixed points and the center of the round as the radius, the location of the point to be measured can be inferred by the intersections of triangular geometry. If using the angle as the reference positioning basis, location is identified by the angle of the signals.

The positioning concepts of Scene Analysis are mainly to use the RSSI and mathematical models to construct database of the collected parameters regarding specific place or location. In the positioning of certain object, the measured parameters can be matched and compared with the database to find out similar data to infer the location of the object (Bouet and Santos 2008).

Proximity approach is also known as the connectivity approach, which mainly uses the proximity to characteristics in the judgment of location. It can be mainly divided into the centralized and the distributed method. The former is to set up antenna in specific location. When the point to be positioned approaches a certain location, the antenna will receive the information about the point to be positioned and uses the location of strongest RSSI as the coordinates. The latter uses a large amount of reference points of coordinates. When a certain reference point approaches, it will read its coordinates to realize positioning (Ward et al. 1997).

Spot ON positioning system is the first indoor positioning system using the RFID technology. Spot ON uses self-developed RFID equipment to realize the function of indoor positioning. It mainly uses the RFID reader and a number of sensing tags to construct an indoor wireless sensing network environment covering a certain range (Hinckley and Sinclair 1999).

Location Identification based on dynamic Active RFID Calibration (LANDMARC) is a recently developed positioning system using the RFID technology. LANDMARC system mainly follows the method of the Spot ON positioning system to predict the location of the unknown object by relative RSSI estimated distance. The main idea is to use the additional reference tags of fixed positions to enable the LANDMARC to considerably improve the accuracy rate of location determination.

Neural network is a mathematical model. It is an in-formation processing system composed of biological simulation and neural network system. It can conduct a series of actions including storage, learning and feedback to the input signals. The neural network has high capability of information processing with excellent non-linear mapping capability for non-linear calculation. At present, the commonly used neural networks can be divided by network connection architecture into the feed-forward neural network and feedback neural network (Basheer and Hajmeer 2000).

3 Research Method

This study is mainly to develop a real picking positioning environment on the basis of the RFID technology. Since it does not need too many RFID readers and the environmental equipment for the experiment is relatively simple, coupled with the built-in chips of the RFID tags that can store object information, it can be a system for warehouse management and positioning to save costs considerably. The RSSI can be sent back to the back end application systems via readers for analysis by using the BPN (Back-Propagation Network) method to realize the effects of positioning.

In this study, we mainly use the RFID readers, antennas and a number of RFID tags developed by the Omron Company to build the actual positioning environment for warehouse picking. The reader type is Omron V750-series UHF RFID System, the communications frequency is 922–928 MHz, and is in line with the standards of EPC global Class 1 Gen2, it is suitable for the process management in manufacturing site, the order delivery of logistics units and material incoming inspections.

The experimental situation of this study is: the environment is assumedly set up in an open space. A RFID Reader and a number of receiving antennas fixed in different places are used in the system. According to different distances between the antenna and the personnel, when positioning, it can read K RSSI values in one reading. In this experiment, objects of different impacts will be placed on the shelf (such as water, metal etc.). By the RSSI values the reader receives, we can calculate all the possible locations of the order picking personnel. The experimental scenarios are as shown in Fig. 1.

In this study, we use Matlab software as the programming tool to build the BPN. Among all neural net-work learning models, BPN model is the so far the most representative and most widely applied model. It is an architecture of multiple-layer

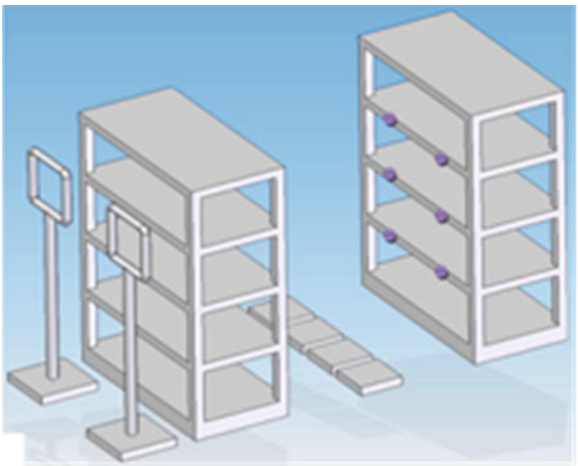


Fig. 1 Experimental scenarios

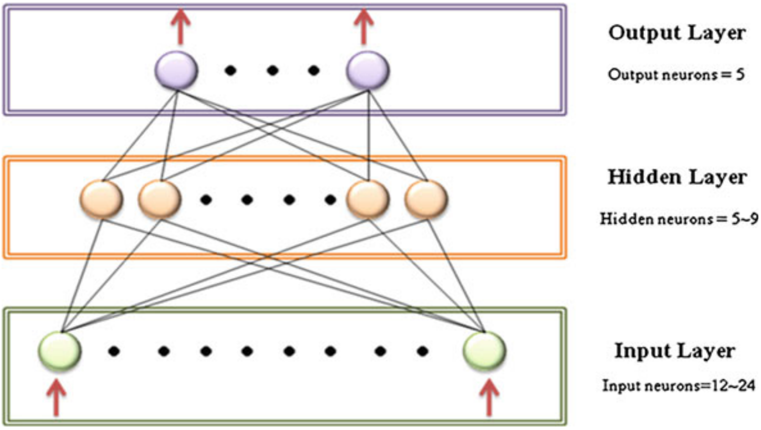


Fig. 2 Architecture of neural network

sensors. It is a multiple layers of feed-forward neural network using the super-vising learning algorithm. It is suitable for applications including classification, identification, prediction, system control, noise filtering and data compression.

During the learning process, BPN will give training examples to the neural network. Each training example contains input item and target output value, and the target output value will continuously urge the network to modify the weight value of the transmission connectivity, and the repeatedly adjust the strengths of the network links by training to reduce the difference between the network output value and target output values until the difference is below the critical value.

The network used in this study contains three layers: input layer, hidden layer and output layer, and its architecture are as shown in Fig. 2.

Input layer: the number of neurons is determined by the corresponding number of input vectors. In this study, the experimental design has 12–24 features, hence the number of the neurons of the input layer is set in the range of 12–24 neurons.

Output layer: in this study, the output value is the location of the personnel. The location of the order picking personnel is assumed in the experiment in five cases including Position 0 representing that the picking personnel is not at the site of the warehouse, Position 1–4 representing that the picking personnel is at the No. 1, No. 2 … location, respectively. Hence, the number of neurons of the output layer in this experiment is set as five.

Hidden layer: generally, the unit number of the hidden layer is set as (input layer unit number + output layer unit number) $\div 2$. To improve the accuracy of the experiment, in this study, we set the hidden layer unit number in the range of 5–9 in search of the optimal number of units.

The BPN training process is to input the training examples in the network to allow the network to slowly adjust the weighted value matrix and partial weight vectors to comply with the requirements of training example target value T.

4 Experiment Design and Analysis

Since the RFID operation and positioning are subject to the impact of external environmental factors such as object properties, blocking, multiple routes, and dispersion. Hence, this study tests the system in case of empty shelf and shelf with objects of different properties to simulate the positioning in actual picking environment. This study designs four scenarios in experiment. Scenario 1 is the shelf without any object. Scenario 2 is the shelf with paper products, Scenario 3 is the shelf with liquid objects and Scenario 4 is the shelf with metal objects. Regarding five locations of Position 0–4, we collect the RSSI values when the personnel standing at different locations in case of four scenarios and input them into the BPN model for prediction to determine the location of the personnel. The photos of experimental scenarios are as shown in Figs. 3, 4, 5 and 6.

Before the analysis RSSI value, the data should be processed. The pre-processing steps in this study can be summarized as shown below:

Step 1: list the RSSI values read by tags of same number in a same column
Step 2: make up for the omitted value with the minimum value of the receiving level
Step 3: set the target output vector of each location (T)
Step 4: data normalization

In this study, we divide the variable data into the training set and testing set by ratio of 7: 3. The collected data are divided into two parts: the first part consists of 1,440 data of 1,000 training samples and 440 testing samples; the second part consists of 2,860 samples of 2,000 training samples and 860 testing samples. Compare the data of the two parts to analyze the relationship be-tween the accuracy rate and Mean Square Error (MSE) value in case of different scenarios.

Fig. 3 Scenario 1: without any object on the shelf

Fig. 4 Scenario 2: paper products on the shelf

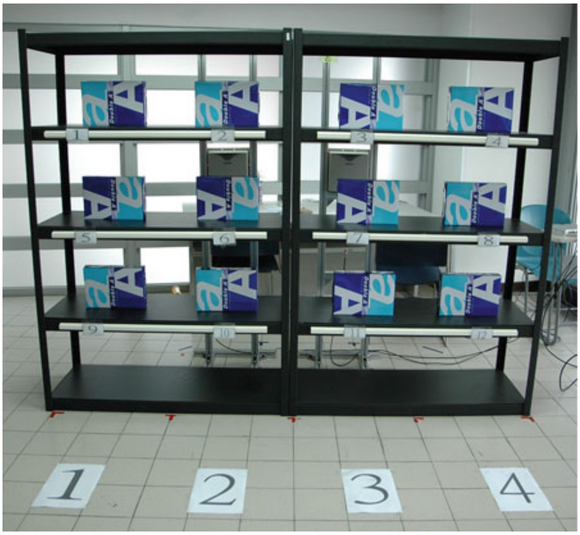


Fig. 5 Scenario 3: liquid objects on the shelf

Since there is no definite standard regarding the se-lection of neural network architecture and relevant parameter setting, we have to use the trial and error method. Therefore, this study will explore the impact of different parameter setting on the network accuracy (for example: Hidden layer, Hidden node, Learning rate, Epoch and Momentum). After the comparison of the tests of different parameters, the BPN optimal parameter settings of this study are as shown in Table 1:

After the network analysis of the four scenarios, the accuracy rate and MSE value of the analysis results are as shown in Fig. 4.

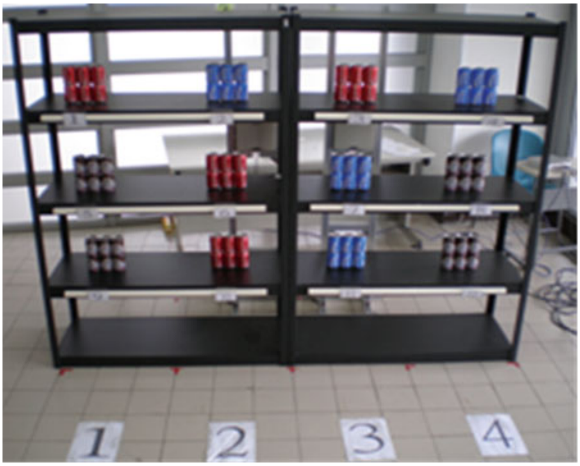


Fig. 6 Scenario 4: metal objects on the shelf

Table 1 Parameter setting

Parameters	Value
Input Node	12
Hidden Node	7
Output Node	5
Learning Rate	0.3
Momentum	0.7
Epoch	2,000

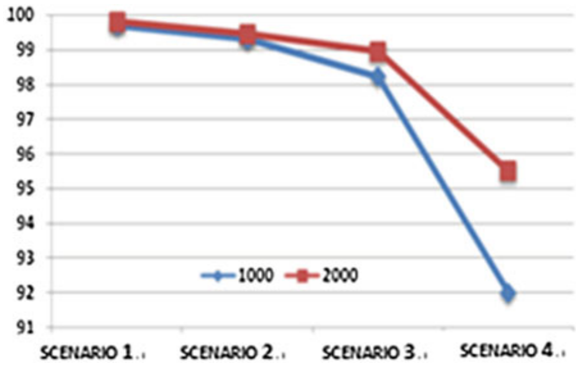


Fig. 7 Accuracy rate of the analysis results

According to the analysis results in this study, no matter 1,000 or 2,000 training samples, it can be learnt from Fig. 7, the accuracy rate in case of four scenarios gradually reduces from that of the empty shelf (99.7 %) → paper products (99.3 %) → liquids (98.22 %) → metals (92 %). It can be learnt from Fig. 8, the MSE value gradually rises from that of the empty shelf (0.00080418) → paper

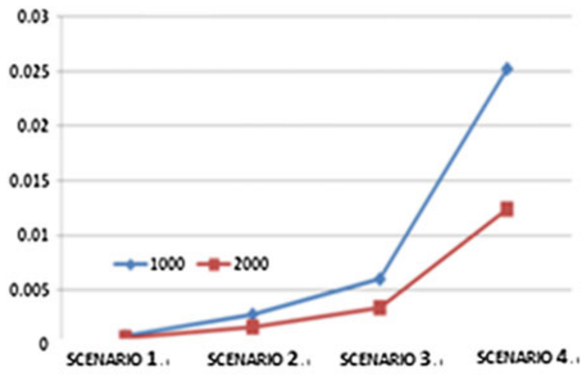


Fig. 8 Mean square error of the analysis results

products (0.0027778) → liquids (0.0060043) → metals (0.025204). Hence, according to the experimental results, the RSSI will be more severely interfered in case of being blocked by metal products. As a result, the ac-curacy rate and MSE value will be poorer consequently.

5 Conclusion

According to the experimental results, more training samples can lead to better accuracy rate and MSE value, and the accuracy rate and MSE value in case of picking metal products is the worst. Namely, when positioning and reading, the receiving level of RSSI will be more affected in case of the blocking of metal objects than other objects. In this study, we compare the predicted location and the original data and the result can effectively predict the location of the picking personnel.

Hence, the proposed picking positioning system is expected to reduce unnecessary labor and equipment cost in picking activities to maximize effectiveness. Moreover, the system is expected to respond quickly to temporary orders or emergent orders to increase picking efficiency.

References

Basheer IA, Hajmeer M (2000) Artificial neural networks: fundamentals, computing, de-sign, and application. J Microbiol Methods 43:3–31

Bouet M, Santos ALD (2008) RFID tags: positioning principles and localization techniques. Paper presented at the wireless days, Dubai, 24–27 Nov 2008

Glover B, Bhatt H (2006) RFID essential. O'Reilly Media, California

Hinckley K, Sinclair M (1999) Touch-sensing input devices. Paper presented at the 1999 conference on human factors in computing systems, Pittsburgh, 18–20 May 1999
Lahiri S (2006) RFID sourcebook. IBM Press, Indiana, USA
Ward A, Jones A, Hopper A (1997) A new location technique for the active office. IEEE Wireless Commun 4:42–47

An Innovation Planning Approach Based on Combining Technology Progress Trends and Market Price Trends

Wen-Chieh Chuang and Guan-Ling Lin

Abstract Innovation planning is important for manufactures to maximize the payoffs of their limited research and development expenditures. The key to the success of such innovation planning relies on a valid approach to estimate the value of each R&D project can produce. The purpose of this research is to build a model that considers a broad spectrum of trends in technology development and market price trends. Base on the assumption that the market prices can be a good indication of customer values, this modeling method collects historical product feature data, as well as their historical market prices and trains a neural network to track how electronic product specifications evolutions affect market prices. Predictions can be made from the behavior of the trained model to evaluate the value of each product improvement and, therefore, effective innovation plan can be made based on this model. The structure of this paper is threefold. First, it describes the evolutionary patterns of electronic products and their market prices. Second, it proposes artificial neural network methods to model the evolutionary processes; predictions concerning digital cameras to prove the validity of the model. Third, this research discusses the implications of these findings and draws conclusions.

Keywords Innovation planning · Technology trends · Market trends · Neural network

W.-C. Chuang (✉) · G.-L. Lin
Department of Industrial Engineering and Systems Management, Feng-Chia University, Taichung, Taiwan
e-mail: wcchuang@fcu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_64,

1 Introduction

Every year, market competition forces electronics manufacturers to develop products with new specifications. A new model of any electronic product typically offers new features or improved specifications. Manufacturers compete by frequent introductions of new products with slightly better specifications than previous products. For example, Canon, one of the largest digital camera manufactures of the world, has brought in at least 7 series, 165 in total compact camera models for the U.S. market along since 1998. The resolutions of these cameras have been evolving from 810 k pixel, for the early models, to 12.1 megapixel for the latest products (Canon 2013).

Most products can be improved in many ways. For example, a digital camera manufacturer might need to decide whether to invest on making its new model to capture 200 more pixels, or to weigh 20 g less, or to increase optical zooming by 20 %. Omae (1982) referred to the various possible directions of product improvement as the strategic degrees of freedom (SDFs). For the new product strategic developers, with the fact that each of these improvements might require separate product improvement projects to achieve, each cost different R&D resources, it is important for them to use innovation planning to maximize the payoffs of their limited research and development (R&D) expenditures;

An innovation planning, therefore, can be simply defined as the determination of the value of each product improvement project in this paper. Such value can be complicated in many ways. In fact, to determine the valuation of a technology development has long been described as an art (Park and Park 2004) rather than a science. Davenport et al. (1996), have pointed out that any study on knowledge work improvement should focus on making products/services more attractive (to customers) in order to increase value. Although how attractive a product improvement is can be somehow derived using some market survey techniques, these results are subjective to how far the survey reached. An alternative approach is therefore proposed in this paper to evaluate product improvement values. The historical data of the technology evolving trend, as well as market price evolving trend is collected to form a model. Based on the assumption that the value of each product improvement can be measured by the amount of money that customers are willing to pay, which can be indicated by their market price, a neural network is trained to model how specification improvement as well as time factors to affect product prices. The price of future product can be therefore predicted by projecting; as a result the value of each product improvement can be estimated.

The structure of this paper is threefold. First, it describes the evolutionary patterns of electronic products and their market prices. Second, it proposes artificial neural network methods to model the evolutionary processes; predictions concerning digital cameras to prove the validity of the model. Third, this research discusses the implications of these findings and draws conclusions.

2 Technology Progress Trends and Market Price Trends for Electronic

Ever-shortening product life cycles (PLCs) and technology s-curves are two important notions for electronic product evolution trends. The first notion, PLC, can be defined as "the period of a product in the market" (Abernathy and Utterback 1975). It has been widely used to represent the sales pattern of a product from its introduction to termination. Rink and Swan (1979) presented some typical product life cycle patterns and suggested that businesses might improve their planning processes by changing their product patterns. Due to rapid developments in technology and brisk competition, electronic products often have life cycles that can be measured in months. According to data collected from Intel's website, Intel's microprocessors have evolved at least 72 times between the company's inception in 1971 and 2013 (Intel 2013).

The second idea, the s-curve, is often used to depict technological progress over time (Abernathy and Clark 1988). Movement along a given s-curve generally results from incremental improvements within an existing technological approach. When the progress reaches its limit and starts to slow down, one expects a new s-curve to replace older curves as a driver of technological growth. Theoretical as well as empirical discussion of s-curve models can be found in Nieto et al. (1998).

By combining the two notions above, an evolutionary model for electronic products can be built. Figure 1 illustrates this model. S1 and S1 in Fig. 1 represent two technological s-curves. As the technology progresses overtime, new products (P1, P2, …, etc.), each holds better specifications than previous models, are introduced to market and replace the market share of the old models quickly.

It is more interesting when to add the information of product price into the model. Although the relationship between advances in performance and price has long been recognized (Porter 1980), price does not usually move in lockstep with technological innovations. Generally, new products with higher specifications are expected to be more valuable and deserve higher price tags. However, empirical studies do not support this notion. For example, a study to Google's computing infrastructure equipments showed that, in compared with three successive

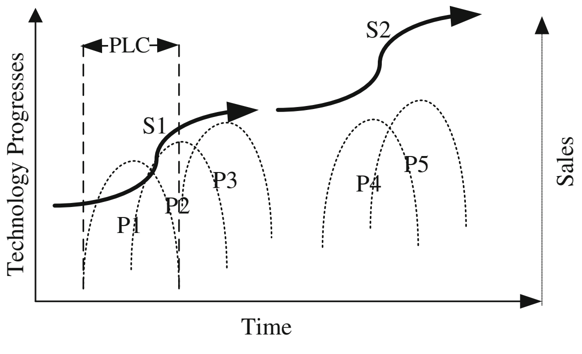


Fig. 1 Typical technology progress trends for electronics

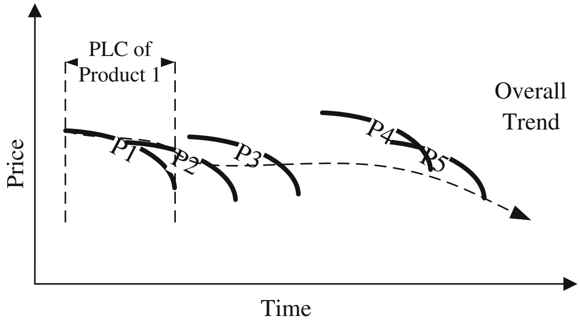


Fig. 2 Typical market price trends for electronics

generations of Google hardware of servers, the performance trend goes up with a much steeper pattern than the performance/server price trend (Barroso 2005). One likely cause of this divergence between price and performance is that technological advances reduce manufacturing costs while improving product features. Other factors might include the competition effects or even strategic considerations. While the patterns of new product pricing are hard to track, a typical price pattern can be easily observed for many electronics; Companies cutting the prices of old products while some new products with higher specifications are introduced to market. A typical new product price pattern can be therefore summarized as Fig. 2.

Note that the curves in Fig. 2 overlap; at any given time it is likely that multiple products with different features and prices will be offered to the same consumers. Foster (1982) and McGrath (1998) have emphasized that products with similar price/performance ratio tend to share the market. For example, in January, 2010, there were more than 23 CPU products on the market from Intel only, ranging from \$51 to \$998 in pricing (Sharky Extreme 2013). The wide spread of prices range is mainly derived from their technical features differences.

It can be concluded that, in spite of non-technical factors which are hard to be predict, the prices of electronics are affected by two major factors. First, how attractive their features are in compared with other competition product in the market; Second, the time factor itself. Based on this conclusion, an evolutionary model that takes specification evolution as input and the market prices as output can be built. Using this model, the price of future product can be therefore predicted by projecting; as a result the value of each product innovation plan can be estimated.

3 Artificial Neural Network for Electronics Price Trend Modeling

The nonlinear interactions and non-numeric data of this domain can be modeled by an artificial neural network. An artificial neural network (ANN) is an interconnected collection of artificial neurons that uses a mathematical or computational model for information processing (Smith 1993). Neural networks have long been applied as practical non-linear statistical data modeling tools. A predetermined "neural network" is built and a set of known examples "trains" the correct linkage strengths, or weights, between input and output neurons. Once the "correct" weights have been obtained from training, the model can be used for prediction.

To illustrate the proposed methodology and to verify its validity, a prediction model is constructed for a real-world case—namely, point-and-shoot digital cameras.

3.1 Model Construction and Testing

In order to construct the model, 269 records, describing a 58-month period, were collected from the point-and-shoot digital camera market in Taiwan. Six variables were selected as inputs: effective pixels, optical zooms, ISO, camera size, weight, and data collection time. The market price of each record at the data collection time was assigned as the model output.

Various network structures were tested; a simple multi-layer neural network (1 hidden layer with 3 neurons) was selected because of the training results. Twenty records that are after the date of 2010/7/1 were selected as the verification set. The other 249 records were randomly divided into three groups: a training set (180 records); a cross-validation set (25 records); and a testing set (44 records). Data in the cross-validation set was used in the training process to prevent possible over-training.

After the weights had been obtained, data from the testing set were used to verify that the trained ANN model would be valid with respect to new data. Figure 3 compares the results of model prediction with actual prices of the testing set data. As shown in Fig. 3, the average differences between predicted data to actual data is about 18 %, which were satisfactory in this case.

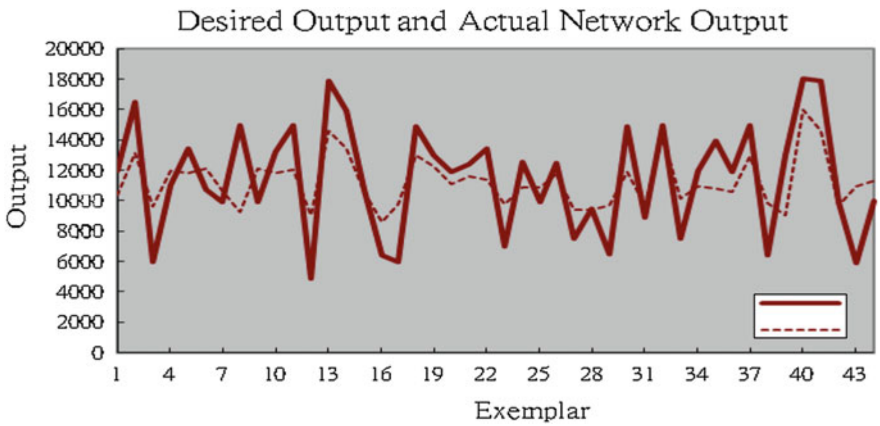


Fig. 3 Comparison between predicted prices and actual prices for the testing set data

Table 1 Comparison between predicted prices to actual prices

No.	Time	Effective Pixel	Optical Zoom	Max ISO	Volume (cm3)	Weight (gram)	Prices (predicted)	Prices (Actual)	Diff. (%)
1	2010/7/1	1,410	2.3	3200	88,536	105	8,727	7,980	9
2	2010/7/1	1,200	2.3	3200	101,834	133	9,188	13,980	34
3	2010/7/1	1,220	2.3	3200	102,323	130	9,121	9,980	9
4	2010/7/1	600	2.3	6400	658,419	341	11,827	8,800	34
5	2010/7/1	504	2	3200	117,494	141	8,215	8,000	3
6	2010/7/1	1,510	24	6400	954,180	496	16,506	20,450	19
7	2010/7/1	1,410	2.3	3200	88,536	105	8,727	8,800	1
8	2010/8/1	1,410	2.3	6400	152,712	180	11,383	11,150	2
9	2010/8/1	1,410	2.3	3200	98,532	116	8,867	9,100	3
10	2010/8/1	1,410	2.3	3200	92,806	103	8,529	6,200	38
11	2010/8/1	1,000	3.8	3200	132,151	190	10,201	11,700	13
12	2010/8/1	1,000	3.8	3200	171,935	170	9,292	14,300	35
13	2010/8/1	1,200	3	1600	130,014	135	8,044	7,980	1
14	2010/8/19	1,210	4	1600	379,845	260	9,985	8,500	17
15	2010/9/1	1,010	1.7	12800	395,010	360	12,728	17,900	29
16	2010/9/1	1,210	2.3	6400	106,029	133	10,267	9,900	4
17	2010/9/1	1,210	2.3	3200	184,080	209	10,643	9,900	8
18	2010/9/2	600	2	12800	202,488	195	11,845	10,000	18
19	2010/10/10	1,410	35	1600	1223,037	552	14,293	15,600	8
20	2010/10/20	1,000	5	3200	412,580	351	12,858	17,900	28

3.2 *Model Application for Innovation Planning*

The trends in the data were extrapolated to predict future market behavior. The inputs from the verification data set were applied to the model to test the performance of the model to extrapolated data. Table 1 shows the testing results.

As shown in Table 1, the differences between actual prices and predicated prices are ranging from 1 to 38 % with an average 15 %. The accuracy of the prediction model is within acceptable range. Further test the accuracy trend of the prediction model. The average accuracy decreases gradually from 15 % for the first projected month to 18 % for the fourth projected month. This information can be use to evaluate how far the model can be projected.

4 Conclusions

Traditional technology models have often applied s-curves to explain how market prices arrived at their present states. This paper has combined PLCs and s-curves to predict how feature advances will affect market prices. This research trained a neural network from data about product features and market prices over a period of time. Price trends affected by product features were identified. The trained model was used to predict digital camera prices as a proof of concept. Corporations can use the methods explained in this paper to plan future product innovations.

References

Abernathy WJ, Clark KB (1988) Innovation: mapping the winds of creative destruction. In: Tushman ML, Moore WL (eds) Readings in the management of innovation. Harper, New York, pp 55–78

Abernathy W, Utterback J (1975) A dynamic model of process and product innovation. Omega 3:639–656

Barroso LA (2005) The price of performance, queue—multiprocessors. Queue, 3(7):48–53

Canon (2013) Canon home page. http://www.cannon.com/

Davenport T, Javenpaa S, Beers M (1996) Improving knowledge work processes. Sloan Manage Rev 37:53–65

Foster R (1982) Boosting the payoff from R&D. Research Manage 26:22

Intel (2013) Intel website, http://www.intel.com/

McGrath RN (1998) Technological discontinuities and media patterns: assessing electric vehicle batteries. Technovation 18(11):677–687

Nieto M, Lopez F, Cruz F (1998) Performance analysis of technology using the s curve model: the case of digital signal processing (DSP) technologies. Technovation 18(6/7):439–457

Omae K (1982) The mind of the strategist: the art of Japanese business. McGraw-Hill, New York

Park Y, Park P (2004) A new method for technology valuation in monetary value: procedure and application. Technovation 24:387–394

Porter ME (1980) Competitive strategy. The Free Press, New York

Rink D, Swan J (1979) Product life cycle research: a literature review. J Bus Res, 40, 219–243

Sharky Extreme (2013) Sharky extreme website. http://www.sharkyextreme.com

Smith M (1993) Neural networks for statistical modeling. Van Nostrand Reinhold, New York

Preemptive Two-Agent Scheduling in Open Shops Subject to Machine Availability and Eligibility Constraints

Ming-Chih Hsiao and Ling-Huey Su

Abstract We address the scheduling problem in which two agents, each with a set of preemptive jobs with release dates, compete to perform their jobs on open shop with machine availability and eligibility constraints. The objective of this study is to minimize make span, given that one agent will accept a schedule of time up to Q. We proposed a heuristic and a network based linear programming to solve the problem. Computational experiments show that the heuristic generates a good quality schedule with a deviation from the optimum of 0.25 % on average and the network based linear programming model can solve problems up to 110 jobs combined with 10 machines.

Keywords Scheduling · Two-agent · Open shop · Preemptive · Machine availability constraint · Machine eligibility

1 Introduction

Consider two agents who have to schedule two sets of jobs on an m-machine open shop. Each job has k operations, $k \leq m$, and each operation must be performed on the corresponding specialized machine. The order in which the operations of each job are performed is irrelevant. Operation preemption is allowed and the machine availability and eligibility constraints are considered. The machine availability arises when machines are subject to breakdowns, maintenance, or perhaps high

M.-C. Hsiao (✉) · L.-H. Su
Department of Industrial and System Engineering, Chung-Yuan Christian University, Chung-Li, Taiwan, Republic of China
e-mail: Miller_Hsiao@aseglobal.com

L.-H. Su
e-mail: linghuey@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_65,

priority tasks are prescheduled in certain time intervals. The machine eligibility constraints are imposed when the number of operations of each job i can be less than m. Each machine can handle at most one operation at a time and each operation can be processed on at most one machine at a time. Two agents are called Agent A and B. Agents A and B have n_a (n_b) jobs. Let n denote the total number of jobs, i.e., $n = n_a + n_b$, and each job j of agent A (B) is denoted by $J_j^a\left(J_j^b\right)$. The processing time of a job j of agent A (B) on machine i is denoted by $P_{ji}^a\left(P_{ji}^b\right)$. The release time of a job j of agent A (B) is denoted by $r_j^a\left(r_j^b\right)$. Each machine i is available for processing in the given $N(i)$ intervals, which are $\left[b_i^k, f_i^k\right]$, $i = 1, \ldots, m$, $k = 1, \ldots, N(i)$, and $b_i^{k+1} > f_i^k$, where b_i^k and f_i^k are the start time and end time of the kth availability interval of machine i, respectively. The operations of job j of agent A (B) are processed on a specified subset $\mathrm{M}_j^a\left(\mathrm{M}_j^b\right)$ of the machines in an arbitrary order. We use C_j^a (C_j^b) to denote the completion time of J_j for agent A (B) and $C_{\max} = \max\{\max_{1 \le j \le n_a} C_j^a, \max_{1 \le j \le n_b} C_j^b\}$ to denote the makespan. The objective is to minimize makespan, given that agent B will accept a schedule of cost up to Q. According to the notation for machine scheduling, the problem is denoted as $O, NC_{win}|pmtn^a, r_j^a, M_j^a : pmtn^b, r_j^b, M_j^b\left|C_{\max} : C_{\max}^b \le Q\right.$, where O indicates open machines, NC_{win} means that the machines are not available in certain time intervals, $pmtn^{a(b)}$ signifies job preemption, $r_j^{a(b)}$ implies that each job has a release date, $M_j^{a(b)}$ denotes the specific subset of machines to process job j, and $C_{\max}^b \le Q$ denotes agent B will accept a schedule of time up to Q.

The multi-agent scheduling problems have received increasing attention recently. However, most of the research focuses on the single machine problem. The Baker and Smith study (2003) was perhaps the first to consider the problem in which two agents compete on the use of a single machine. They demonstrated that although determining a minimum cost schedule according to any of three criteria: makespan, minimizing maximum lateness, and minimizing total weighted completion time for a single machine, is polynomial, the problem of minimizing a mix of these criteria is NP-hard. Agnetis et al. (2004) studied a two-agent setting for a single machine, two-machine flowshop and two-machine open shop environments. The objective function value of the primary customer is minimized subject to the requirement that the objective function value of the second customer cannot exceed a given number. The objective functions are the maximum of regular functions, the number of late jobs, and the total weighted completion times. The problem in a similar two-agent single machine were further studied by Cheng et al. (2006), Ng et al. (2006), Agnetis et al. (2007), Cheng et al. (2008), Agnetis et al. (2009), and Leung et al. (2010). When release times are considered, Lee et al. (2012) proposed three genetic algorithms to minimize the total tardiness of jobs for the first agent given that the second agent will accept a schedule with maximum tardiness up to Q. Yin et al. (2012a) address the same problem while using the approaches of mixed integer programming, branch and bound, and marriage in honey-bees optimization to solve the problem.

The multi-agent problems are extended by considering variations in job processing time such as controllable processing time (Wan et al. 2010), deteriorating job processing time (Cheng et al. 2011a; Liu et al. 2011), learning effect (Cheng et al. 2011b; Lee and Hsu 2012; Wu et al. 2011; Yin et al. 2012b; Cheng 2012), and setup time (Ding and Sun 2011). Mor and Mosheiov (2010) considered minimizing the maximum earliness cost or total weighted earliness cost of one agent, subject to an upper bound on the maximum earliness cost of the other agent. They showed that both minimax and minsum cases are polynomially solvable while the weighted minsum case is NP-hard.

Lee et al. (2011) extended the single machine two-agent problem to the two-machine flowshop problem where the objective is to minimize the total completion time of the first agent with no tardy jobs for the second agent. A branch-and-bound and simulated annealing heuristic were proposed to find the optimal and near-optimal solutions, respectively.

As for the preemptive open shop, Gonzalez and Sahni (1976) proposed a polynomial time algorithm to obtain the minimum makespan. Breit et al. (2001) studied a two-machine open shop where one machine is not available for processing during a given time interval. The objective is to minimize the makespan. They showed that the problem is NP-hard and presented a heuristic with a worst-case ratio of 4/3. When time-windows is considered for each job on an open shop and the objective is to minimize makespan, Sedeno-Noda et al. (2006) introduced a network flow procedure to check feasibility and a max-flow parametrical algorithm to minimize the makespan. Sedeno-Noda et al. (2009) extended the same problem by considering performance costs including resource and personnel involvement.

So far as we know, there is no result related to a preemptive open shop wherein two-agents and machine availability and eligibility, as well as job release times, are considered.

2 Computational Results

The objective of the computational experiments described in this section is to evaluate both the performances of the heuristic and the exact algorithms. All experimental tests were run on a personal computer with AMD 2.91 GHz CPU. The heuristic algorithm was coded in Visual Basic, and the linear programming model and the constraint programming model were solved by LINGO11.0 and ILOG OPL 6.1, respectively. The experiment involves the instances with the number of jobs n = 40, 60, 80, 100 and 110 in which three pairs of n_a and n_b are set as

$\{(n_a = 20,\ n_b = 20),\ (n_a = 25,\ n_b\ =\ 15), \text{ and } (n_a = 15, n_b = 25)\}$
$\{(n_a = 30,\ n_b = 30),\ (n_a = 35,\ n_b\ =\ 25), \text{ and } (n_a = 25,\ n_b = 35)\}$
$\{(n_a = 40,\ n_b = 40),\ (n_a = 45,\ n_b\ =\ 35), \text{ and } (n_a = 35,\ n_b = 45)\}$
$\{(n_a = 50,\ n_b = 50),\ (n_a = 60,\ n_b\ =\ 40), \text{ and } (n_a = 40,\ n_b = 60)\}$, and
$\{(n_a = 55,\ n_b = 55),\ (n_a = 60,\ n_b\ =\ 50), \text{ and } (n_a = 50,\ n_b = 60)\}$, respectively.

The processing time of p_{ji}^x are randomly generated from a uniform distribution $U[0, 10]$. The job arrival time r_j^x refers to Chu (1992) and are generated from $U[0, \bar{P}]$, where $\bar{P} = (\sum_{i=1}^{m}\sum_{j=1}^{n_a} p_{ji}^a + \sum_{i=1}^{m}\sum_{j=1}^{n_b} p_{ji}^b) \Big/ m$ is the mean processing time on each machine. The number of machine m is set as m = 6, 8 and 10. To generate the upper bound of makespan for agent b, we refer to Bank and Werner (2001) with $Q = \beta \left[\frac{n}{m} \left(p + \frac{\sum_{j=1}^{n_a} r_j^a + \sum_{j=1}^{n_b} r_j^b}{n} \right) \right] \frac{n_b}{n}$, where $\overline{P} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n_a} p_{ji}^a + \sum_{i=1}^{m}\sum_{j=1}^{n_b} p_{ji}^b}{n}$ and $\beta \in \{1.2, 1.5, 2, 2.5\}$. The rate of machine availability θ is set as 0.7, 0.9 and 1.0. Five instances are generated for each combination of n, m, p_{ji}^x, r_j^x, θ, Q, yielding 900 instances. In comparing heuristic performance, the following formula is used to determine the deviation of the heuristic solution over the optimal solution. Deviation (%) = [(heuristic-optimum)/optimum] × 100 %.

Table 1 shows the solution quality of the heuristic. The influences of m, n, n_a/n_b and θ on the solution quality of the heuristic are analyzed.

Table 1 illustrates that the deviation of the heuristic from the optimal solution appears in descending trend as the value of m increases. The reason is that the heuristic selects the maximum total remaining processing time of each job, instead of that of each machine, to be processed on the corresponding machine. For the rate of machine availability θ, the value of 1 showing that all machines are available at any times. Since none of $[b_i^k, f_i^k]$, $i = 1, \ldots, m, k = 1, \ldots, N(i)$ incurred, the number of time intervals decreases and the span of time interval increases, therefore more jobs are competing to be scheduled in each time interval and hence the error increases. As to the number of jobs, the higher value that n is, the better the performance of the heuristic. One reason is that the higher value for n implies more time epochs r_j^x incurred and a smaller time span for each T_l making the heuristic easier to assigning the operations correctly. Another reason is that the denominator increases, whereas the deviation of the heuristic solution from the optimal solution may not increase in proportion to the denominator. There is no significant difference in the performance of the heuristic on the value of n_a/n_b, but $n_a/n_b = 0.5$ gives the best performance. When n_a/n_b increases, the deviation increases due to the fact that the heuristic gives priority to agent B and thus more operations of agent A should compete to schedule in each time interval.

Table 1 The average solution quality of the heuristic algorithm

			40			60			80			100			110		
θ	m	β	na,nb 20,20 Dev (%)	na,nb 25,15 Dev (%)	na,nb 15,25 Dev (%)	na,nb 30,30 Dev (%)	na,nb 35,25 Dev (%)	na,nb 25,35 Dev (%)	na,nb 40,40 Dev (%)	na,nb 45,35 Dev (%)	na,nb 35,45 Dev (%)	na,nb 50,50 Dev (%)	na,nb 60,40 Dev (%)	na,nb 40,60 Dev (%)	na,nb 55,55 Dev (%)	na,nb 60,50 Dev (%)	na,nb 50,60 Dev (%)
0.7	6	1.2	0.00	4.78	0.28	0.31	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	0.00	4.52	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.39	0.48	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8	1.2	0.62	–	0.78	2.04	0.18	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	0.00	–	0.00	0.00	0.57	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.00	0.65	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10	1.2	2.09	–	0.00	2.88	–	1.19	1.00	1.49	2.70	0.63	0.75	0.00	0.00	0.10	0.00
		1.5	0.57	–	1.31	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.25	0.42	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.00	1.81	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.9	6	1.2	0.00	0.75	0.00	1.12	0.00	0.48	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8	1.2	0.00	–	0.00	0.38	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.43
		2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.78	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.64
	10	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	3.28	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(continued)

Table 1 (continued)

			40			60			80			100			110		
θ	m	β	na,nb 20,20 Dev (%)	na,nb 25,15 Dev (%)	na,nb 15,25 Dev (%)	na,nb 30,30 Dev (%)	na,nb 35,25 Dev (%)	na,nb 25,35 Dev (%)	na,nb 40,40 Dev (%)	na,nb 45,35 Dev (%)	na,nb 35,45 Dev (%)	na,nb 50,50 Dev (%)	na,nb 60,40 Dev (%)	na,nb 40,60 Dev (%)	na,nb 55,55 Dev (%)	na,nb 60,50 Dev (%)	na,nb 50,60 Dev (%)
		2	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		2.5	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	6	1.2	0.00	1.64	0.00	0.00	0.00	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
		1.5	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.84	1.47	1.38	0.00	0.00
		2	1.56	1.91	1.06	0.00	0.00	0.00	0.00	0.48	0.11	0.00	0.00	0.00	0.00	0.82	0.00
		2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00
	8	1.2	2.92	–	0.00	0.14	3.16	1.85	1.31	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
		1.5	0.00	1.58	2.01	0.00	0.00	0.00	0.65	0.00	0.87	0.00	0.00	0.7	0.00	0.00	0.00
		2	1.40	0.00	0.00	1.15	0.00	1.67	0.00	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00
		2.5	4.64	1.40	0.00	2.56	0.00	0.00	0.00	1.03	1.41	0.00	0.00	0.00	0.00	0.00	0.00
	10	1.2	4.30	–	1.37	0.00	2.36	3.22	1.05	0.00	1.35	0.00	0.00	0.00	2.89	0.00	2.53
		1.5	0.00	–	0.00	1.20	1.39	0.00	0.86	0.00	1.37	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.00	2.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	0.00	0.00	0.00	0.00
		2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Total average deviation: 0.25 %

"–" no feasible solution is incurred due to that the time limit Q for the second agent is too small.

Table 2 Execution times of Lingo and Heuristic for small-size instances

m	N	Lingo(ss)	Heuristic(ss)
6	90	19.25	1.25
6	100	37.75	1.75
6	110	30.25	1.75
8	90	32.25	1.75
8	100	165.25	2.25
8	110	71.25	2.50
10	90	181.25	2.00
10	100	629.00	3.00
10	110	1002.75	3.00

Based on this analysis, we found that decreasing machine number m and the value of n_a/n_b reduced the deviation of the heuristic, while decreasing job number n increased the deviation of the heuristic. The heuristic generates a good quality schedule with a deviation from the optimum of 0.25 % on average.

As to the execution time of the heuristic, Table 2 shows the average execution time of the network based linear programming and the heuristic. The average execution time of the heuristic is small compared to that of the linear programming.

In Table 3, the average execution times in seconds for Linear Programming model, Constraint Programming model, and Combined model (Linear programming and Constraint Programming) are shown in columns lingo, OPL, and Total, respectively. For $n = 80$ and $m = 10$, the average execution time for the combined model exceeds two hours. Therefore, an efficient heuristic algorithm is much required.

3 Conclusions

In this paper, we have analyzed the preemptive open-shop with machine availability and eligibility constraints for two-agent scheduling problem. The objective is to minimize makespan, given that one agent will accept a schedule of time up to Q. This problem arises in environments where both TFT-LCD and E-Paper are manufactured and units go through a series of diagnostic tests that do not have to be performed in any specified order. We proposed an effective heuristic to find a nearly optimal solution and a linear programming model that based on minimum cost flow network to optimally solve the problem. Computational experiments show that the heuristic generates a good quality schedule with a deviation from the optimum of 0.25 % on average.

Table 3 Execution times of L P model, OPL model and those of both models

			n								
			40			60			80		
θ	m	β	lingo	OPL	Total	Lingo	OPL	Total	Lingo	OPL	Total
0.7	6	1.2	1.67	3471.55	3473.22	5.83	5632.6	5638.43	12.50	5383.2	5395.70
		1.5	2.50	1621.4	1623.90	5.83	4866.14	4871 .97	12.33	6217.37	6229.70
		2	1.83	4443.77	4445.60	4.83	3658.6	3663.43	12.83	8374.42	8387.25
		2.5	1.67	2189.61	2191.28	5.50	4569.55	4575.05	11.00	7941.41	7952.41
	8	1.2	4.83	3563.08	3567.91	21.50	4424.8	4446.03	78.67	6268.49	6347.16
		1.5	7.00	1443.82	1450.82	18.50	3954.75	3973.25	38.17	7704.92	7743.09
		2	7.67	5066.59	5074.26	18.83	6614.74	6633.57	27.33	2103.56	2130.89
		2.5	3.33	4791.44	4794.77	27.33	5982.09	6009.42	40.17	7497.72	7537.89
	10	1.2	6.00	4189.73	4195.73	54.83	6148.1	6202.93	143.00	5235.4	5378.40
		1.5	8.50	3821.1	3829.60	49.50	5743.97	5793.47	114.33	6818.86	6933.19
		2	19.00	4693.21	4712.21	49.17	7330.26	7379.43	183.17	8758.87	8942.04
		2.5	15.50	2043.46	2058.96	46.17	6236.85	6283.02	62.17	8695.65	8757.82
0.9	6	1.2	3.67	3039.84	3043.51	6.67	2850.65	2857.32	26.33	5551.2	5577.53
		1.5	1.67	2232.66	2234.33	9.50	3644.31	3653.81	20.17	5946.28	5966.45
		2	3.00	2767.03	2770.03	8.50	1418.79	1427.29	15.83	7841.27	7857.10
		2.5	3.00	1283.03	1286.03	13.67	3345.55	3359.22	17.50	6982.52	7000.02
	8	1.2	4.33	2918.39	2922.72	44.17	3 86.79	430.96	121.17	6002.08	6123.25
		1.5	3.83	1051.23	1055.06	1 1 .67	2515.51	2527.18	50.83	6147.72	6198.55
		2	12.33	3845.41	3857.74	51.50	4309.71	4361.21	84.00	6349.53	6433.53
		2.5	15.50	2504.07	2519.57	17.17	4862.58	4879.75	45.83	6600.61	6646.44
	10	1.2	9.17	3579.19	3588.36	25.50	6039.01	6064.51	168.33	7074.55	7242.88
		1.5	14.83	298.89	313.72	58.00	5946.64	6004.64	183.00	6661.49	6844.49
		2	14.83	4352.03	4366.86	51.67	7150.68	7202.35	123.00	8079.32	8202.32
		2.5	11.67	2143.27	2154.94	25.33	6270.04	6295.37	99.00	7973.84	8072.84
1	6	1.2	1.50	3215.97	3217.47	15.83	3695.52	371 1.35	12.17	6414.66	6426.83
		1.5	1.83	3013.4	3015.23	4.50	5124.51	5129.01	16.83	6301.5	6318.33
		2	2.17	2111.1	2113.27	4.50	4288.64	4293.14	25.50	6042.42	6067.92
		2.5	1.67	1390.48	1392.15	5.50	5092.22	5097.72	12.17	1745.63	1757.80
	8	1.2	2.67	2791.07	2793.74	17.00	2167.23	2184.23	48.50	5986.16	6034.66
		1.5	4.50	2551.8	2556.30	12.17	2216.43	2228.60	53.00	6284.06	6337.06
		2	2.67	3868.56	3871.23	15.00	4533.6	4548.60	20.00	5285.74	5305.74
		2.5	9.17	4052.98	4062.15	13.67	5139.19	5152.86	86.33	6349.87	6436.20
	10	1.2	6.50	3989.02	3995.52	35.17	6148.1	6183.27	101.17	9280.7	9381.87
		1.5	6.33	3484	3490.33	39.50	5743.97	5783.47	139.83	6818.86	6958.69
		2	4.83	3693.21	3698.04	13.00	7330.26	7343.26	36.17	8758.87	8795.04
		2.5	3.33	3043.1	3046.43	14.67	6236.85	6251.52	54.00	8695.65	8749.65

Acknowledgements We acknowledge the support given to this project by the National Science Council of Taiwan, R.O.C. under NSC 101-2221-E-033-022.

References

Agnetis A, Mirchandani PB, Pacciarelli D, Pacifici A (2004) Scheduling problems with two competing agents. Oper Res 52:229–242

Agnetis A, Pacciarelli D, Pacifici A (2007) Multi-agent single machine scheduling. Ann Oper Res 150:3–15

Agnetis A, de Pascale G, Pacciarelli D (2009) A Lagrangian approach to single-machine scheduling problems with two competing agents. J Sched 12:401–415

Bank J, Werner F (2001) Heuristic algorithms for unrelated parallel machine scheduling with a common due date, release dates, and linear earliness and tardiness penalties. Math Comput Model 33:363–383

Breit J, Schmidt G, Strusevich VA (2001) Two-machine open shop scheduling with an availability constraint. Oper Res Lett 29:65–77

Baker KR, Smith JC (2003) A multiple-criterion model for machine scheduling. J Sched 6:7–16

Chu CB (1992) A branch-and-bound algorithm to minimize total tardiness with different release dates. Naval Res Logistics 39:265–283

Cheng TCE, Ng CT, Yuan JJ (2006) Multi-agent scheduling on a single machine to minimize total weighted number of tardy jobs. Theoret Comput Sci 362:273–281

Cheng TCE, Ng CT, Yuan JJ (2008) Multi-agent scheduling on a single machine with max-form criteria. Eur J Oper Res 188:603–609

Cheng TCE, Cheng SR, Wu WH, Hsu PH, Wu CC (2011) A two-agent single-machine scheduling problem with truncated sum-of-processing-times-based learning considerations. Comput Ind Eng 60:534–541

Cheng TCE, Wu WH, Cheng SR, Wu CC (2011b) Two-agent scheduling with position-based deteriorating jobs and learning effects. Appl Math Comput 217(21):8804–8824

Cheng SR (2012) A single-machine two-agent scheduling problem by GA approach. Asia-Pacific J Oper Res 29:1250013 (22 pages)

Ding G, Sun S (2011) Single machine family scheduling with two cometing agents to minimize makespan. Asia-Pacific J Oper Res 28:773–785

Gonzalez T, Sahni S (1976) Open shop scheduling to minimize finish time. Ann Oper Res 23:665–679

Leung JYT, Pinedo M, Wan GH (2010) Competitive two-agent scheduling and its applications. Oper Res 58:458–469

Lee WC, Chen SK, Chen CW, Wu CC (2011) A two-machine flowshop problem with two agents. Comput Oper Res 38:98–104

Liu P, Yi N, Zhou X (2011) Two-agent single-machine scheduling problems under increasing linear deterioration. Appl Math Model 35:2290–2296

Lee DC, Hsu PH (2012) Solving a two-agent single-machine scheduling problem considering learning effect. Comput Oper Res 39:1644–1651

Lee WC, Chung YH, Hu MC (2012) Genetic algorithms for a two-agent single-machine problem with release time. Comput Oper Res. doi:10.1016/j.asoc.2012.06.015

Mor B, Mosheiov G (2010) Scheduling problems with two competing agents to minimize minmax and minsum earliness measures. European J Oper Res 206:540–546

Ng CT, Cheng TCE, Yuan JJ (2006) A note on the complexity of the problem of two-agent scheduling on a single machine. J Comb Optim 12:386–393

Sedeno-Noda A, Alcaide D, Gonzalez-Martin C (2006) Network flow approaches to pre-emptive open-shop scheduling problems with time-windows. Eur J Oper Res 174:1501–1518

Sedeno-Noda A, Pablo de DAL, Gonzalez-Martin C (2009) A network flow-based method to solve performance cost and makespan open-shop scheduling problems with time-windows. Eur J Oper Res 196:140–154

Wan GH, Vakati SR, Leung JYT, Pinedo M (2010) Scheduling two agents with controllable processing times. Eur J Oper Res 205:528–539

Wu CC, Huang SK, Lee WC (2011) Two-agent scheduling with learning consideration. Comput Ind Eng 61:1324–1335

Yin Y, Cheng SR, Wu CC (2012a) Scheduling problems with two agents and a linear non-increasing deterioration to minimize earliness penalties. Inf Sci 189:282–292

Yin Y, Wu WH, Cheng SR, Wu CC (2012b) An investigation on a two-agent single-machine scheduling problem with unequal release dates. Comput Oper Res 39:3062–3073

Supply Risk Management via Social Capital Theory and Its Impact on Buyer's Performance Improvement and Innovation

Yugowati Praharsi, Maffie Linda Araos Dioquino and Hui-Ming Wee

Abstract Today's supply chain managers are facing plenty of risks due to uncertainties of inbound supplies. Buyer must learn how to mitigate those unexpected risks. In this study, we explore supply risk management via structural, relational, and cognitive approaches from a buying firm's perspective based on the social capital theory. We also propose that the three forms of social capitals are positively related to buyer–supplier performance improvements. Consequently, the performance improvement of buyer–supplier will positively influence the innovation performance.

Keywords Supply risk · Social capital theory · Buyer performance improvement · Supplier performance improvement · Innovation performance

1 Introduction

Modern supply chain managers have to deal with uncertainties of inbound supplies such as changes of demand volume, on-time delivery, competitive pricing, technologically behind competitors, and quality standards. Buyer must learn how to mitigate those unexpected risks.

Firms establish networking relationships to obtain resources, valuable information, and knowledge to overcome uncertainty in the business environment. Buyers and suppliers that work closely with one another tend to form social

Y. Praharsi (✉) · H.-M. Wee
Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chung Li, Taiwan
e-mail: yugowati.praharsi@staff.uksw.edu

M. L. A. Dioquino
Department of Information Technology, Satya Wacana Christian University, Salatiga, Indonesia

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_66,

networks and develop relationships in uncertain situations to manage supply risk (Acquaah 2006). Social capital is an important risk management strategy because social relationships are one of the ways to deal with uncertainty (Woolcock 2001).

Nahapiet and Ghoshal (1998) proposed 3 dimensions of social capital, i.e.: the relational, the cognitive, and the structural dimensions. Research that has examined buyer–supplier relationship effects on buyer–supplier performance has primarily focused on relational capital (Johnston et al. 2004; Cousins et al. 2006). More recently researchers have begun to consider other dimensions of social capital. Krause et al. (2007) considered the structural and cognitive aspects of social capital and their effects on various aspects of buyer and supplier performance. Lawson et al. (2008) considered the effects of relational and structural capital, resulting from relational and structural embeddedness. Embeddedness refers to the degree to which economic activity is constrained by non-economic institutions. The term was created by economic historian Karl Polanyi. Carey et al. (2011) proposed an integrative model examining the relationships among relational, structural, and cognitive dimensions of social capital. Hughes and Perrons (2011) explored the evolution of social capital dimensions. Tsai et al. (2012) postulated that innovation performance is indirectly affected by 3 forms of social capital.

There are few studies that discuss on risk management in the relationship with social capital. Cheng et al. (2012) explored supply risk management via the relational approach in the Chinese business environment (i.e. guanxi). The current study jointly examines three forms of social capital as a form to perceive supply risk. Also, there are few studies explored the dimensions of social capital embeddedness. Lawson et al. (2008) considered relational embeddedness such as supplier integration and supplier closeness and structural embeddedness such as managerial communication and technical exchange. Our study thus considers transaction-specific supplier development in addition to relational embeddedness and shared norms in addition to cognitive embeddedness. Either social capital theory or social capital theory embeddedness has been respectively included in the previous research as form to perceive supply risk, but none of the previous research has tried to simultaneously take both into account for explaining performance outcomes. Hence, this study is motivated by their initiatives.

In answering these gaps, we make four key contributions to the supply chain literature. First, we show that when a buying firm faces supply risk, it tends to form social networks with its key supplier to reduce risk in 3 forms of social capital. Secondly, we extend the application of social capital theory in SC research by explicitly recognizing relational aspect of embeddedness (transaction-specific supplier development) and cognitive aspect of embeddedness (shared norms). Thirdly, we propose that the dimensions of social capital theory (social interaction ties, trust in supplier, shared vision) and the dimensions of social capital embeddedness (managerial communication, technical exchange, supplier integration, transaction-specific supplier development, shared norms) influence buyer and supplier performance improvements. Finally, we propose that the performance improvement of buyer and supplier will positively influence the innovation performance.

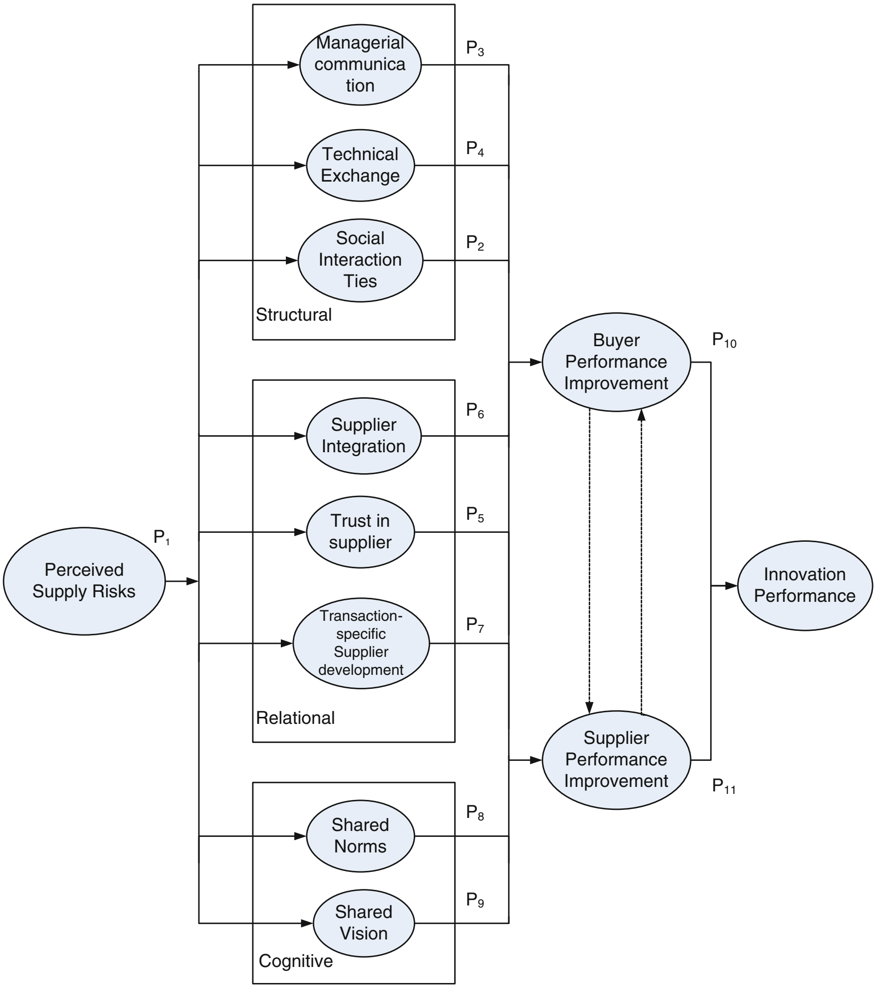


Fig. 1 Proposed research framework

2 Literature Review and Model Formulation

In this study, we explore supply risk management via structural, relational, and cognitive approaches from a buying firm's perspective. Figure 1 shows a major framework in this study.

2.1 Supply Risk Management

Risk exists in supply chains and its occurrence can detrimentally affect the provision of products and services to the final consumer. Supply risk has been defined as the probability of an incident associated with inbound supply from individual supplier failures or the supply market, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety (Zsidisin and Ellram 2003). Cheng et al. (2012) proposed that when buyers perceive a supply risk situation with their key supplier, they amass social capital to deal with uncertainty and risk. Social capital can be used as a resource to reduce uncertainty and risk in different forms above. This leads to:

Proposition 1 *Perceived supply risk has a positive relationship with social capital development*

2.2 Social Capital Theory

The social capital theory is used to explain the relationship between the buyer and the supplier. Social capital theory (SCT) has become an important perspective for theorizing the nature of connection and cooperation between organizations (Adler and Kwon 2002). As interactions within the linkage between the firms increase, social capital is improved, thereby potentially increasing the flow of benefits. These benefits can include access to knowledge, resources, technologies, markets, and business opportunities (Inkpen and Tsang 2005).

Nahapiet and Ghoshal (1998) proposed 3 dimensions of social capital: (1) the relational dimension (e.g. trust, friendship, respect, reciprocity, identification and obligation), referring to the strength of social relationships developed between buyers and suppliers in the network that is developed through a history of prior interactions among these people and that influences their subsequent behaviors in the network; (2) the cognitive dimension (e.g. shared ambition, goals, vision, culture, and values), referring to rules and expectations of behaviors between buyers and suppliers in a network that define how a community or society will perform; (3) the structural dimension (e.g. strength and number of ties between actors, social interaction ties), referring to structural links or interactions between buyers and suppliers in social relationship.

Structural social capital refers to the configuration of linkages between parties that is whom you know and how you reach them (Nahapiet and Ghoshal 1998). Conceptualizing structural capital as the strength of the social interaction ties exists between buyer–supplier (Tsai and Ghoshal 1998). Social interaction ties facilitate cooperation in dyadic buyer–supplier relationships, and are defined as purposefully designed, specialized processes or events, implemented to coordinate and structurally embed the relationship between buyer and supplier (Cousins et al. 2006; Nahapiet and Ghoshal 1998).

Social interaction ties have also been linked to performance improvements and value creation in buyer–supplier relationships (Cousins et al. 2006), because they provide a forum whereby buyers and suppliers can share information and identify gaps that may exist in current work practices. This leads to:

Proposition 2 *Social interaction ties positively influence buyer and supplier performance improvements*

Structural embeddedness creates the opportunity for future structural capital benefits. There are two factors in the structural embeddedness, i.e.: managerial communication and technical exchange (Lawson et al. 2008). In order to achieve the benefits of collaboration, effective communication between partners' personnel is essential (Cummings 1984). Quality performance was superior between buyers and suppliers when communication occurred among design, engineering, quality control, purchasing and other functions. This leads to:

Proposition 3 *Managerial communication positively influence buyer and supplier performance improvements*

Simple technology exchanges can enhance supplier performance and are independent of whether a buyer and supplier have established familiarity through long-term relationship. Others have argued that technical exchanges help to improve buyer performance (Lamming 1993). This leads to:

Proposition 4 *Technical exchange positively influence buyer and supplier performance improvements*

Relational capital dimension refers to personal relationships that develop through a history of interactions, i.e. the extent to which trust, friendship, respect, obligation, identification, and reciprocity exist between parties (Nahapiet and Ghoshal 1998; Villena et al. 2011). These networks encourage buyer and supplier to act according to one another's expectations and to the commonly held values, beliefs, and norms of reciprocity. The latter maintain mutual trust between supply chain partners, which reduces the negative consequences of uncertainty and risk.

Trust is an essential element of relationships and one of the key aspects of relational social capital. Trust reduces the risk of opportunistic behavior and brings partnering firms closer together to collaborate more richly and to withhold potentially relevant resources (Inkpen and Tsang 2005). Improved relationships and trust can lead to improved buyer and supplier performances (Johnston et al. 2004). This leads to:

Proposition 5 *Trust in supplier positively influence buyer and supplier performance improvements*

Relational embeddedness between buyers and their key suppliers can be defined as the range of activities integrated, the direct investments between both parties, and their relational capital. As a relationship evolves with a key strategic supplier, the relationship becomes embedded as the supplier becomes more integrated and the buyer gives more efforts in supplier development. There are two factors in the relational embeddedness, i.e.: supplier integration (Lawson et al. 2008) and transaction-specific supplier development.

When buying firms are committed to full supplier integration, they are arguably prepared to help their key suppliers through information sharing, technical assistance, training, process control, and direct investment in supplier operations, in return for the benefits of improved performance and joint value creation (Frohlich and Westbrook 2001). More strategic suppliers become fully integrated and the more positive experiences draw them closer to a buying firm, the richer the information exchanged (Koka and Prescott 2002). This leads to:

Proposition 6 *Supplier integration positively influence the buyer and supplier performance improvements*

As buying firms increasingly realize that supplier performance is crucial to their establishing and maintaining competitive advantage, supplier development has been a subject of considerable research in supply chain management (Govindan et al. 2010). Supplier development is defined as any effort of a buying firm to increase the performance and capabilities of the supplier and to meet the buying firm's short and/or long term supply needs (Krause and Ellram 1997).

Transaction-specific supplier development significantly correlated with and had direct effects on the performance of both purchasing and supplier organizations in terms of buyer and supplier performance improvement (Krause 1997). Transaction-specific supplier development leads to closer cooperation between manufacturers and their suppliers. This leads to:

Proposition 7 *Transaction-specific supplier development positively influence the buyer and supplier performance improvements*

The cognitive dimension refers to the resources that provide parties with shared expectations, interpretations, representations and systems of meaning (Nahapiet and Ghoshal 1998). The cognitive capital is also defined as symbolic of shared goals, vision and values among parties in a social system (Tsai and Ghoshal 1998). Congruent goals represent the degree to which parties share a common understanding and approach to the achievement of common tasks and outcomes. The establishment of congruent goals can guide the nature, direction, and magnitude of the efforts of the parties (Jap and Anderson 2003).

Shared culture refers to the degree to which norms of behavior govern relationships. Shared norms can be created by expectation that govern appropriate behavior and affect the nature and degree of cooperation among firms. Strong social norms associated with a closed social network encourage compliance with local rules and customs can reduce the need for formal control (Adler and Kwon 2002).

A lack of norms similarities and compatible goals may trigger conflicts that result in frustration and have negative effects on performance (Inkpen and Tsang 2005). Krause et al. (2007) found support for the positive effect of shared norms and goals on cost reduction. This leads to:

Proposition 8 *Shared norms positively influence the buyer and supplier performance improvements*

Proposition 9 *Shared goals positively influence the buyer and supplier performance improvements*

2.3 Buyer and Supplier Performance Outcomes

Performance improvements sought by buying firms are often only possible when they commit to long-term relationships with key suppliers. Long term commitment means that the buyer regards its suppliers as partners (Krause and Ellram 1997). In the global market where buyer's competitive advantage can be rapidly initiated by competitors, a commitment to innovation is inevitable to sustain competitive advantages and innovation performance. Commitment to innovation refers to employee's duty such as pledge or obligation to work on innovation. By boosting commitment to the innovation, great performance on innovation can be primarily achieved. This leads to:

Proposition 10 *Buyer performance improvement positively influence innovation performance*

Supplier performance improvement is defined as upgrading existing suppliers' performance and capabilities has been recognized as one of the initiations of supplier development to meet the changing competitive requirements (Hahn et al. 1990). Rewards for supplier's improvement are also a stimulating tool that indicates buyer's recognition and provides incentive to supplier for further outstanding achievement. This leads to:

Proposition 11 *Supplier performance improvement positively influence innovation performance*

The performance improvement in essence also comes from promoting buyer and supplier cooperative behavior that increases the creativity of their actions (Nahapiet and Ghoshal 1998). The creativity encourages the accomplishment of innovation performance such as the development of new products and markets. More recently, some studies suggested pursuing innovation performance besides the traditional operational improvement. A set of innovation performance shows that it takes longer to reach the threshold of innovation performance compared with operational benefits (Villena et al. 2011). Therefore, in this study we pose innovation performance as the effect of buyer and supplier performance improvements.

3 Conclusion and Future Research

This study developed an integrative framework of structural, relational, and cognitive approaches to supply risk management grounded in the social capital theory and proposed its impact on buyer performance improvement and innovation. Our study contributed to the literature on a number of fronts.

First, we showed that when a buying firm faces supply risk, it tends to form social networks with its key supplier to reduce risk in three dimensions of social capital. Secondly, we extend the application of social capital theory in supply chain research by explicitly recognizing relational aspect of embeddedness and cognitive aspect of embeddedness. Thirdly, we analyze the three dimensions of social capital and the social capital embeddedness in a single model, which has rarely been done in previous studies. Finally, we use a complete set of performance measures to develop a more complete view of how social capital facilitates a value creation. For future works, a more comprehensive study to develop performance criteria and indicators can be done.

References

Acquaah M (2006) The impact of managerial networking relationships on organizational performance in Sub-Saharan Africa: evidence from ghana. Organiz Manage J 3:115–138

Adler PS, Kwon SW (2002) Social capital: prospects for a new concept. Acad Manage Rev 27:17–40

Carey S, Lawson B, Krause DR (2011) Social capital configuration, legal bonds and performance in buyer-supplier relationships. J Oper Manage 29:277–288

Cheng TCE, Yip FK, Yeung ACL (2012) Supply risk management via guanxi in the Chinese business context: The buyer's perspective. Int J Prod Econ 139:3–13

Cousins PD, Handfield RB, Lawson B, Petersen KJ (2006) Creating supply chain relational capital: the impact of formal and informal socialization processes. J Oper Manage 24:851–863

Cummings T (1984) Transorganizational development. Res Organiz Behav 6:367–422

Frohlich MT, Westbrook R (2001) Arcs of integration: an international study of supply chain strategies. J Oper Manage 19:185–200

Govindan K, Kannan D, Haq AN (2010) Analyzing supplier development criteria for an automobile industry. Ind Manage Data Syst 110:43–62

Hahn CK, Watts CA, Kim KY (1990) The supplier development program: a conceptual model. Int J Mater Manage 26:2–7

Hughes M, Perrons RK (2011) Shaping and re-shaping social capital in buyer-supplier relationships. J Bus Res 64:164–171

Inkpen AC, Tsang EWK (2005) Social capital, networks and knowledge transfer. Acad Manag Rev 30:146–165

Jap SD, Anderson E (2003) Safeguarding interorganizational performance and continuity under ex post opportunism. Manage Sci 49:1684–1701

Johnston DA, Mccutcheon DM, Stuart FI, Kerwood H (2004) Effects of supplier trust on performance of cooperative supplier relationships. J Oper Manage 22:23–28

Koka BR, Prescott JE (2002) Strategic alliances as social capital: a multidimensional view. Strat Manage J 23:795–816

Krause DR (1997) Supplier development: current practices and outcomes. Int J Purchasing and Mater Manage 33:2–19

Krause DR, Ellram LM (1997) Critical elements of supplier development. Eur J Purchasing and Supply Manage 3:21–31

Krause DR, Handfield RB, Tyler BB (2007) The relationships between supplier development, commitment, social capital accumulation and performance improvement. J Oper Manage 25:528–545

Lamming RC (1993) Beyond partnership: strategies for innovation and lean supply. Prentice-Hall, London

Lawson B, Tyler BB, Cousins PD (2008) Antecedents and consequences of social capital on buyer performance improvement. J Oper Manage 26:446–460

Nahapiet J, Ghoshal S (1998) Social capital, intellectual capital, and the organizational advantage. Acad Manage Rev 23:242–266

Tsai W, Ghoshal S (1998) Social capital and value creation: the role of intra firm networks. Acad Manage J 41:464–476

Tsai YH, Joe SW, Ding CG, Lin CP (2012) Modeling technological innovation performance and its determinants: an aspect of buyer-seller social capital. Technological forecasting and social change. http://dx.doi.org/10.1016/j.techfore.2012.10.028. Accessed 24 March 2013

Villena VH, Revilla E, Choi TY (2011) The dark side of buyer-supplier relationships: a social capital perspective. J Oper Manage 29:561–576

Woolcock M (2001) The place of social capital in understanding social and economic outcomes. Canadian J Policy Res 2:11–17

Zsidisin GA, Ellram LM (2003) Managerial perceptions of supply risk. J Supply Chain Manage 39:14–25

Variable Time Windows-Based Three-Phase Combined Algorithm for On-Line Batch Processing Machine Scheduling with Limited Waiting Time Constraints

Dongwei Yang, Wenyou Jia, Zhibin Jiang and You Li

Abstract In this paper, a variable time windows-based three-phase combined algorithm is proposed to address the scheduling problem of on-line batch processing machine for minimizing total tardiness with limited waiting time constraints and dynamic arrivals in the semiconductor wafer fabrication system (SWFS). This problem is known to be NP-hard. In the first phase, the on-line information of scheduling parameters is preserved and sent. In the second phase, the computational results of reforming and sequencing are obtained. In the third phase, the super-hot batch is loaded. With the rolling horizon control strategy, the three-phase combined algorithm can update solution continually. Each interval of rolling horizon is a time window. The length of each time window is variable. The experiments are implemented on the real-time scheduling simulation platform of SWFS and ILOG CPLEX to demonstrate the effectiveness of our proposed algorithm.

Keywords Three-phase combined algorithm · Batch processing machine · Variable time windows

D. Yang
Department of Economics & Management, Shanghai University of Electric Power, Shanghai, China

W. Jia · Z. Jiang (✉) · Y. Li
Department of Industrial Engineering and Logistics Engineering, Shanghai Jiao Tong University, Shanghai, China
e-mail: zbjiang@sjtu.edu.cn

W. Jia
e-mail: jiawy@sjtu.edu.cn

Y. Li
e-mail: liyoustar@sjtu.edu.cn

W. Jia
School of Mechanical and Automotive Engineering, Anhui Polytechnic University, Wuhu, China

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_67,

1 Introduction

Batch processing machines (BPM) are frequently encountered in the semiconductor wafer fabrication system (SWFS) such as furnace operations. For an overview of batching and scheduling problems, we invite the reader to refer to Potts and Kovalyov (2000). Johnson (1954) first proposes polynomial time algorithms the items minimizing the total elapsed time. Ahmadi et al. (1992) consider the batching and scheduling problems in a flow-shop scenario with a batch-processing machine and a discrete-processing machine. Lin and Cheng (2001) consider scheduling a set of jobs in two batch machines. Su (2003) formulates a hybrid two-stage model comprising of a BPM in the first stage and a discrete machine in the next stage with limited waiting time constraints. In order to consider on-line scheduling, the rule decomposition-based is a good strategy. Rolling horizon control strategy, a kind of time-sequence-based decomposition method, is developed for dynamic scheduling problems (Ovacikt and Uzsoy 1994, 1995). According to rolling horizon control strategy, a scheduling problem can be divided into several sub-problems along time-axis. Each sub-problem corresponds to a time window of the whole schedule. This approach is extended and applied to schedule in SWFS (Klemmt et al. 2011).

In this paper, we extend time-sequence-based decomposition method to address the problem of scheduling on-line BPM for minimizing total tardiness with limited waiting time constraints and dynamic arrivals in SWFS. Du and Leung (1990) prove that a special case with single machines is NP-hard. Definitely, our problem is also NP-hard. According to time-sequence-based decomposition rule, the large BPM is divided into smaller ones. Each smaller one includes three-phase.

The remaining sections of this paper are organized as follows. In Sect. 2, we present the problem and notations. The methodology of proposed variable time windows-based three-phase combined algorithm is defined in Sect. 3. The computational experiments are designed and conducted in Sect. 4. Section 5 concludes the paper with future research directions.

2 Problem Definition and Notations

In this research, we model two BPMs with limited waiting time constraints and dynamic arrivals. As illustrated by Fig. 1, the definitions are stated as follows.

This model includes many machine groups (MG) such as MG^1, MG^2, and MG^3. The process flow is IN $\rightarrow MG^1 \rightarrow MG^2 \rightarrow MG^1 \rightarrow MG^3 \rightarrow$ OUT, where re-entrant flow is allowed. The information of jobs in Buffer 3 is obtained in the first phase. Once any MG is started, it can't be interrupted. Assume MG^3 group has the same processing time, and is not starved.

For convenience, we use the following notations in the rest of the paper.

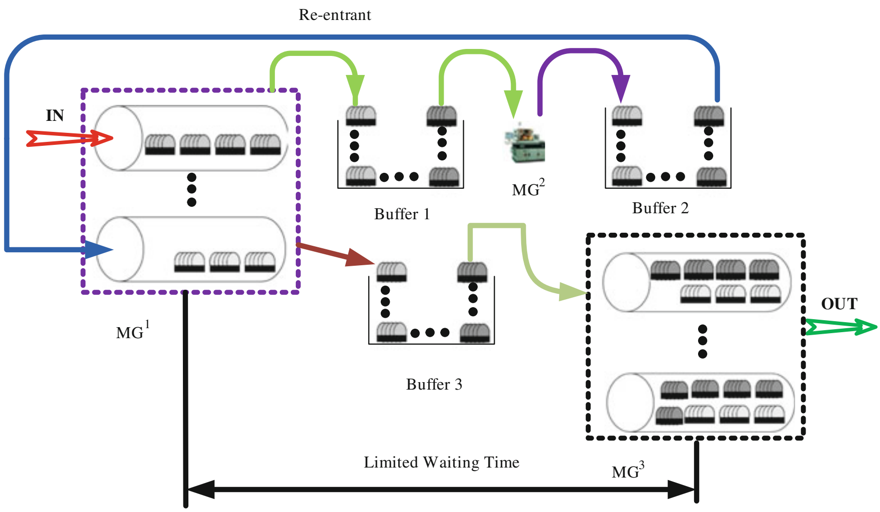


Fig. 1 The process flow of the manufacturing system

Let I be number of different products, J number of different batches coming from MG^1 group in Buffer 3, N number of reforming batches waiting to be scheduled on MG^3 group and S capacity of MG^3 group. t denotes current time of simulation clock. P_{MG}^{3} presents processing time of MG^3 group. For batch j, q_j, s_j, r_j, d_j, ZS_j, DS_j, PR_j, and P_{kj} stand for limited waiting time between MG^1 group and MG^3 group, size, arriving time, due date time, total number of processing steps, number of processing step on MG^3 group, pure remaining processing time after MG^3 group, and processing time of the kth processing step, respectively. For the reforming batch n, dr_n, Cr_n and PRr_n denote due date time, completion time, and pure remaining processing time after MG^3 group, respectively. M is an extremely huge positive integer.

3 Methodology

In this section, a variable time windows-based three-phase combined algorithm is proposed. We begin with introducing the overall algorithm structure. Then we analyze the slack-based mixed integer linear programming (MILP) model.

Based on decomposition rule and rolling horizon control strategy, the problem can be decomposed into many time windows. The length of each time window is variable, which is equivalent to the interval of between two adjacent time points of the super-hot batch to be loaded. At each time window, the problem includes three sub-problems (i.e., three phases): to get information of scheduling parameters, to reform and sequence batches, and to load super-hot reforming batch and update the state of manufacturing system. The first and third sub-problems are resolved by real-time scheduling simulation (ReS^2) platform of SWFS (Liu et al. 2005). The second sub-problem is resolved by slack-based MILP model which is executed by ILOG CPLEX and the program developed by ourselves. The proposed algorithm is illustrated in Fig. 2 and implemented as follows.

step 1 The last idle and available BPM (i.e., MG^3 group) is loaded. Initialize the time window and start to run the first phase strategy. Read and preserve the on-line information of batches in Buffer 3. Check the on-line status of MG^3 group.

step 2 When a condition that one MG^3 group is idle and available is met, the event of loading batch is registered.

step 3 Because no reformed and sequenced batch can be loaded, the idle and available MG^3 group must be a status of waiting.

step 4 Compute the total number (N) of reformed batches which are waiting to be scheduled on MG^3 group. If N > 1, then go to *Step* 5; else go to *Step* 9.

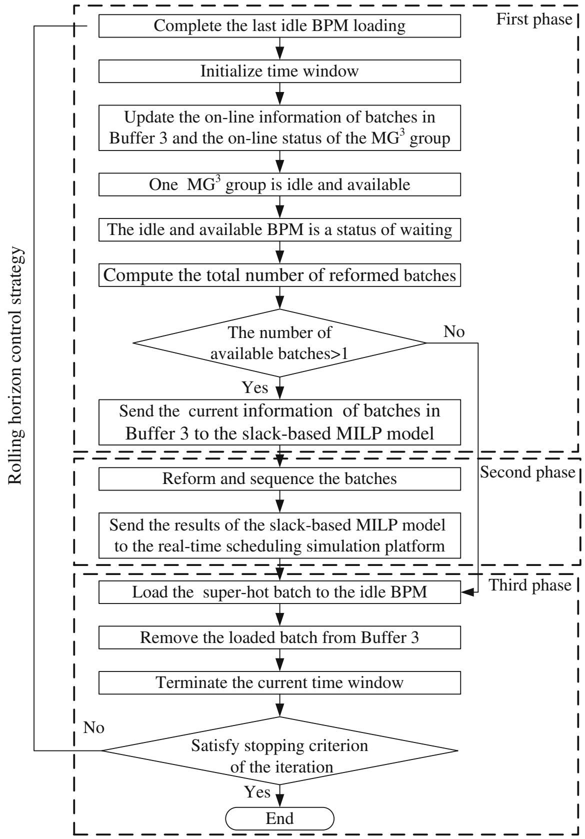


Fig. 2 The overall flow chart of three-phase combined algorithm

step 5 Output the on-line information of batches in Buffer 3 and set up a database. The database is the inputs of the slack-based MILP model.

step 6 The event of reforming and sequencing batch is registered. That is, start to run the ILOG CPLEX and the program developed by ourselves.

step 7 Generate an array of the optimal batches sequencing and output database of this position array. This database is returned to ReS^2 platform.

step 8 The event of loading the super-batch is registered.

step 9 Start to load the super-batch to idle and available MG^3 group.

step 10 Remove the loaded batch from Buffer 3. Update the status of MG^3 group. Terminate the current time window.

step 11 If the stopping criterion of the iteration is reached, the procedure stops. Otherwise, it returns to *Step 1*. Where, the stopping criterion of the iteration is controlled by the total running time of the ReS^2 platform of SWFS.

For the event of reforming and sequencing batch, we consider the optimal sequence positions indices that can be found efficiently by slack-based MILP model.

The reforming batches binary parameters and optimal sequencing positions indices are the decision variables. The processing time requirements need to be satisfied, which are the constraints. The total weighted tardiness is to be minimized, which is the objective function. We define the optimal sequencing positions indices as the one-dimensional array which are noted the [Position (1), Position (2), …, Position (N)]. Such problems are conventionally formulated as follows.

Minimize

$$\sum T = \sum_{n=1}^{N} \max[(Cr_n - dr_n), 0] \tag{1}$$

Subject to

$$Cr_n = t + \text{Position}\,(n) \cdot P_{MG^3} + PRr_n \tag{2}$$

$$\text{Position}\,(n) \in \{1, 2, \cdots, N\}; \forall n \in \{1, 2, \cdots, N\} \tag{3}$$

$$\text{If } n \neq l \text{ then Position}\,(n) \neq \text{Position}\,(l);\ \forall n \text{ and } l \in \{1, 2, \cdots, N\} \tag{4}$$

$$x_{jn} = \begin{cases} 1 & \text{If the batch } j \text{ in Buffer3 is assigned the reforming batch } n \\ 0 & \text{Otherwise} \end{cases}$$

$$\forall n \in \{1, 2, \cdots, N\};\ \forall j \in \{1, 2, \cdots, J\} \tag{5}$$

$$\sum_{n=1}^{N} x_{jn} = 1; \forall j \in \{1, 2, \cdots, J\} \tag{6}$$

$$PRr_n = \sum_{j=1}^{J} x_{jn} \cdot PR_j; \forall n \in \{1, 2, \cdots, N\} \tag{7}$$

$$PR_j = \sum_{\mathrm{k=DS_j+1}}^{ZS_j} P_{kj}; \forall j \in \{1, 2, \cdots, J\} \tag{8}$$

$$dr_n = \sum_{j=1}^{J} x_{jn} \cdot d_j; \forall n \in \{1, 2, \cdots, N\} \tag{9}$$

$$\sum_{j=1}^{J} x_{jn} \cdot s_j \le S; \ \forall n \in \{1, 2, \cdots, N\} \tag{10}$$

$$t - r_j + \text{Position}\,(n) \cdot P_{GM^3} - M(1 - x_{jn}) \le q_j; \forall n \in \{1, 2, \cdots, N\}; \ \forall j \in \{1, 2, \cdots, J\} \tag{11}$$

$$N = \left\lceil \left(\sum_{j=1}^{J} s_j \right) / S \right\rceil \tag{12}$$

Objective function (1) minimizes total weighted tardiness for each time window. Constraint (2) is used to compute the completion time of the nth reforming batch. Constraints (3) and (4) ensure that each reforming batch is sequenced to a position and each position has only one reforming batch to be assigned. Constraint (5) imposes the reforming batches binary restrictions. Constraint (6) ensures that each batch in Buffer 3 is assigned to exactly one reforming batch. Constraint (7) is used to compute the pure remaining processing time of the nth reforming batch after MG^3 group. Constraint (8) is used to compute the pure remaining processing time of the batch j after MG^3 group. Constraint (9) is used to compute the due date time of the nth reforming batch. Constraint (10) ensures that the total size of all batches assigned to a reforming batch does not exceed MG^3 group capacity. Constraint (11) ensures that the total waiting time of the jth batch in Buffer 3 does not exceed the limited waiting time. Constraint (12) is used to compute the total number of reformed batches waiting to be scheduled on MG^3 group. Constraints (1–12) conduct slack-based mathematical linear model, we call it slack-based MILP model which can be fit for being solved by ILOG CPLEX .

4 Simulation Experiments

In this section, a computational experiment is invested to evaluate the proposed three-phase combined algorithm, so a virtual semiconductor manufacturing system (VSMS) is modeled and set to run. As shown in Fig. 3, there are 8 different

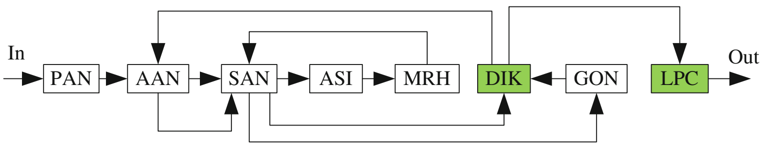


Fig. 3 The typical process flow of VSMS with batch processors

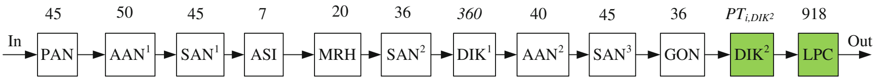


Fig. 4 The processing time of the different processing steps

equipment areas. Among the overflow of VSMS, DIK (i.e., GM^1 group) and LPC (i.e., GM^3 group) belong to BPMs with limited waiting time constraints and dynamic arrivals which are our object of research.

Four different types of wafer products are assumed to be processed simultaneously (I = 4). We assume that each product has the same processing steps, i.e., $ZS_j = DS_j = 12$. The processing time of each processing step is shown in Fig. 4, where $PT_{i,\,DIK}2$ represents processing time of product i which is processed in DIK group for the second time (i.e., re-entrant). The values of $PT_{i,\,DIK}2$ ($i = 1, 2, 3, 4$) are 180, 263, 410, and 300. The maximum capacity of LPC is 12 jobs (S = 12). For each batch, let q_j be 11360. Because LPC is the last processing step, $PR_j = 0$.

In order to evaluate efficiency of the proposed three-phase combined algorithm, genetic algorithm (GA) is used as reference heuristics to assess the performance of slack-based MILP method. The computational experiments are programmed and implemented in Visual Basic. NET 2008 and ILOG CPLEX 12.2 on a Intel Core 2 Duo 2.0 GHz with 2 GB DDR-2 RAM. We consider four different performance measures and two cases. The four different performance measures include CPU time, improvement rate, objective function (optimal) value and deviation.

Whenever one machine in LPC is idle, the information of scheduling parameters of LPC is sent to the slack-based MILP model. Two cases are Case 1 and Case 2. With respect to Case 1 the total number of batches waiting to be scheduled for LPC is 8 ($J = 8$). The detailed database is that s_j = [3, 4, 5, 6, 6, 7, 8, 9], r_j = [100, 150, 200, 300, 180, 263, 410, 300] and d_j = [1,211, 1,211, 1,227, 1,227, 1,236, 1,236, 1,245, 1,245]. While Case 2, J = 16, the detailed database is that s_j = [3, 4, 5, 6, 6, 7, 8, 9, 3, 4, 5, 6, 6, 7, 8, 9], r_j = [100, 150, 200, 300, 180, 263, 410, 300, 100, 150, 200, 300, 180, 263, 410, 300] and d_j = [1,211, 1,211, 1,227, 1,227, 1,236, 1,236, 1,245, 1,245, 1,211, 1,211, 1,227, 1,227, 1,236, 1,236, 1,245, 1,245].

For the main parameters of GA, let population size, crossover probability, mutation probability, and number of generations be 80, 0.8, 0.1 and 120, respectively.

Table 1 The comparisons between slack-based MILP method and GA method

Case	CPU time (s)		Percentage improvement (%)	$\min(\sum T)$		Deviation (%)
	Slack-based MILP	GA		Slack-based MILP	GA	
Case 1	0.06	55.83	+99.87	1,500	1,542	+2.72
Case 2	77.58	77.46	−0.15	15,762	15,870	+0.68

The experimental results of slack-based MILP method and GA are listed in Table 1. In Case 1, the objective function value obtained from slack-based MILP is better than GA by 2.72 %, the CPU time of slack-based MILP is better than GA by 99.87 %. In Case 2, although the objective function value obtained from slack-based MILP is better than GA by 0.68 %, the CPU time of slack-based MILP is longer than GA by 0.15 %. From Table 1, slack-based MILP method performs quite well, especially for smaller number of scheduling batches. Table 1 also shows that our proposed slack-based MILP method can provide the tradeoff between CPU time and solution quality.

5 Conclusions

In this paper, we have discussed a scheduling problem of on-line BPM for minimizing total tardiness with limited waiting time constraints and dynamic arrivals in SWFS. To resolve this NP-hard problem, we have proposed a variable time windows-based three-phase combined algorithm. According to the VSMS experiment, we have evaluated the performance of the proposed algorithm. The results have demonstrated the effectiveness. Our ongoing work is on where real SWFS industry BPM scheduling can be considered.

Acknowledgments This work is supported by National Science and Technology Major Special Projects (2011ZX02501-005) and Research Grant from National Natural Science Foundation of China (No.50475027). We also acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Ahmadi JH, Ahmadi RH, Dasu S, Tang CS (1992) Batching and scheduling jobs on batch and discrete processors. Oper Res, 40 (4):750–763

Du J, Leung JYT (1990) Minimizing total tardiness on one machine is np-hard. Math Oper Res, 15 (3):483–495

Johnson SM (1954) Optimal two-and three-stage production schedules with setup times included. Naval Res Logistics Q 1(1):61–68

Klemmt A, Weigert G, Werner S (2011) Optimisation approaches for batch scheduling in semiconductor manufacturing. Eur J Ind Eng 5(3):338–359

Lin BMT, Cheng T (2001) Batch scheduling in the no-wait two-machine flow shop to minimize the make span. Comput Oper Res 28(7):613–624

Liu H, Fung RYK, Jiang Z (2005) Modelling of semiconductor wafer fabrication systems by extended object-oriented petri nets. Int J Prod Res 43(3):471–495

Ovacik IM, Uzsoy R (1995) Rolling horizon procedures for dynamic parallel machine scheduling with sequence-dependent setup times. Int J Prod Res 33(11):3173–3192

Ovacikt I, Uzsoy R (1994) Rolling horizon algorithms for a single-machine dynamic scheduling problem with sequence-dependent setup times. Int J Prod Res 32(6):1243–1263

Potts CN, Kovalyov MY (2000) Scheduling with batching: a review. Eur J Oper Res, 120 (2):228–249

Su LH (2003) A hybrid two-stage flow shop with limited waiting time constraints. Comput Ind Eng 44(3):409–424

Optimal Organic Rankine Cycle Installation Planning for Factory Waste Heat Recovery

Yu-Lin Chen and Chun-Wei Lin

Abstract As Taiwan's industry developed rapidly, the energy demand also rises simultaneously. In the production process, there's a lot of energy consumed in the process. Formally, the energy used in generating the heat in the production process. In the total energy consumption, 40 % of the heat was used in process heat, mechanical work, chemical energy and electricity. The remaining 50 % were released into the environment. It will cause energy waste and environment pollution. There are many ways for recovering the waste heat in factory. Organic Rankine Cycle (ORC) system can produce electricity and reduce energy costs by recovering the waste of low temperature heat in the factory. In addition, ORC is the technology with the highest power generating efficiency in low-temperature heat recycling. However, most of factories are still hesitated because of the implementation cost of ORC system, even they generate a lot of waste heat. Therefore, this study constructed a nonlinear mathematical model of waste heat recovery equipment configuration to maximize profits, and generated the most desirable model and number of ORC system installed by using the particle swarm optimization method.

Keywords Waste heat · Low temperature · Organic rankine cycle · Particle swarm optimization

Y.-L. Chen (✉) · C.-W. Lin
Industrial Engineering and Management, National Yunlin University of Science & Technology, 123 University Road, Sect. 3, Douliou, Yunlin 64002, Taiwan, Republic of China
e-mail: m10021048@yuntech.edu.tw

C.-W. Lin
e-mail: lincwr@yuntech.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_68,

1 Introduction

It is required large amounts of energy and fuel consumption when factories in the process of manufacturing. According to Taiwan's department of energy distribution, the industrial department accounted 38.56 % with total energy, and 50 % of carbon dioxide emissions with total national emissions (Bureau of Energy 2011a). However, the energy is used in the form of heat energy, thermal energy is accounted for the total energy consumption by more than 90 %, only 40 % of heat energy is converted into process heat, mechanical work, chemical energy, and electricity, other 50 % heat released as waste heat form to environment, it is causing of energy waste and environmental pollution (Kuo et al. 2012). According to statistics, the temperature of most Industry waste heat discharge is between 130 °C and 650 °C, and about 2 million (KLOE) of waste heat below 250 °C, accounting for 62.72 % of the total waste heat, belongs to the low temperature of waste heat discharge. Then, the temperature between 251 °C and 650 °C (middle temperature waste heat) and above 651 °C (high temperature waste heat) account for 19.08 and 18.20 % of total waste heat (Bureau of Energy 2011b).

Today for low-temperature waste heat recovery power generation system, the organic rankine cycle (ORC) system is the highest technology with power generation efficiency, it is widely used in industrial waste heat, geothermal hot springs, biomass heat and waste heat power generation purposes (Kuo and Luo 2012). In addition, ORC system almost has no fuel consumption during it running period, it can also reduce carbon dioxide and sulfur dioxide emissions and other pollutants (Wei et al. 2007). ORC system use organic working fluid as a medium of pick up thermal power generation (Lee et al. 2011). It can choose suitable low boiling point substances as the working fluid (such as refrigerant, ammonia, etc.) by different heat source temperature range, and making low temperature heat energy converted into electricity or brake horsepower output. For the medium and the low temperature heat source, converted to electricity, is more efficient than water (Drescher and Brüggemann 2007). The loop circuit of ORC system, the main components include: pump, evaporator, expander, generator and the condenser. Working fluid circulating in the circuit model is started form (1) booster pump, (2) evaporated into vapor, (3) promote the expansion machine and generators, (4) then condensing to liquid, to complete the cycle (Durma et al. 2012; Somayaji et al. 2007; Chang et al. 2011; Kuo and Luo 2012).

However, in Taiwan the environment of tariffs is generally low, invest of ORC generator have high risk of too long investment recovery period and low return on investment, so the industry still maintain hesitated, even if the factory has lots of waste heat but still lack of invest desire, only few factories are willing to invest in ORC generator to conduct waste heat recovery power generation (Lee et al. 2011).

Therefore, the goal of this study is using ORC power generation units to construct a nonlinear mathematical model of waste heat recovery equipment configuration to maximize profits, will let the low temperature waste heat into electric power via ORC system, and using particle swarm algorithm to find out the suitable generator set number and model, that will be an effectively assist of factory in their waste heat recovery.

2 Model Construction

This study focus on the factory's low temperature waste heat with recycling value, and through ORC system for it recovery. With the condition of maximum output power, only considering heat source temperature and discharge temperature, heat source mass flow rate and specific heat, the working fluid evaporation temperature, and the condensing temperature, than obtained by waste heat of heat capacity (Fenn 2003). It is include the loss of power transmission and the generator efficiency, therefore, without discussing each element thermal efficiency, achieve the overall optimization cycle thermal efficiency (Lee 2009; Lee et al. 2011). In the cost analysis of investment of ORC generator, the most important is the purchased equipment costs of unit itself. Besides, have to consider generating set surrounding the installation costs (Lukawski 2009), and taking into consideration of the time value of money, use levelization concept. The times change might also change the money value, transform to annuity. In addition, the operation and maintenance costs of waste heat recovery equipment operate will increase year by year, must through constant-escalation-levelization-factor to the cost of the time value of money considerations (Lukawski 2009; Meng and Jacobi 2011).

In this study, the objective function is maximize the annual net profit, include the annual sell electricity income, annual investment cost, annual operation and maintenance costs, government subsidies and annual salvage value. At last, it can figure out the suitable number of units from the waste heat recovery equipment configuration optimization. Then can be learned that all of the waste heat source in factory should be parallel configuration of those generators model and number.

2.1 Parameters

I	Number of heat source in factory
J	Number of generators model of ORC
HT_i	The temperature of the heat source i (°C)
LT_i	The discharge temperature of the factory requirements (°C)
M_i	Total mass of the heat source i (kg/h)
S_i	Specific heat of the heat source i [cal/g(°C)]
ET_j	The evaporation temperature of the working fluid in the model j of ORC (kelvin, K)
CT_j	The condensing temperature of the working fluid in the model j of ORC (kelvin, K)
RH	The running hours of the model j of ORC in a year (h)
EP	Electricity price per kWh

EGR	Electricity growth rate
PEC_j	Purchased equipment cost of the model j of ORC
SV_j	Salvage value of the model j of ORC
A_j	Each generator government grants of the model j of ORC
CI_j	Cost of installation of the model j of ORC
CP_j	Cost of piping of the model j of ORC
CEE_j	Cost of electrical equipment of the model j of ORC
CC_j	Cost of civil and structural work of the model j of ORC
CS_j	Cold source of the model j of ORC
DPC_j	Design and planning costs of the model j of ORC
MC_{ij}	Maintenance costs of the model j of ORC installation at the heat source i
PRC_{ij}	Plant repair costs of the model j of ORC installation at the heat source i
$GRMC$	Growth rate of the maintenance costs
B	Factory budget
FPB	Payback required by the factory
$MARR$	Minimum acceptable rate of return
n	Assessment of useful life

2.2 Variables

x_{ij}	The number of the model j of ORC installation at the heat source i
m_{ij}	The mass diverted to the model j of ORC from the heat source i (kg/h)

$$y_{ij} = \begin{cases} 1, \text{ the heat source} i \text{ has installed the model } j \text{ of ORC }; \\ 0, \text{ the heat source } i \text{ has not installed the model} j \text{ of ORC} \end{cases}$$

$$Y_j = \begin{cases} 1, \text{ the factory hasinstalled the model } j \text{ of ORC} \left(\sum_{i=1}^{I} y_{ij} \geq 1 \right); \\ 0, \text{ the factoryhas not installed the model } j \text{ of ORC} \left(\sum_{i=1}^{I} y_{ij} = 0 \right) \end{cases}$$

2.3 Mathematical Model

Objective function for waste heat recovery equipment configuration profits (annual sell electricity income-annual investment cost-annual operation and maintenance costs + government subsidies + annual salvage value) maximize is:

$$
\begin{aligned}
P = & \left\{ \begin{array}{l} \left\{ \sum_{i=1}^{I} \sum_{j=1}^{J} \left[m_{ij} \cdot S_i \cdot (HT_i - LT_i) \div 860 \right] \times \left(1 - \sqrt{CT_j \div ET_j} \right) \times RH \right\} \\ \times EP \times \left[\frac{(1+EGR)^n - 1}{(1+EGR) - 1} \right] \times \left[\frac{MARR \times (1+MARR)^n}{(1+MARR)^n - 1} \right] \end{array} \right\} \\
& - \left\{ \left\{ \sum_{j=1}^{J} \left[\sum_{i=1}^{I} \begin{pmatrix} PEC_j + CI_j + CP_j \\ +CEE_j + CC_j + CS_j \end{pmatrix} \times x_{ij} \atop +DPC_j \times Y_j \right] \right\} \times \left[\frac{MARR \times (1+MARR)^n}{(1+MARR)^n - 1} \right] \right\} \\
& - \left\{ \begin{array}{l} \left[\sum_{i=1}^{I} \sum_{j=1}^{J} \left(MC_{ij} + PRC_{ij} \right) \times x_{ij} \right] \times \left(\frac{1+GRMC}{1+MARR} \right) \\ \times \left\{ \left[1 - \left(\frac{1+GRMC}{1+MARR} \right)^n \right] \div \left[1 - \left(\frac{1+GRMC}{1+MARR} \right) \right] \right\} \times \left[\frac{MARR \times (1+MARR)^n}{(1+MARR)^n - 1} \right] \end{array} \right\} \\
& + \left\{ \sum_{i=1}^{I} \sum_{j=1}^{J} A_j ij \div n \right\} + \left\{ \left[\sum_{i=1}^{I} \sum_{j=1}^{J} \left(SV_j \times x_{ij} \right) \right] \times \left\{ MARR \div \left[(1+MARR)^n - 1 \right] \right\} \right\}.
\end{aligned}
\tag{1}
$$

s.t.

$$ET_j \times y_{ij} \le HT_i \quad \forall i,\ \forall j. \tag{2}$$

$$y_{ij} \le x_{ij} \le M \cdot y_{ij} \quad \forall i,\ \forall j. \tag{3}$$

$$Y_j \le \sum_{i=1}^{I} y_{ij} \le M \cdot Y_j \quad \forall j. \tag{4}$$

$$\sum_{j=1}^{J} m_{ij} \le M_i \quad \forall i. \tag{5}$$

$$\left\{ \left[m_{ij} \cdot S_i \cdot (HT_i - LT_i) \div 860 \right] \times \left(1 - \sqrt{CT_j \div ET_j} \right) \right\} \div x_{ij} \le GC_j \quad \forall i,\ \forall j. \tag{6}$$

$$\left\{ \sum_{j=1}^{J} \left[\sum_{i=1}^{I} \begin{pmatrix} PEC_j + CI_j + CP_j \\ +CEE_j + CC_j + CS_j \end{pmatrix} \times x_{ij} + DPC_j \times Y_j \right] \right\} \div P \le FPB \ \ \forall i, \forall j. \tag{7}$$

$$\sum_{j=1}^{J} \left[\sum_{i=1}^{I} \begin{pmatrix} PEC_j + CI_j + CP_j \\ +CEE_j + CC_j + CS_j \end{pmatrix} \times x_{ij} + DPC_j \times Y_j \right] \le B \ \ \forall i, \forall j. \tag{8}$$

$$P \div \left\{ \sum_{j=1}^{J} \left[\sum_{i=1}^{I} \begin{pmatrix} PEC_j + CI_j + CP_j \\ +CEE_j + CC_j + CS_j \end{pmatrix} \times x_{ij} + DPC_j \times Y_j \right] \right\} \ge MARR \ \ \forall i, \forall j. \tag{9}$$

$$x_{ij} \ge 0, x_{ij} \in \mathrm{Z}, m_{ij} \ge 0, y_{ij} \ge 0, y_{ij} \in \{0,1\}, Y_j \ge 0 \ \ \forall i, \forall j. \tag{10}$$

Equation (1) is the objective function of this study. Equation (2) as the heat source i with model j of ORC, the evaporation temperature of ORC can't higher than the temperature of that source. Equation (3) for the generator heat source have no install, the installation number is 0. If factory installed the j generator, then Eq. (4) represent at least one heat source will installed the generators, which must consider the generator design and planning costs. M of Eqs. (3) and (4) as an infinite value. Equation (5) as the sum of mass diverted to the model j of ORC from heat source i, those mass can't more than the total mass of that source. Equation (6) as available generating capacity by the heat source i installed the model j of ORC, it can't more than the generating capacity of that model. Equation (7) is restriction of payback period. Equation (8) is restriction of budget. Equation (9) is restriction of return on investment. Equation (10) tells all variables must be greater than or equal to zero.

3 Validation

This study discusses the case for a steel works within the two color coating line, in the process of production will produce waste heat. The heat source data is below Table 1, the conditions of ORC generator power generation, and the relative of investment cost, according to the literature and the case data which company provided, the simulation parameters set as Table 2 (Lukawski 2009; Lee et al. 2011; Chang et al. 2011; Kuo et al. 2012). This case company for investment restrictions: *MARR* is 10 (%), *FPB* is 5(year), *B* is 50,000,000 (NT). And assuming *RH* is 8,000 (h/year), *EP* is 3.01 (NT/kWh), *EGR* is 2 (%), *n* is 20 (year), *GRMC* is 1 (%).

This study use Particle Swarm Optimization of simulate the flock foraging, through global search and particle search, then find the best solution after iterative

Table 1 Heat source data

Heat source	M_i (kg/h)	S_i (cal/g °C)	HT_i (°C)	LT_i (°C)
$i = 1$	23,760	0.31	320	170
$i = 2$	23,280	0.31	332	170

Table 2 Parameters of the ORC

Model of ORC	GC_j (kW)	ET_j (K)	CT_j (K)	PEC_j (NT)	SV_j (NT)	A_j (NT)	CI_j (NT)
$j = 1$	50	381.15	313.15	4,500,000	450,000	2,000,000	270,000
$j = 2$	125	394.15	294.15	11,250,000	1,125,000	5,000,000	675,000
Model of ORC	CP_j (NT)	CEE_j (NT)	CC_j (NT)	CS_j (NT)	DPC_j (NT)	MC_j (NT)	PRC_j (NT)
$j = 1$	405,000	180,000	135,000	225,000	225,000	225,000	225,000
$j = 2$	1,012,500	450,000	337,500	562,500	562,500	562,500	562,500

Table 3 PSO parameter table

Parameters	Generations	Particle number	Maximum weight (w_{max})	Minimum weight (w_{min})	Studying factor 1 c_1	Studying factor 2 C_2
Value	500	100	0.9	0.4	2	2

Table 4 Results of the validation

Heat source i with model j of ORC	$i = 1, j = 1$	$i = 1, j = 2$	$i = 2, j = 1$	$i = 2, j = 2$
Number of installation x_{ij}	1	1	1	1
Mass m_{ij} (kg/h)	6,715	16,920	7,494	15,662
Annual net profit (NT/year)	14,845,764			

update (Xia and Wu 2005). This research use linear decreasing weighting method (Kennedy and Eberhart 1995), set the related parameters as Table 3. Use MATLAB 7.10 to write a program, get the results in Table 4.

4 Conclusions

This study constructed a nonlinear mathematical model of waste heat recovery equipment configuration to maximize profits of ORC system, with the problem of painting process of waste heat emissions in steel company as a case, using particle swarm algorithm for validation. Then find out the best configuration of company's color coating process for optimal of waste heat recovery equipment, to achieve the objective of the waste heat recovery.

Acknowledgments Thanks for my professor and the assistant manager of steel company, Mr. Lin, Thank you for helping this study complete with smoothly way. Also sincerely thanks for the seminar last review committee members and all the coworkers.

References

Bureau of energy, ministry of economic affairs (2011a) Energy statistics handbook. Taiwan, Republic of China

Bureau of energy, ministry of economic affairs (2011b) 能源局採取「創新管理」方式推動能源回收再利用 http://www.moea.gov.tw/Mns/populace/news/News.aspx?kind=1&menu_id=40&news_id=22745

Chang K-H, Kuo C-R, Hsu S-W, Wang C-C (2011) Analysis of a 50 kW organic Rankine cycle system and its heat exchangers. Energ HVAC Eng 72:45–56

Drescher U, Brüggemann D (2007) Fluid selection for the organic rankine cycle (ORC) in biomass power and heat plants. Therm Eng 27:223–228

Durma A, Pugh R, Yazici S, Erdogan K, Kosan A (2012) Novel application of organic rankine cycle (ORC) technology for waste heat recovery from reheat furnace evaporative cooling system. Papers presented at the AISTech conference, Atlanta, Georgia, pp 7–10

Fenn JB (2003) Engines, energy, and entropy: a thermodynamics primer. USA

Kennedy J, Eberhart R (1995) Particle swarm optimization. Proc IEEE Int Conf Neural Networks 4:1942–1948

Kuo C-R, Luo S-T (2012) 低溫熱能發電系統現況與展望. Energ Monthly 7:31–34

Kuo C-R, Li Y-R, Hsu S-W (2012) Product development and applications of organic Rankone cycle power units. Mechatronic Ind 355:93–100

Lee Jhe-Yu (2009) Finite time endoreversible maximum useful energy rate analysis of thermodynamics cogeneration cycles. National Cheng Kung University, Dissertation

Lee Yu-Ren, Kuo Chi-Ron, Hsu Sung-Wei, Kuo Y-L (2011) Development of ORC for low grade thermal energy conversion. Mechatronic Ind 343:138–148

Lukawski M (2009) Design and optimization of standardized organic rankine cycle power plant for European conditions. Dissertation, University of Akureyri

Meng L, Jacobi AM (2011) Optimization of polymer tube-bundle heat exchangers using a genetic algorithm. papers presented at the ASME 2011 International Mechanical Engineering Congress And Exposition, Colorado, USA

Somayaji C, Chamra LM, Mago PJ (2007) Performance analysis of different working fluids for use in organic Rankine cycles. Power and Energ 221:255–263

Wei D, Lu X, Lu Z, Gu J (2007) Performance analysis and optimization of organic Rankine cycle (ORC) for waste heat recovery. Energy Convers Manage 48:1113–1119

Xia Wu, Wu Z (2005) An effective hybrid optimization approach for multi-objective flexible job-shop scheduling problems. Comput Ind Eng 48:409–425

Evaluation of Risky Driving Performance in Lighting Transition Zones Near Tunnel Portals

Ying-Yin Huang and Marino Menozzi

Abstract Driving behavior is affected by rapidly varying lighting conditions that frequently occur in transition zones near tunnel portals. When entering a tunnel in daytime, car drivers might encounter various difficulties in keeping high performance for safety concerns: (1) Physiological issues caused by high-level glare—the adaptation of the eye requires recovery time, during which time there will be impaired vision and reduced visibility of on-road objects; (2) Psychological issues caused by visual discomfort and distraction—limited resources for performing information processing are shared by the distracting and disturbing sensation; (3) Behavioral issues caused by driving patterns of the driver and other road users—many drivers reduce their speeds when entering the tunnel; thus a car driver must react to the sudden speed change. This study investigated the records of traffic accidents on Zurich highways in tunnel areas and conducted experiments using a driving simulator. The analysis of accident records shows that the frequency of accidents increases near tunnel portals. Experimental results show that discomfort glare impairs both peripheral visual attention and motion discrimination in simulated driving tasks. In conclusion, we suggest considering tunnel portals as a key factor causing elevated risk in traffic safety. Lighting designs and road layout near tunnel portal areas should be carefully defined.

Keywords Driving performance · Lighting transition · Tunnel portal · Risky event · Visual attention · Motion discrimination

Y.-Y. Huang (✉)
Department of Management, Technology and Economics and Department of Health Sciences and Technology, Ergonomics of Information Media Research Group, ETH Zurich, Scheuchzerstrasse 7, CH-8092 Zurich, Switzerland
e-mail: yingyinhuang@ethz.ch

M. Menozzi
Department of Health Sciences and Technology, Ergonomics of Information Media Research Group, ETH Zurich, Scheuchzerstrasse 7, CH-8092 Zurich, Switzerland
e-mail: mmenozzi@ethz.ch

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_69,

1 Introduction

Modern development and applications of the tunnel construction technology have enabled fast and convenient transportation in our daily life. With the increasing number of travelers using tunnel connections, efficient management of traffic flows and traffic safety have become an important topic. Continuously improved design concepts regarding tunnel constructions have been proposed in order to fulfill various aspects of major importance, such as safety concerns and optimized traffic volumes, as well as economic and energy considerations. For example, an Austrian study has suggested that traffic safety in uni-directional traffic tunnels is significantly higher than in bi-directional traffic tunnels (Nussbaumer 2007). Other suggestions have also been discussed and made for the layout of tunnels, lighting systems in tunnels (DIN 2008), traffic organization and fast control of tunnels, and so on, regarding safety. In fact, studies have shown that road tunnels are as safe as (or even safer than) other high standard open stretches of roads (Amundsen and Ranes 2000; Nussbaumer 2007) in terms of the probability of accidents occurring and road users being injured. However, when an accident happens in a tunnel, the cost and severity are higher than on open stretches of roads. Besides, higher accident rates occurred in the entrance zone of tunnels.

Several issues arise when one is driving into a tunnel. Car drivers encounter various difficulties in the transition zones of tunnels, i.e. from outside to inside of tunnels, which may result in risky driving performance. Firstly, rapidly changing lighting conditions may perturb one's visual system. Depending on lighting conditions and on individual susceptibility, glare may cause visual disability, discomfort or a combination of both (Boyce 2003). On a sunny day, for instance, a driver may be exposed to an extremely high-level luminance of 10,000 cd/m^2 when gazing on the tunnel entrance wall from the outside of the tunnel; as soon as the driver enters the dark environment inside the tunnel, the eye must get adapted to a very low-level luminance of 5 cd/m^2 within a short time. Such an abrupt and great variation of luminance causes so called disability glare and affects one's visual performance because of the inertia of the light adaptation mechanism of the eye. As visibility of objects depends on the light level one's eye is adapted to, and the light adaptation process is rather slow, a car driver may therefore face a risky driving event during the transition period due to reduced visibility of on-road objects. In addition to disability glare, the changing lighting conditions may result in visual discomfort without affecting acute visual performance, known as discomfort glare. Discomfort glare, which causes visual distraction, and/or vice versa (Lynes 1977), has been discussed mainly for some work-place related issues (Osterhaus 2005; Sheedy et al. 2005; Hemphälä and Eklund 2012). Little is known about its potential effects on traffic safety in tunnel portal areas. When discomfort glare acts as a distracter, our cognitive mechanism decides how to proceed with our visual attention for incoming driving events. As a result, while we are suffering from sensations of discomfort, discomfort glare shares our perception resources and increases our mental loads. As the amount of available resources for information processing are limited (Wickens et al. 2005), discomfort glare may bind resources therefore reducing the amount of available resources during the transition phase. Secondly, changes in the driving environment in the transition areas require car drivers' attention resources. When entering a tunnel, drivers have to proceed and rebuild the radical image changes of the visual environment from an open road to a closed and narrower area. Besides, some events may take place during the transition period such as switching the radio channel, adapting speed, changing lane, adjusting the head-lamp, attending to traffic signs and indicators, etc. More resources are occupied and less is left for handling any unexpected or sudden critical driving event. Thirdly, driving behaviors and patterns of road users towards a tunnel may affect other drivers. It has been noticed that drivers tend to reduce the car speed when approaching a tunnel entrance. This means that a driver must keep alert to any sudden speed changes of other cars and react simultaneously, especially to keep a safe distance with the front car. Again, such a task uses the limited resources and increases the mental load of a driver.

In conclusion, to drive in lighting transition zones near tunnel portals is a heavy driving task of a road user. Factors among physiological issues of light adaptation, psychological and behavioral issues of increased loads and reduced resources being available, may raise the probability of a risky driving event. In this study we aimed to analyze some car accident records near highway tunnel portals in Switzerland and support the hypothesis that an elevated potential of risk of car accidents may be expected in the transition zones near tunnel portals. In addition, by summarizing results of several experiments carried out in our driving simulator, we aimed to investigate certain abovementioned effects which could result in a risky driving performance caused by visual discomfort and distraction. Finally we aimed to conclude with some suggestions which may help in preventing risky driving performance near tunnel portals.

2 Method

2.1 Data Analysis: Records of Accidents on Zurich Highway Within the Last Decade

Support to the hypothesis of an elevated risk for accidents in proximity of tunnel portals is investigated by analyzing records of accidents on Zurich highways, traffic data etc., which were collected within the last decade. Data from 1,110 accidents were included and analyzed in this study, the factors bring considered are lighting, meteorological and other environmental factors, traffic parameters and individual factors of drivers involved in the accidents.

2.2 *Visual Attention Tests in Simulated Driving Tasks: Evaluation of Effects on Visual and Mental Performance Caused by Discomfort Glare*

Several experiments were carried out in a driving simulator in virtual reality. First, we investigated the effect of discomfort glare on peripheral visual attention in a realistic driving scenario. Participants performed the attention test (Fig. 1a) which required detection of simultaneously presented visual information both in the central visual field and in periphery. In a two alternative forced choice task, participants reported whether the orientations of two arrows, one in the central visual field (0°) and the other in the peripheral visual field (18°), were the same or not under different glare conditions. In 50 % of the total trials, a white frame with a luminance of 25 cd/m^2 was flashed prior to the presentation of the arrow set. In the other 50 %, no glare stimuli were applied.

In another experiment we investigated the effect of discomfort glare on the speed discrimination of a front car. Participants performed the motion detection test in a simulated city-scenario (Fig. 1b) under different glare conditions. Participants reported whether the perceived speed of a front car was faster or slower than own car speed. The car speed of the participants was fixed at 50 km per hour. The speed of the front car was given pseudo-randomly among the total trials, varying from 45 to 54 km per hour. One-third of the total trials were applied a flash of a white frame with a luminance of 19 cd/m^2 before the stimuli were presented. In another one-third of the trials, a grey glare mask with a luminance of 3.5 cd/m^2 was flashed before the front car presentation. In the rest trials no glare was applied.

Fig. 1 **a** Template scene of the attention test—*two arrows* were simultaneously presented and participants were asked to report whether the orientations of two arrows were the same **b** Template scene of the motion detection test—a front car with different speed settings was presented and participants were asked to report whether the speed of the front car was faster or slower than his/her own speed

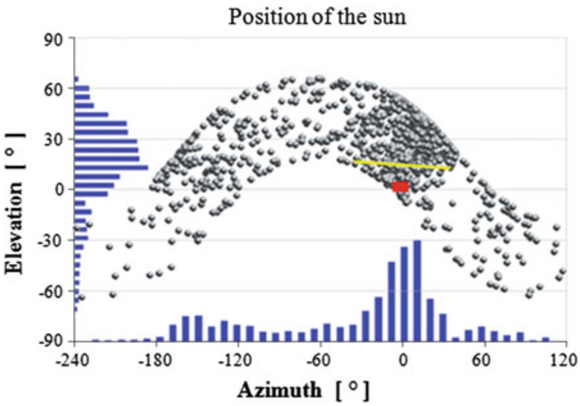


Fig. 2 Accidents with elevation and azimuth of the position of the sun. The tunnel portal is marked with a *red box* (indicative, not true to scale) and the horizon with a *yellow line* (indicative). Columns on the axes represent the frequency distribution of the elevation and the azimuth (Mauch 2012)

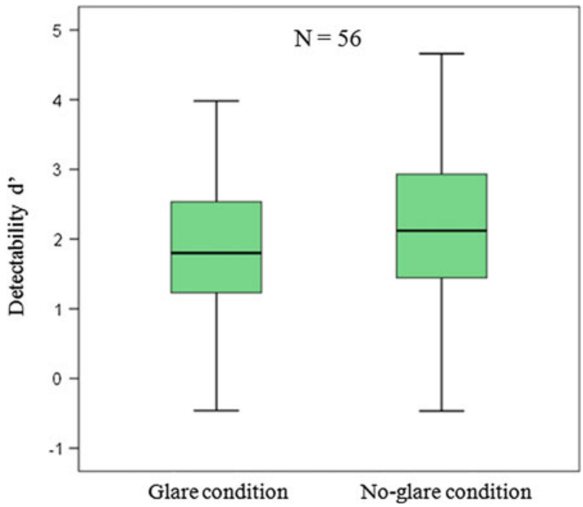


Fig. 3 Box-plot diagram presenting the distribution of detectability d′ in the glare condition and the no-glare condition of the total 56 participants

After analyzing the data, it was found that there is a strong relation of accidents frequency increase with near tunnel portal areas (Mauch 2012). In extreme cases, it was found that there is about seven times higher accident frequency occurred at the tunnel entrance compare to the inner section of the tunnel. An elevated accident frequency was also found at the exit portal of tunnels. One interest finding is that the luminance level before the tunnel portal area does not affect the accident frequency, however, the position of the sun at the time of accident occurrence shows significantly correlation with the accident frequency (Fig. 2).

Results of the attention test were evaluated based on the theory of signal detection (Gescheider 1985). Participants performed significantly better when no glare stimuli were presented (two-tailed *t* test, $t(55) = -2.614$, $p = 0.01$) in detectability d′ ($d'_{glare} = 1.87$; $d'_{no\ glare} = 2.11$; $\Delta d' = 0.24$) as illustrated in Fig. 3. Discomfort glare was shown to cause peripheral visual attention

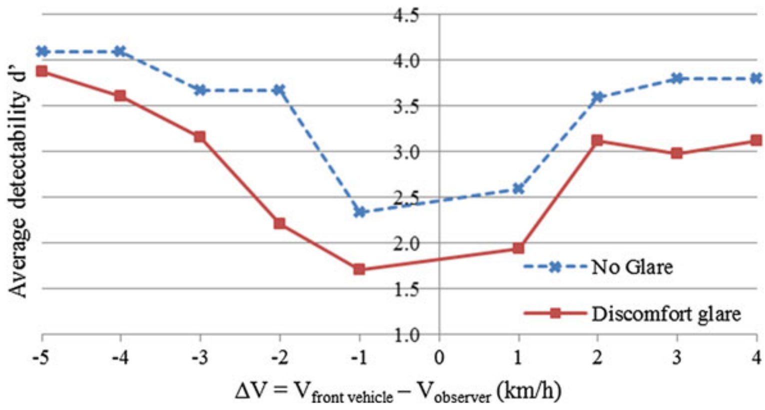


Fig. 4 Graphical representation of the results of average detectability d′ versus the speed difference between the participant and the front car under different glare conditions

impairment in a complex and temporarily varying visual environment. As attention and in particular peripheral attention have been identified as a predominant factor directly related to driving skills (Ball et al. 1993), we therefore propose to consider discomfort glare as an important cause of risky driving performance in lighting transition zones of tunnels.

Results of the motion detection test revealed that participants performed the speed discrimination task significantly better in the no glare condition (Fig. 4). Discomfort glare interfered in visual perception of motion and caused reduced detectability in speed discrimination of a front car, which could be a major concern of safety issues during the transition period.

Above-mentioned effects on drivers' attention of abruptly varying lighting situations, as can be found in the transition zones, seem to play a role on traffic safety. Inattentiveness while entering a tunnel was named as one of the most important causes leading to impact with the front car in the transition zones. Possibly a lack of attention might have prevented some drivers in correctly estimating the speed of the front car, despite good visibility of the car ahead in terms of luminance contrast.

3 Conclusions

We suggest that tunnel portal areas may contain several risky factors which increase the probability of risky driving performance regarding traffic safety. Car drivers face various difficulties in the lighting transition zones when driving into a tunnel. Discomfort glare impairs drivers' attention to visual information on the road and impair their ability to estimate a front car's speed. Therefore, we suggest considering discomfort glare as a major importance in driving safety in addition to effects caused by a disturbed light adaptation of the eye. Among measures for improving driving safety in tunnel portal areas, we suggest increasing the lighting level at tunnel entrances with respect to current regulations by an important amount, e.g. a factor of 5–10, and/or reducing the lighting level before tunnel entrances by introducing some penumbra using roofs, windows, etc. for instance. Additionally, we recommend that the coefficient of reflection of the tunnel portal surface be reduced by changing the painting material or using dark-green vegetation, or smaller surface areas of tunnel portals, Furthermore, we suggest avoiding complex driving environments before tunnel portal areas, such as by decreasing the amount of road indicators and traffic signs, avoiding junction-connections, and so on.

Acknowledgments The authors thank the Federal Road Office of Switzerland (ASTRA) for supporting our research work on traffic safety.

References

Amundsen FH, Ranes G (2000) Studies on traffic accidents in Norwegian road tunnels. Tunn Undergr Space Technol 15(1):3–11

Ball K, Owsley C, Sloane ME, Roenker DL, Brun JR (1993) Visual attention problems as a predictor of vehicle crashes in older drivers. Invest Ophthalmol Vis Sci 34(11):3110–3123

Boyce PR (2003) Human factors in lighting, 2nd edn. Taylor & Francis, New York

DIN 67524 (2008) Lighting of street tunnels and underpasses

Gescheider GA (1985) Psychophysics: method, theory, and application, 2nd edn. Lawrence Earlbaum Associated, Houndmills

Hemphälä H, Eklund J (2012) A visual ergonomic intervention in mail sorting facilities: Effects on eyes, muscles and productivity. Applied Ergonomics 43:217–229

Lynes JA (1977) Discomfort glare and visual distraction. Light Res Technol 9:51–52

Mauch D (2012) Accidents in the Gubrist Tunnel: an analysis on the momentary inattention. Master Thesis, MSc MTEC, ETH Zürich

Nussbaumer C (2007) Comparative analysis of safety in tunnels. Paper presented at the Young Researchers Seminar, Austrian Road Safety Board, Brno, 2007

Osterhaus WKE (2005) Discomfort glare assessment and prevention for daylight applications in office environments. Solar Energy 79:140–158

Sheedy JE, Smith R, Hayes J (2005) Visual effects of the luminance surrounding a computer display. Ergonomics 48:1114–1128

Wickens CD, McCarley JS, Alexander AL, Thomas LC, Ambinder M, Zheng S (2005) Attention-Situation Awareness (A-SA) Model of Pilot Error. Technical Report AHFD-05-15/NASA-04-5

Application of Maple on Solving Some Differential Problems

Chii-Huei Yu

Abstract This article takes the mathematical software Maple as the auxiliary tool to study the differential problem of some types of functions. We can obtain the infinite series forms of any order derivatives of these functions by using differentiation term by term theorem, and hence greatly reduce the difficulty of calculating their higher order derivative values. On the other hand, we propose some functions to evaluate their any order derivatives, and calculate some of their higher order derivative values practically. The research methods adopted in this study involved finding solutions through manual calculations and verifying these solutions by using Maple. This type of research method not only allows the discovery of calculation errors, but also helps modify the original directions of thinking from manual and Maple calculations. For this reason, Maple provides insights and guidance regarding problem-solving methods.

Keywords Derivatives · Differentiation term by term theorem · Infinite series forms · Maple

1 Introduction

As information technology advances, whether computers can become comparable with human brains to perform abstract tasks, such as abstract art similar to the paintings of Picasso and musical compositions similar to those of Mozart, is a natural question. Currently, this appears unattainable. In addition, whether computers can solve abstract and difficult mathematical problems and develop abstract mathematical theories such as those of mathematicians also appears unfeasible.

C.-H. Yu (✉)
Department of Management and Information, Nan Jeon Institute of Technology, No.178, Chaoqin Rd., Yanshui Dist, Tainan City, 73746 Taiwan, ROC
e-mail: chiihuei@mail.njtc.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_70,

Nevertheless, in seeking for alternatives, we can study what assistance mathematical software can provide. This study introduces how to conduct mathematical research using the mathematical software Maple. The main reasons of using Maple in this study are its simple instructions and ease of use, which enable beginners to learn the operating techniques in a short period. By employing the powerful computing capabilities of Maple, difficult problems can be easily solved. Even when Maple cannot determine the solution, problem-solving hints can be identified and inferred from the approximate values calculated and solutions to similar problems, as determined by Maple. For this reason, Maple can provide insights into scientific research. Inquiring through an online support system provided by Maple or browsing the Maple website (www.maplesoft.com) can facilitate further understanding of Maple and might provide unexpected insights. For the instructions and operations of Maple, we can refer to (Abell 2005; Dodson and Gonzalez 1995; Garvan 2001; Richards 2002; Robertson 1996; Stroeker and Kaashoek 1999).

In calculus courses, determining the nth order derivative value $f^{(n)}(c)$ of a function $f(x)$ at $x = c$, in general, needs two procedures: firstly finding the nth order derivative $f^{(n)}(x)$ of $f(x)$, and secondly taking $x = c$ into $f^{(n)}(x)$. These two procedures will make us face with increasingly complex calculations when calculating higher order derivative values of a function (i.e. n is larger), Therefore, to obtain the answers by manual calculations is not easy. For the study of differential problems can refer to (Edwards and Penney 1986, Chap. 3; Grossman 1992, Chap. 2; Larson et al. 2006, Chap. 2; Flatto 1976, Chap. 3; Yu 2013a, b, c, d, e, 2012). In this paper, we mainly studied the differential problems of the following two types of functions

$$f(x) = \frac{x^p}{(1 + x^q + x^{2q} + \cdots + x^{nq})^m} \tag{1}$$

$$g(x) = \frac{x^p}{[1 - x^q + x^{2q} - \cdots + (-1)^n x^{nq}]^m} \tag{2}$$

where m, n, p, q are positive integers. We can determine any order derivatives of these two types of functions by using differentiation term by term theorem; these are the main results of this study (i.e., Theorems 1 and 2), and hence greatly reduce the difficulty of evaluating their higher order derivative values. Additionally, two examples in which Theorems 1 and 2 were practically employed to determine any order derivatives of these two functions and calculate some of their higher order derivative values. The research methods adopted in this study involved finding solutions through manual calculations and verifying these solutions by using Maple. This type of research method not only allows the discovery of calculation errors, but also helps modify the original directions of thinking from manual and Maple calculations. For this reason, Maple provides insights and guidance regarding problem-solving methods.

2 Main Results

Firstly, we introduce some notations and theorems used in this study.

Notations.

Suppose r is any real number, n is any positive integer. Define

$$(r)_n = r(r-1)\cdots(r-n+1), \text{ and } (r)_0 = 1.$$

Finite geometric series.

Suppose n is a positive integer, y is a real number, $y \neq 1$. Then

$1 + y + y^2 + \cdots + y^n = \frac{1-y^{n+1}}{1-y}$, where $y \neq 1$.

$1 - y + y^2 - \cdots + (-1)^n y^n = \frac{1-(-1)^{n+1}y^{n+1}}{1+y}$, where $y \neq -1$.

Binomial theorem.

Assume u is a real number, m is a positive integer. Then $(1+u)^m = \sum_{k=0}^{m} \frac{(m)_k}{k!} u^k$.

Binomial series (Apostol 1975, p. 244).

If w, a are real numbers, $|w| < 1$. Then $(1+w)^a = \sum_{q=0}^{\infty} \frac{(a)_q}{q!} w^q$.

Differentiation term by term theorem (Apostol 1975, p. 230).

If, for all non-negative integer k, the functions $g_k : (a,b) \to R$ satisfy the following three conditions: (1) there exists a point $x_0 \in (a,b)$ such that $\sum_{k=0}^{\infty} g_k(x_0)$ is convergent, (2) all functions $g_k(x)$ are differentiable on open interval (a, b), (3) $\sum_{k=0}^{\infty} \frac{d}{dx} g_k(x)$ is uniformly convergent on (a, b). Then $\sum_{k=0}^{\infty} g_k(x)$ is uniformly convergent and differentiable on (a, b). Moreover, its derivative $\frac{d}{dx} \sum_{k=0}^{\infty} g_k(x) = \sum_{k=0}^{\infty} \frac{d}{dx} g_k(x)$.

Firstly, we determined the infinite series forms of any order derivatives of function (1).

Theorem 1 *Suppose m, n, p, q are positive integers and let the domain of the function*

$$f(x) = \frac{x^p}{(1 + x^q + x^{2q} + \cdots + x^{nq})^m}$$

be $\{x \in R | x \neq 0, \pm 1\}$.

(1) *If* $|x| < 1$ *and* $x \neq 0$, *then the kth order derivative of* $f(x)$,

$$f^{(k)}(x) = \sum_{r=0}^{m} \sum_{s=0}^{\infty} \frac{(-1)^{r+s}(m)_r(-m)_s(qr + p + nqs + qs)_k}{r!s!} x^{qr+p+nqs+qs-k} \quad (3)$$

(2) If $|x| > 1$, then

$$f^{(k)}(x) = \sum_{r=0}^{m}\sum_{s=0}^{\infty}\frac{(-1)^{m+r+s}(m)_r(-m)_s(qr+p-nqm-nqs-qm-qs)_k}{r!s!}x^{qr+p-nqm-nqs-qm-qs-k} \tag{4}$$

Proof
(1) If $|x|<1$ and $x \neq 0$, then

$$\begin{aligned} f(x) &= \frac{x^p}{(1+x^q+x^{2q}+\cdots+x^{nq})^m} \\ &= \frac{x^p(1-x^q)^m}{[1-x^{(n+1)q}]^m} \text{ (by finite geometric series)} \end{aligned} \tag{5}$$

$$= x^p \cdot \sum_{r=0}^{m}\frac{(m)_r}{r!}(-x^q)^r \cdot \sum_{s=0}^{\infty}\frac{(-m)_s}{s!}[-x^{(n+1)q}]^s$$

(by binomial theorem and binomial series)

$$= \sum_{r=0}^{m}\frac{(-1)^{r+s}(m)_r}{r!}x^{qr+p} \cdot \sum_{s=0}^{\infty}\frac{(-m)_s}{s!}x^{(n+1)qs}$$

$$= \sum_{r=0}^{m}\sum_{s=0}^{\infty}\frac{(-1)^{r+s}(m)_r(-m)_s}{r!s!}x^{qr+p+nqs+qs} \tag{6}$$

By differentiation term by term theorem, differentiating x by k times on both sides of (6), we obtained the kth order derivative of $f(x)$,

$$f^{(k)}(x) = \sum_{r=0}^{m}\sum_{s=0}^{\infty}\frac{(-1)^{r+s}(m)_r(-m)_s(qr+p+nqs+qs)_k}{r!s!}x^{qr+p+nqs+qs-k}$$

(2) If $|x| > 1$, then by (5) we obtained

$$\begin{aligned} f(x) &= x^p(1-x^q)^m \cdot \frac{1}{[1-x^{(n+1)q}]^m} \\ &= x^p(1-x^q)^m \cdot \frac{(-1)^m}{x^{(n+1)qm}[1-x^{-(n+1)q}]^m} \\ &= \sum_{r=0}^{m}\frac{(-1)^r(m)_r}{r!}x^{qr+p-nqm-qm} \cdot \sum_{s=0}^{\infty}\frac{(-1)^{m+s}(-m)_s}{s!}x^{-(n+1)qs} \\ &= \sum_{r=0}^{m}\sum_{s=0}^{\infty}\frac{(-1)^{m+r+s}(m)_r(-m)_s}{r!s!}x^{qr+p-nqm-nqs-qm-qs} \end{aligned} \tag{7}$$

Also, using differentiation term by term theorem, differentiating x by k times on both sides of (7), we determined $f^{(k)}(x)$

$$= \sum_{r=0}^{m} \sum_{s=0}^{\infty} \frac{(-1)^{m+r+s}(m)_r(-m)_s(qr+p-nqm-nqs-qm-qs)_k}{r!s!} x^{qr+p-nqm-nqs-qm-qs-k}$$

The similar proof of Theorem 1, we can easily determine the infinite series forms of any order derivatives of function (2).

Theorem 2 *If the assumptions are the same as Theorem 1, and let the domain of function* $g(x) = \frac{x^p}{[1-x^q+x^{2q}-\cdots+(-1)^n x^{nq}]^m}$ *be* $\{x \in R | x \neq 0, \pm 1\}$.

(1) *If* $|x| < 1$ *and* $x \neq 0$, *then the kth order derivative of* $g(x)$,

$$g^{(k)}(x) = \sum_{r=0}^{m} \sum_{s=0}^{\infty} \frac{(-1)^{ns}(m)_r(-m)_s(qr+p+nqs+qs)_k}{r!s!} x^{qr+p+nqs+qs-k} \quad (8)$$

(2) *If* $|x| > 1$, *then* $g^{(k)}(x)$

$$= \sum_{r=0}^{m} \sum_{s=0}^{\infty} \frac{(-1)^{ns+nm}(m)_r(-m)_s(qr+p-nqm-nqs-qm-qs)_k}{r!s!} x^{qr+p-nqm-nqs-qm-qs-k} \quad (9)$$

3 Examples

In the following, we provide two examples, aimed at the differential problem of two types of rational functions to demonstrate our results. We determined their any order derivatives and some of their higher-order derivative values by using Theorems 1 and 2. On the other hand, we employ Maple to calculate the approximations of these higher-order derivative values and their infinite series forms for verifying our answers.

Example 1 Suppose the domain of function

$$f(x) = \frac{x^3}{(1+x^2+x^4+x^6)^4} \quad (10)$$

is $\{x \in R | x \neq 0, \pm 1\}$. By (i) of Theorem 1, we determined the 7th order derivative value of $f(x)$ at $x = 1/2$,

$$f^{(7)}\left(\frac{1}{2}\right) = \sum_{r=0}^{4}\sum_{s=0}^{\infty}\frac{(-1)^{r+s}(4)_r(-4)_s(8s+2r+3)_7}{r!s!}\cdot\left(\frac{1}{2}\right)^{8s+2r-4} \tag{11}$$

We use Maple to verify our answer.
>f: = x → x^3/(1 + x^2 + x^4 + x^6)^4;

$$f := x \to \frac{x^3}{(1+x^2+x^4+x^6)^4}$$

>evalf((D@@7)(f)(1/2), 14);
−35551.764617819
>evalf(sum(sum((−1)^(r + s)*product(4−i, i = 0⋯(r − 1))*product(−4−j,j = 0⋯(s − 1))* product(8*s + 2*r + 3 − k, k = 0⋯6)/(r!*s!)*(1/2)^(8*s + 2*r − 4),s = 0⋯infinity), r = 0⋯4),14);
−35551.764617819

On the other hand, using (2) of Theorem 1, we obtained the 10th order derivative value of $f(x)$at $x = -2$,

$$f^{(10)}(-2) = \sum_{r=0}^{4}\sum_{s=0}^{\infty}\frac{(-1)^{r+s}(4)_r(-4)_s(2r-8s-29)_{10}}{r!s!}\cdot(-2)^{2r-8s-39} \tag{12}$$

Using Maple to verify the correctness of (12).
>evalf((D@@10)(f)(−2), 14);
−2255.1259338446
>evalf(sum(sum((−1)^(r + s)*product(4 − i,i = 0..(r − 1))*product(−4 − j,j = 0⋯(s − 1))* product(2*r − 8*s − 29 − k, k = 0..9)/(r!*s!)*(−2)^(2*r − 8*s − 39), s = 0⋯infinity), r = 0⋯4), 14);
−2255.1259338446

Example 2 Suppose the domain of function

$$g(x) = \frac{x^5}{(1-x^3+x^6-x^9+x^{12})^3} \tag{13}$$

is $\{x \in R | x \neq 0, \pm 1\}$. Using (i) of Theorem 2, we obtained the 6th order derivative value of $g(x)$ at $x = 1/3$,

$$g^{(6)}\left(\frac{1}{3}\right) = \sum_{r=0}^{3}\sum_{s=0}^{\infty}\frac{(3)_r(-3)_s(3r+15s+5)_6}{r!s!}\cdot\left(\frac{1}{3}\right)^{3r+15s-1} \tag{14}$$

We can use Maple to verify the correctness of (14).
>g: = x → x^5/(1 − x^3 + x^6 − x^9 + x^12)^3;

$$g := x \to \frac{x^5}{(1-x^3+x^6-x^9+x^{12})^3}$$

>evalf((D@@6)(g)(1/3), 14);

11133.205916540

>evalf(sum(sum(product(3 − i,i = 0···(r − 1))*product(−3 − j, j = 0···(s − 1))*product(3*r + 15*s + 5 − k, k = 0···5)/(r!*s!)*(1/3)^(3*r + 15*s − 1), s = 0···infinity), r = 0···3), 14);

11133.205916540

Next, by (ii) of Theorem 2, we obtained the 9th order derivative value of $g(x)$ at $x = 3$,

$$g^{(9)}(3) = \sum_{r=0}^{3}\sum_{s=0}^{\infty}\frac{(3)_r(-3)_s(3r-15s-40)_9}{r!s!}\cdot 3^{3r-15s-49} \tag{15}$$

Using Maple to verify the correctness of (15).

>evalf((D@ @9)(g)(3), 14);

−0.0000079153266419116

>evalf(sum(sum(product(3 − i, i = 0···(r − 1))*product(−3 − j, j = 0···(s − 1))*product(3*r − 15*s − 40 − k, k = 0···8)/(r!*s!)*3^(3*r − 15*s − 49), s = 0···infinity), r = 0···3), 14);

−0.0000079153266419116

4 Conclusions

As mentioned, the differentiation term by term theorem plays a significant role in the theoretical inferences of this study. In fact, the application of this theorem is extensive, and can be used to easily solve many difficult problems; we endeavor to conduct further studies on related applications.

On the other hand, Maple also plays a vital assistive role in problem-solving. In the future, we will extend the research topic to other calculus and engineering mathematics problems and solve these problems by using Maple. These results will be used as teaching materials for Maple on education and research to enhance the connotations of calculus and engineering mathematics.

References

Abell ML, Braselton JP (2005) Maple by example, 3rd edn. Elsevier, Amsterdam

Apostol TM (1975) Mathematical analysis, 2nd edn. Addison-Wesley Publishing Co., Inc, Reading, MA

Dodson CTJ, Gonzalez EA (1995) Experiments in mathematics using Maple, Springer, Berlin

Edwards CH Jr, Penney DE (1986) Calculus and analytic geometry, 2nd edn. Prentice-Hall, Inc, Englewood Cliffs, NJ

Flatto L (1976) Advanced calculus. The Williams & Wilkins Co, Baltimore, MD

Garvan F (2001) The Maple book, Chapman & Hall/CRC, London

Grossman SI (1992) Calculus, 5th edn. Saunders College Publishing, London

Larson R, Hostetler RP, Edwards BH (2006) Calculus with analytic geometry, 8th edn. Houghton Mifflin, Boston

Richards D (2002) Advanced mathematical methods with Maple, Cambridge University Press, Cambridge

Robertson JS (1996) Engineering mathematics with Maple, McGraw-Hill, New York

Stroeker RJ, Kaashoek JF (1999) Discovering mathematics with Maple: an interactive exploration for mathematicians, engineers and econometricians, Birkhauser Verlag, Basel

Yu CH (2013a) The differential problems of fractional type and exponential type of functions. De Lin J 26:33–42

Yu CH (2013b) The differential problem of two types of rational functions. Meiho J, 32(1) (accepted)

Yu CH (2013c) The differential problem of four types of functions, Kang-Ning J 15 (accepted)

Yu CH (2013d) A study on the differential problem of some trigonometric functions. Jen-Teh J 10 (accepted)

Yu CH (2013e) The differential problem of two types of exponential functions. Nan Jeon J 16 (accepted)

Yu CH (2012) Application of Maple on the differential problem of hyperbolic functions. International Conference on Safety & Security Management and Engineering Technology 2012, WuFeng University, Taiwan, pp 481–484

Six Sigma Approach Applied to LCD Photolithography Process Improvement

Yung-Tsan Jou and Yih-Chuan Wu

Abstract Liquid Crystal Display (LCD) makes to pursue light and thin trend, and towards high resolution development. To promote the LCD high resolution, the process requires more precise micromachining. The major key is lithography, but also generally known as the photolithography process. This research uses Six Sigma DMAIC steps (Define, Measure, Analyze, Improve, Control) to an empirical study of the pattern pitch machining process in a domestic optoelectronic manufacturer. Constructed in the photolithography process, the pattern pitch machining process capability improves and a process optimization prediction mode. Taguchi method is used to explore the parameters combination of photolithography process optimization and to understand the impact of various parameters. The findings of this research show that C_{pk} can upgrade from 0.85 to 1.56 which achieve quality improvement goals and to enhance the LCD photolithography process capability.

Keywords DMAIC · LCD · Photolithography · Six sigma · Taguchi method

1 Introduction

The liquid crystal display (LCD) has major advantages over its competitors. It is thinner, smaller and lighter than other displays and also has low power consumption, low-radiation, high-contrast and high-dpi. Hence, the LCD panel is

Y.-T. Jou (✉) · Y.-C. Wu
Department of Industrial & Systems Engineering, Chung Yuan Christian University, No.200, Chung-Pei Rd, Chung Li, Taoyuan, Taiwan
e-mail: ytjou@cycu.edu.tw

Y.-C. Wu
e-mail: jason_wu1102@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_71,

widely applied in daily electronic products, and the demand for the LCD panel increases. LCD production process consists of the following three main processes: TFT Array process, Cell assembly process, and Module assembly process, and each process consists of some sub-processes (Chen et al. 2006). The most critical modules that include mask process numbers and LCD resolution quality are photolithography technology. Significantly reduction in manufacturing costs result if there are fewer a mask process number during photolithography process. In addition, the higher resolution of the photolithography process will improve the LCD quality. This study focuses on the LCD array process which requires 4–8 mask process numbers and each mask process needs handling after photolithography process. It hopes to find a suitable model for the LCD photolithography process improvement by actual machining experiments of one domestic optoelectronic manufacturer.

In recent years, Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control) approach has been widely used in many research areas (Breyfogle et al. 2001). Through Six Sigma approach, Analysis of variance (ANOVA), and Taguchi method (TM), the study aims to construct a suitable LCD photolithography process improvement mode for the optoelectronics industry. Therefore, the study has the following objectives: (1) Six Sigma DMAIC approach is used to establish a project process, and combined with Taguchi method and ANOVA analysis to design a new process analysis and prediction mode. (2) Taguchi method is used to identify the various design parameters and key factors of the photolithography process to find out the optimal process conditions and to verify the results of the experiments.

2 Literature Review

2.1 Six Sigma

Dr. Mike J. Harry developed Six Sigma for management practices in 1980s. Six Sigma's most common and well-known methodology is its problem-solving DMAIC approach. The 5-step DMAIC method is often called the process improvement methodology. Traditionally, this approach is to be applied to a problem with an existing, steady-state process or product and service offering. DMAIC resolves issues of defects or failures, deviation from a target, excess cost or time, and deterioration (Pete and Larry 2002). DMAIC identifies key requirements, deliverables, tasks, and standard tools for a project team to utilize when tackling a problem. The DMAIC process and key steps are shown as in Fig. 1.

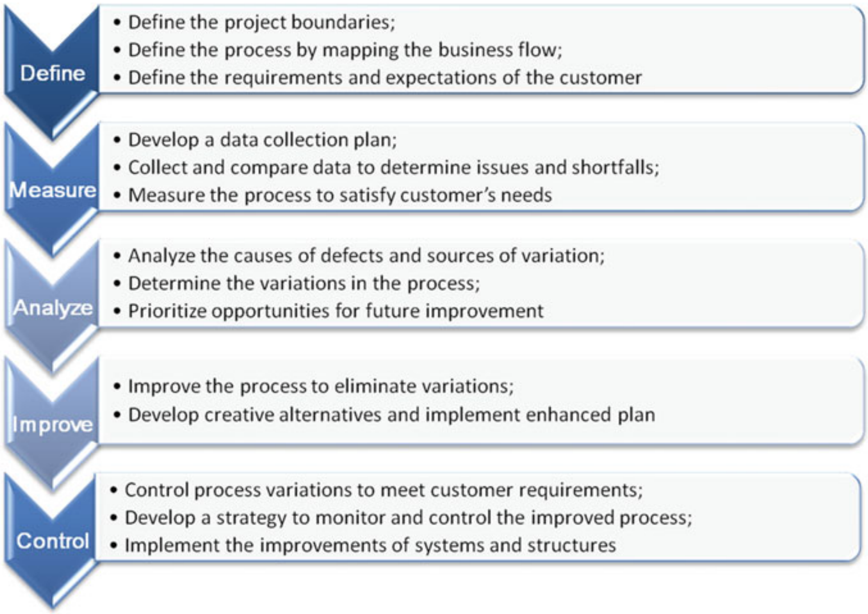


Fig. 1 DMAIC process and key steps

2.2 Taguchi Method

Taguchi technique provides a simple, efficient, and systematic approach to optimize design for performance, quality, and cost. Taguchi quality control is divided into three stages, system design, parameter design, and tolerance design (Su 2008). This methodology is valuable when design parameters are qualitative and discrete. Taguchi parameter design can optimize the performance characteristics through the setting of design parameters and reduce the sensitivity of the system performance to the source of variation (Chen and Chuang 2008).

This study focuses on the photolithography process of LCD Array and adopts nominal-the-best, NTB characteristic. The closer to the original mask design value, the better the quality characteristics after developing pattern pitch. It means that the quality characteristics measured value close to the target is better. The Signal-to-Noise ratio, S/N for each design parameter level is computed based on S/N analysis. The nominal S/N ratio corresponds to a better performance characteristic. Hence, the optimal design parameter level is the level with the nominal S/N ratio. The nominal S/N ratio can be written as given in Eq. (1). The confidence interval, *CI* then can be calculated as Eqs. (2) and (3) (Su 2008).

$$\eta = -10\log_{10}\left(\frac{u^2}{\sigma^2}\right) = -10\log_{10}(MSD) = -10\log_{10}\left[(u-m)^2 + \sigma^2\right] \qquad (1)$$

$$CI_1 = \sqrt{F_{\alpha;1,2} \times V_e \times \left[\frac{1}{n_{eff}}\right]} \quad (2)$$

$$CI_2 = \sqrt{F_{\alpha;1,2} \times V_e \times \left[\frac{1}{n_{eff}} + \frac{1}{r}\right]} \quad (3)$$

where, represents S/N ratio; *MSD* stands for Mean Square Deviation. F_α represents critical values of the F-distribution for the significance level α; V_e represents the pooled error variance.

3 Methodology

3.1 Define

A TFT-LCD array process consists of three main modules—Thin Film, Photolithography, and Etching (Chen et al. 2006). Photolithography process includes some sub-processes such as dehydration bake, HMDS, photoresist coating, soft/pre-bake, exposure, development, and post-exposure (as in Fig. 2). The high complexity and precision processing, means that every sub-process directly influences the success or failure to the entire photolithography process. LCD manufacturing is a glass substrate which must go through photolithography process 4–8 times to achieve complete circuit. Therefore photolithography process plays an important role of the entire LCD manufacturing process.

Patterns after developing the photolithography process can be classified into normal developing, incomplete developing, under-development and over-development etc. This study focuses on the pattern pitch after developing of the

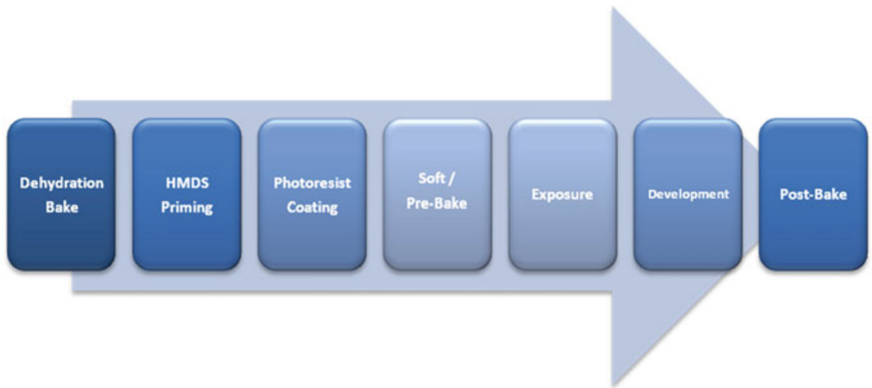


Fig. 2 Photolithography process

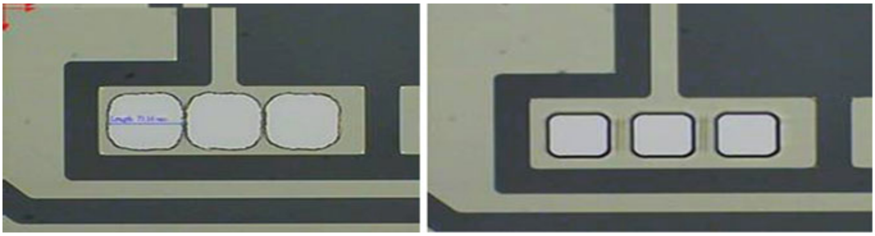


Fig. 3 Actual pattern pitch from developing

photolithography process to meet the design target value 60 ± 5 (nm). The closer to the original mask design value, the better it is. Developing from the pattern pitch the left is incomplete developing, and the right is developing normally, as shown in Fig. 3.

3.2 Measurement

Process capability indices (PCIs) are practical and powerful tools for measuring process performance. Process capability indices have been widely used in the manufacturing industry to provide numerical measures on whether a process is capable of reproducing items meeting the manufacturing quality requirement preset in the factory. Numerous capability indices have been proposed to measure process potential and performance. The two most commonly used indices C_p and C_{pk} discussed in Kane (1974), and the two more-advanced indices C_{pm} and C_{pmk} are developed by Chan et al. (1990), and Pearn et al. (1992). C_{pk} measures how close one is to one's target and how consistent one is to one's average performance (Wright 1995). The larger the index, the less likely it is that any item will be outside the specifications. Of this study before improvement the C_{pk} $0.85 < 1.33$ presents the process is substandard, unstable and insufficient process. Process improvements must be given high priority and documented in a corrective action plan. The measurement data of the pattern pitch by 30 randomly selected developing products are shown in Table 1.

Table 1 Measure data of pattern pitch (nm)

57.90	58.97	58.34	60.39	57.36	62.39
59.99	62.39	61.80	59.64	62.90	58.90
57.91	59.64	60.50	62.84	63.20	63.28
59.45	61.32	62.32	60.30	58.00	57.65
56.00	63.75	63.90	61.09	61.50	60.12

Note 1 pitch = 130 nm

Table 2 Control factors and fixed factors

Factors		Range	Conditions
Control factors	Developing time (sec)	45 ~ 80	50
	Exposure energy (mj)	200 ~ 700	300
	Photoresist thickness (Å)	25,000 ~ 29,000	26,000
	Temperature (°C)	110 ~ 125	115
Fixed factors	Ingredients	TMAH	
	Photoresist developers	2.5 %	

3.3 Analyze

Three senior engineers with an average engineering experience of more than six years in the photolithography process, participated in this project. These experts identified control factors and fixed factors. The control factor chosen for this study had 4 control factors, including developing time, exposure energy, photoresist developers, and temperature. Table 2 presents the chosen control factors and the developer ingredients are Tetra Methyl Ammonium Hydride (TMAH).

3.4 Improve

Design of experiments (DOE) is a discipline that has very broad application across all the natural and social sciences and engineering. An excellent solution to this project is an approach known as Taguchi Parameter Design. As a type of fractional factorial design, Taguchi Parameter Design is similar to traditional DOE methods in that multiple input parameters can be considered for a given response. There are, however, some key differences, for which Taguchi Parameter Design lends itself well to optimizing a production process (Muthukrishnan et al. 2012). Taguchi Parameter Design methodology includes selection of parameters, utilizing an orthogonal array (OA), conducting experimental runs, data analysis, determining the optimum combination, and verification. In this experiment, the pattern pitch 60 $\pm$ 5 (nm) after the developing be used to obtain a set of best combination of experimental parameters. The use of orthogonal array can effectively reduce the number of experiment necessary. The experiment layout using a Taguchi's L'_9OA, as shown in Table 3, was used to design the Taguchi experiment in this study.

The greater the S/N ratio, the better quality has. The largest S/N ratio can get the best parameter level combinations. The experimental data shows that the S/N ratios for optimal factors combination are $A_2B_3C_2D_2$. Figure 4 presents main effects plot for S/N ratios.

Perform ANOVA to identify significant parameters. ANOVA establishes the relative significance of parameters. Factors A, C, and D are significant in this experiment. The percentage of the experimental error of 2.42 %, less than 15 %

Table 3 Experimental layout using $L_9'(3^4)$ OA

A	B	C	D	Developing time	Exposure energy	PR thickness	Temp.	SN
1	1	1	1	60	300	25,000	115	40.869
1	2	2	2	60	400	27,000	120	75.607
2	3	3	3	60	500	29,000	125	70.692
2	1	2	3	70	300	29,000	125	80.281
2	2	3	1	70	400	25,000	115	68.871
2	3	1	2	70	500	27,000	120	71.406
3	1	3	2	80	300	27,000	120	65.550
3	2	1	3	80	400	25,000	125	41.147
3	3	2	1	80	500	29,000	115	57.332

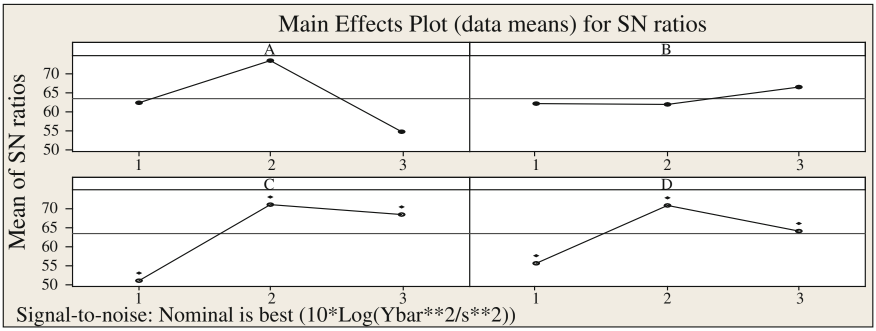


Fig. 4 Response graph for SN ratios

Table 4 Results of confirmation experiment

Factors				Pattern pitch values after developing			SN
A	B	C	D	Observed value 1	Observed value 2	Observed value 3	
2	3	2	2	60.3	60.31	60.32	75.6078
2	3	2	2	59.64	59.63	59.64	80.2815
2	3	2	2	60.31	60.29	60.32	71.9275

can be identified in this experiment did not ignore some important factors. The *F* value of experimental factors A, C, D is greater than 4, which means that the factors' effect is considerable. The calculated optimal expectation S/N ratios and CI_1 are 88.39 and 16.82. According to S/N ratios and CI_1, the range of the optimal conditions is $[88.39 \pm 16.82] = [71.57, 105.21]$. This experiment performed three trials. Table 4 presents the results of the confirmation experiment.

Further, CI_2 is 20.103, the S/N ratio confidence interval of confirmation experiment is $[88.39 \pm 20.103] = [68.287, 105.50]$. Through the confirmation experiment, S/N ratios fall within the 95 % confidence interval which indicates the success of the experimental results. Using the patterns pitch after developing and

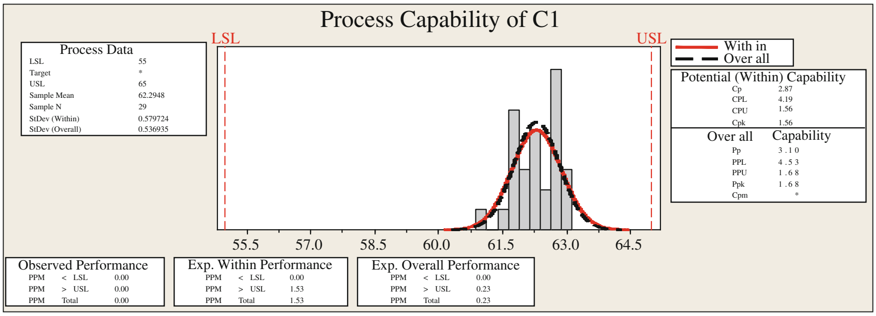


Fig. 5 Process capability after improvement

optimal factors combination of the experiment perform 30 times, process capability indices C_{pk} is improved from 0.85 to 1.56 in experimentation (as in Fig. 5). This study clearly shows that through optimal factors combination $A_2B_3C_2D_2$, including the developing time of 70 s, the exposure energy of 500 mj, the photoresist thickness of 27,000 Å, and temperature of 115 °C, machining process is greatly improved for photolithography process.

3.5 Control

After confirmation experiments and process capability analysis, this study thus can verify conclusions and has two-point suggestions for control. (1) Changing the factors combination, the control factors of the developing time from 50 to 70 s, exposure energy from 300 to 500 mj, the photoresist thickness from 26,000 to 27,000 Å, and maintaining the temperature at 115 °C. (2) Keeping observation the photolithography process records and monitoring the process capability analysis, the products quality and process stability will be improved.

4 Conclusions

This study uses Six Sigma DMAIC steps, technical data of one domestic optoelectronics manufacturer, to do investigate the potential improvement of photolithography process. Combined with Taguchi DOE and ANOVA analysis, the chosen key factors are use to identify the pattern pitch 60 ± 5 (nm) process optimization. Taguchi method was applied to this experiment to get the optimal processing factors including the developing time of 70 s, the exposure energy of 500 mj, the photoresist thickness of 27,000 Å, the temperature of 115 °C, and its process capability analysis results show that C_{pk} is upgraded from 0.85 to 1.56 in experimentation. It will obviously improve the products quality of precision and process capability. In addition to increasing the competitiveness of products, the experiment results of photolithography process can also provide technical references for the domestic optoelectronic manufacturers and related industries.

References

Breyfogle FW, Cupello JM, Meadows B (2001) Managing six-sigma. John Wiley & Sons, New York

Chan LK, Xiong Z, Zhang D (1990) On the asymptotic distributions of some process capability indices. Commun Stat-Theor Methods 19(1):11–18

Chen CC, Chuang MC (2008) Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. Int J Prod Econ 114:667–681

Chen KS, Wang CH, Chen HT (2006) A MAIC approach to TFT-LCD panel quality improvement. Microelectron Reliab 46:1189–1198

Kane VE (1974) Process capability indices. J Qual Technol 18(1):41–52

Muthukrishnan N, Mahesh Babu TS, Ramanujam R (2012) Fabrication and turning of A1/S_iC/B_4C hybrid metal matrix composites optimization using desirability analysis. J Chin Inst Ind Eng 29(8):515–525

Pearn WL, Kotz S, Johnson NL (1992) Distributional and inferential properties of process capability indices. J Qual Technol 24:216–231

Pete P, Larry H (2002) A brief introduction to Six Sigma for employees. McGraw-Hill, Taiwan

Su CT (2008) Quality engineering. Chin Soc Qual, Taiwan

Wright PA (1995) A process capacity index sensitive to skewness. Commun Stat-Simul Comput 52:195–203

A Study of the Integrals of Trigonometric Functions with Maple

Chii-Huei Yu

Abstract This paper uses Maple for the auxiliary tool to evaluate the integrals of some types of trigonometric functions. We can obtain the Fourier series expansions of these integrals by using integration term by term theorem. On the other hand, we propose some related integrals to do calculation practically. Our research way is to count the answers by hand, and then use Maple to verify our results. This research way can not only let us find the calculation errors but also help us to revise the original thinking direction because we can verify the correctness of our theory from the consistency of hand count and Maple calculations.

Keywords Integrals · Trigonometric functions · Integration term by term theorem · Fourier series expansions · Maple

1 Introduction

The computer algebra system (CAS) has been widely employed in mathematical and scientific studies. The rapid computations and the visually appealing graphical interface of the program render creative research possible. Maple possesses significance among mathematical calculation systems and can be considered a leading tool in the CAS field. The superiority of Maple lies in its simple instructions and ease of use, which enable beginners to learn the operating techniques in a short period. In addition, through the numerical and symbolic computations performed by Maple, the logic of thinking can be converted into a series of instructions. The computation results of Maple can be used to modify previous thinking directions, thereby forming direct and constructive feedback that

C.-H. Yu (✉)
Department of Management and Information, Nan Jeon Institute of Technology, No. 178, Chaoqin Road, Yanshui, Tainan 73746, Taiwan, Republic of China
e-mail: chiihuei@mail.njtc.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_72,

can aid in improving understanding of problems and cultivating research interests. Inquiring through an online support system provided by Maple or browsing the Maple website (www.maplesoft.com) can facilitate further understanding of Maple and might provide unexpected insights. For the instructions and operations of Maple, we can refer to (Abell 2005; Dodson and Gonzalez 1995; Garvan 2001; Richards 2002; Robertson 1996; Stroeker and Kaashoek 1999).

In calculus courses, we learnt many methods to solve the integral problems, including change of variables method, integration by parts method, partial fractions method, trigonometric substitution method, and so on. The introduction of these methods can refer to (Edwards and Penney 1986, Chap. 9; Grossman, 1992, Chap. 7; Larson et al. 2006, Chap. 8). This paper mainly studies the integrals of the following two types of trigonometric functions, which are not easy to obtain their answers by using the methods mentioned above.

$$f(x) = \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \tag{1}$$

$$g\,(x) = \frac{r^{m+1}\sin(m-1)\lambda x - ar^m \sin m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \tag{2}$$

where a, λ, $r$are real numbers, a, λ, $r \neq 0$, m is any integer, and $|r| \neq |a|$. The integrals of these two types of trigonometric functions are different from the integrals studied in Yu (2011, 2012a, b, c). We can obtain the Fourier series expansions of the integrals of trigonometric functions (1) and (2) by using integration term by term theorem; these are the main results of this study (i.e., Theorems 1 and 2). On the other hand, we propose two integrals to do calculation practically. The research methods adopted in this study involved finding solutions through manual calculations and verifying these solutions by using Maple. This type of research method not only allows the discovery of calculation errors, but also helps modify the original directions of thinking from manual and Maple calculations. Therefore, Maple provides insights and guidance regarding problem-solving methods.

2 Main Results

Firstly, we introduce some theorems used in this study.

Geometric series.

Suppose z is a complex number, $|z|<1$. Then $\frac{1}{1-z} = \sum_{k=0}^{\infty} z^k$.

Integration term by term theorem (Apostol 1975, p. 269).

Suppose $\{g_n\}_{n=0}^{\infty}$ is a sequence of Lebesgue integrable functions defined on inteval I. If $\sum_{n=0}^{\infty} \int_I |g_n|$ is convergent, then $\int_I \sum_{n=0}^{\infty} g_n = \sum_{n=0}^{\infty} \int_I g_n$.

Before deriving our main results, we need a lemma.

Lemma *Suppose* z *is a complex number*, m *is any integer,* a *is a real number,* $a \neq 0$ *and* $|z| \neq |a|$. Then

$$\frac{z^m}{z-a} = -\sum_{k=0}^{\infty} \frac{1}{a^{k+1}} z^{k+m} \quad \text{if } |z| < |a| \tag{3}$$

$$= \sum_{k=0}^{\infty} a^k z^{-k-1+m} \quad \text{if } |z| > |a| \tag{4}$$

Proof If $|z| < |a|$, then

$$\begin{aligned} \frac{z^m}{z-a} &= -z^m \cdot \frac{1}{a} \cdot \frac{1}{1-\frac{z}{a}} \\ &= -z^m \cdot \frac{1}{a} \cdot \sum_{k=0}^{\infty} \left(\frac{z}{a}\right)^k \ \text{(by geometric series)} \\ &= -\sum_{k=0}^{\infty} \frac{1}{a^{k+1}} z^{k+m}. \end{aligned}$$

If $|z| > |a|$, then

$$\begin{aligned} \frac{z^m}{z-a} &= z^m \cdot \frac{1}{z} \cdot \frac{1}{1-\frac{a}{z}} \\ &= z^m \cdot \frac{1}{z} \cdot \sum_{k=0}^{\infty} \left(\frac{a}{z}\right)^k \ \text{(by geometric series)} \\ &= \sum_{k=0}^{\infty} a^k z^{-k-1+m} \end{aligned}$$

□

Next, we determine the Fourier series expansion of the integral of trigonometric function (1).

Theorem 1 *Suppose* a, λ, r *are real numbers,* a, λ, $r \neq 0$, m*is any integer, and* $|r| \neq |a|$. *Let* $\delta(m) = \begin{cases} 1 & m \leq 0 \\ 0 & m > 0 \end{cases}$, $\sigma(m) = \begin{cases} 1 & m \geq 1 \\ 0 & m < 1 \end{cases}$. *Then the integral*

$$\int \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \mathrm{d}x$$

$$= -\delta(m) \cdot a^{m-1} x - \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq -m}}^{\infty} \frac{r^{k+m}}{a^{k+1}(k+m)} \sin(k+m)\lambda x + C \quad \text{if } |r| < |a| \tag{5}$$

$$= \sigma(m) \cdot a^{m-1}x + \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq m-1}}^{\infty} \frac{a^k}{r^{k+1-m}(k+1-m)} \sin(k+1-m)\lambda x + C \tag{6}$$

if $|r| > |a|$

Proof Because

$$\begin{aligned} f(x) &= \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \\ &= \mathrm{Re}\left[\frac{r^{m+1}e^{i(m-1)\lambda x} - ar^m e^{im\lambda x}}{(re^{i\lambda x} - a)(re^{-i\lambda x} - a)}\right] \\ &= \mathrm{Re}\left(\frac{z^m}{z-a}\right) \quad (\text{where } z = re^{i\lambda x}) \end{aligned} \tag{7}$$

We obtained $\int \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \mathrm{d}x$

$$= \int \mathrm{Re}\left(\frac{z^m}{z-a}\right)\mathrm{d}x$$

[by(7)]

$$= \mathrm{Re}\left(\int \frac{z^m}{z-a}\mathrm{d}x\right) \tag{8}$$

If $|r| < |a|$, then $\int \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \mathrm{d}x$

$= \mathrm{Re}\left(\int - \sum_{k=0}^{\infty} \frac{1}{a^{k+1}} z^{k+m} \mathrm{d}x\right)$ [by (3), where $z = re^{i\lambda x}$]

$= \int \left[- \sum_{k=0}^{\infty} \frac{r^{k+m}}{a^{k+1}} \cos(k+m)\lambda x\right] \mathrm{d}x$ (because $z = re^{i\lambda x}$)

$$= -\delta(m) \cdot a^{m-1}x - \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq -m}}^{\infty} \frac{r^{k+m}}{a^{k+1}(k+m)} \sin(k+m)\lambda x + C.$$

(by integration term by term theorem)

If $|r| > |a|$, then $\int \frac{r^{m+1}\cos(m-1)\lambda x - ar^m \cos m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \mathrm{d}x$

$= \mathrm{Re}\left(\int \sum_{k=0}^{\infty} a^k z^{-k-1+m} dx\right)$ [by (4)]

$= \int \left[\sum_{k=0}^{\infty} \frac{a^k}{r^{k+1-m}} \cos(k+1-m)\lambda x\right] \mathrm{d}x$ (because $z = re^{i\lambda x}$)

$$= \sigma(m) \cdot a^{m-1} x + \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq m-1}}^{\infty} \frac{a^k}{r^{k+1-m}(k+1-m)} \sin(k+1-m)\lambda x + C$$

(by integration term by term theorem) □

The same proof as Theorem 1, we can easily determine the Fourier series expansion of the integral of trigonometric function (2).

Theorem 2 *If the assumptions are the same as Theorem 1, then the integral*

$$\int \frac{r^{m+1} \sin(m-1)\lambda x - ar^m \sin m\lambda x}{r^2 - 2ar\cos\lambda x + a^2} \mathrm{d}x$$

$$= \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq -m}}^{\infty} \frac{r^{k+m}}{a^{k+1}(k+m)} \cos(k+m)\lambda x + C \quad \text{if } |r| < |a| \tag{9}$$

$$= \frac{1}{\lambda} \cdot \sum_{\substack{k=0 \\ k \neq m-1}}^{\infty} \frac{a^k}{r^{k+1-m}(k+1-m)} \cos(k+1-m)\lambda x + C \quad \text{if } |r| > |a| \tag{10}$$

3 Examples

In the following, aimed at the integrals of these two types of trigonometric functions, we provide two examples and use Theorems 1 and 2 to determine their Fourier series expansions. On the other hand, we use Maple to calculate the approximations of some definite integrals and their solutions for verifying our answers.

Example 1 In Theorem 1, we take $r = 2, a = 3, \lambda = 4, m = 5$. Then by (5), we obtained the Fourier series expansion of the integral

$$\int \frac{64\cos 16x - 96\cos 20x}{13 - 12\cos 4x} \mathrm{d}x = -\frac{1}{4} \cdot \sum_{k=0}^{\infty} \frac{2^{k+5}}{3^{k+1}(k+5)} \sin(4k+20)x + C \tag{11}$$

Therefore, we can determine the following definite integral

$$\int_{\pi/8}^{\pi/4} \frac{64\cos 16x - 96\cos 20x}{13 - 12\cos 4x} \mathrm{d}x = \frac{1}{4} \cdot \sum_{k=0}^{\infty} \frac{2^{k+5}}{3^{k+1}(k+5)} \sin\frac{(k+5)\pi}{2} \tag{12}$$

We use Maple to verify the correctness of (12) as follows:

```
>evalf(int((64*cos(16*x)−96*cos(20*x))/(13−12*cos(4*x)), x = Pi/8..Pi/4),18);
0.4070527218382429
```

>evalf(1/4*sum(2^(k + 5)/(3^(k + 1)*(k + 5))*sin((k + 5)*Pi/2), k = 0...∞), 18);

0.4070527218382429

Also, in Theorem 1, if we take $r = 5,\ a = 4,\ \lambda = 2,\ m = 3$. Then using (6), the Fourier series expansion of the integral

$$\int \frac{625\cos 4x - 500\cos 6x}{41 - 40\cos 2x}\mathrm{d}x = 16x + \frac{1}{2}\cdot\sum_{\substack{k=0\\k\neq 2}}^{\infty}\frac{4^k}{5^{k-2}(k-2)}\sin(2k-4)x + C \quad (3)$$

Thus, we can determine the definite integral

$$\int_{\pi/4}^{\pi/2} \frac{625\cos 4x - 500\cos 6x}{41 - 40\cos 2x}\mathrm{d}x = 4\pi - \frac{1}{2}\cdot\sum_{\substack{k=0\\k\neq 2}}^{\infty}\frac{4^k}{5^{k-2}(k-2)}\sin\frac{(k+2)\pi}{2} \quad (14)$$

Using Maple to verify the correctness of (14).

>evalf(int((625*cos(4*x)-500*cos(6*x))/(41−40*cos(2*x)), x = Pi/4...Pi/2),18);

−2.8315569234292484

>evalf(4*Pi−1/2*sum(4^k/(5^(k − 2)*(k − 2))*sin((k + 2)*Pi/2),k = 0...1) −1/2*sum(4^k/(5^(k − 2)*(k − 2))*sin((k + 2)*Pi/2), k = 3...∞),18);

−2.83155692342924830

Example 2 In Theorem 2, taking $r = 3, a = 5, \lambda = 2, m = -4$. Then by (9), we obtained the Fourier series expansion of the integral

$$\int \frac{-\frac{1}{27}\sin 10x + \frac{5}{81}\sin 8x}{34 - 30\cos 2x}\mathrm{d}x = \frac{1}{2}\cdot\sum_{\substack{k=0\\k\neq 4}}^{\infty}\frac{3^{k-4}}{5^{k+1}(k-4)}\cos(2k-8)x + C \quad (15)$$

Hence, we determined the following definite integral

$$\int_{\pi/4}^{\pi} \frac{-\frac{1}{27}\sin 10x + \frac{5}{81}\sin 8x}{34 - 30\cos 2x}\mathrm{d}x = \frac{1}{2}\cdot\sum_{\substack{k=0\\k\neq 4}}^{\infty}\frac{3^{k-4}}{5^{k+1}(k-4)}\left(1 - \cos\frac{k\pi}{2}\right) \quad (16)$$

Also, we employ Maple to verify the correctness of (16).

>evalf(int((−1/27*sin(10*x) + 5/81*sin(8*x))/(34 − 30*cos(2*x)),x = Pi/4…Pi),18);

$$-0.000786819398278323030$$

>evalf(1/2*sum(3^(k-4)/(5^(k + 1)*(k-4))*(1-cos(k*Pi/2)),k = 0..3) + 1/2*sum(3^(k-4)/(5^(k + 1)*(k-4))*(1-cos(k*Pi/2)),k = 5..infinity),18);

$$-0.000786819398278323030$$

On the other hand, in Theorem 2, if we take $r = 2, a = 1, \lambda = 3, m = 6$. By (10), the Fourier series expansion of the following integral

$$\int \frac{128\sin 15x - 64\sin 18x}{5 - 4\cos 3x} \mathrm{d}x = \frac{1}{3} \cdot \sum_{\substack{k=0 \\ k\neq 5}}^{\infty} \frac{1}{2^{k-5}(k-5)} \cos(3k-15)x + C \tag{17}$$

Therefore, we can determine the following definite integral

$$\int_{\pi/3}^{2\pi/3} \frac{128\sin 15x - 64\sin 18x}{5 - 4\cos 3x} \mathrm{d}x = \frac{1}{3} \cdot \sum_{\substack{k=0 \\ k\neq 5}}^{\infty} \frac{1}{2^{k-5}(k-5)} [1 - \cos(k+1)\pi] \tag{18}$$

We employ Maple to verify the correctness of (16) as follows.

>evalf(int((128*sin(15*x)−64*sin(18*x))/(5 − 4*cos(3*x)), x = Pi/3…2*Pi/3),18);

$$-7.01157368155507455$$

>evalf(1/3*sum(1/(2^(k − 5)*(k − 5))*(1 − cos((k + 1)*Pi)),k = 0…4) + 1/3*sum(1/(2^(k − 5)*(k − 5))*(1 − cos((k + 1)*Pi)),k = 6…∞),18);

$$-7.01157368155507455$$

4 Conclusions

As mentioned, the integration term by term theorem plays a significant role in the theoretical inferences of this study. In fact, the application of this theorem is extensive, and can be used to easily solve many difficult problems; we endeavor to conduct further studies on related applications.

On the other hand, Maple also plays a vital assistive role in problem-solving. In the future, we will extend the research topic to other calculus and engineering mathematics problems and solve these problems by using Maple. These results will be used as teaching materials for Maple on education and research to enhance the connotations of calculus and engineering mathematics.

References

Abell ML, Braselton JP (2005) Maple by example, 3rd ed. Elsevier Academic Press

Apostol TM (1975) Mathematical analysis, 2nd ed. Addison-Wesley Publishing Co., Inc. Available at http://en.wikipedia.org/wiki/Inverse_trigonometric_functions

Dodson CTJ, Gonzalez EA (1995) Experiments in mathematics using Maple. Springer

Edwards CH Jr, Penney DE (1986) Calculus and analytic geometry, 2nd ed. Prentice-Hall, Inc., New Jersey

Garvan F (2001) The Maple book. Chapman & Hall/CRC

Grossman SI (1992) Calculus, 5th ed. Saunders College Publishing

Larson R, Hostetler RP, Edwards BH (2006) Calculus with analytic geometry, 8th ed. Houghton Mifflin

Richards D (2002) Advanced mathematical methods with Maple. Cambridge University Press

Robertson JS (1996) Engineering mathematics with Maple. McGraw-Hill

Stroeker RJ, Kaashoek JF (1999) Discovering mathematics with Maple: an interactive exploration for mathematicians, engineers and econometricians. Birkhauser Verlag

Yu CH (2011) Application of Fourier series on some integral problems. In: 100-Year general education symposium, National Pingtung University of Science and Technology, Taiwan, pp 307–320

Yu CH (2012a) Application of Maple: taking the integral problems as examples. 2012 digital technology and innovation management seminar, Huafan University, Taiwan, p A74

Yu CH (2012b) Application of Maple on some integral problems. In: 2012 international conference on safety and security management and engineering technology, WuFeng University, Taiwan, pp 290–294

Yu CH (2012c) Application of Maple: taking two special integral problems as examples. In: The 8th international conference on knowledge community, Chinese Culture University, Taiwan, pp 803–811

A Study of Optimization on Mainland Tourist Souvenir Shops Service Reliability

Kang-Hung Yang, Li-Peng Fang and Z-John Liu

Abstract Recently, Taiwan government launched tourism for mainland tourists, who have become the largest inbound tourists. Business opportunities burst, especially a souvenir shop. With rapid growths of souvenir shops, they compete with each other intensely. In order to survive in the competition market, a shop has to promote its service system. The best practice is to assess and optimize the current status of service quality to maintain a high reliability on its service systems. Reliability is a key indicator for the service quality, which is often applied to manufacturing and service. Failure Mode and Effects Analysis (FMEA) is an important tool for analyzing the reliability to forecast a system failure risk. This study applies FMEA to establish a failure risk evaluation model for a mainland tourist souvenir shop. Store H is validated by this approach, which can prioritize the potential failure items of Store H to improve the service quality and suggest persuasive corrective actions. The proposed model essentially ameliorates service level, effectively reduces the mainland tourist souvenir shops failure risks, and enhance the reliability of service. This approach is not only for the mainland tourist souvenir shops, but also be widely used in the general souvenir shops.

Keywords Mainland tourists · Souvenir shops · Service reliability · FMEA

K.-H. Yang (✉) · L.-P. Fang
Department of Industrial and Systems Engineering, Chung Yang Christian University, Taiwan, China
e-mail: kanghungyang@cycu.edu.tw

L.-P. Fang
e-mail: g9902406@cycu.edu.tw

Z.-J. Liu
Department of International Business, Ling Tung University, Taiwan, China
e-mail: b91069025@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_73,

1 Introduction

Since 2008 Taiwan launched tourism for mainland tourists, mainland tourists has become the largest inbound tourists in Taiwan, the growth trend of tourists to Taiwan by country in the past years can be illustrated as Fig. 1 (Taiwan Tourism Bureau 2012), which generated opportunities for businesses, especially like a souvenir shop. While the domestic souvenir shops for mainland tourists increase year by year, those shops compete with each other a lot and operate in difficult with little marginal profits. The quality of service is not only the most important competitive weapon for a shop (Stafford 1996), but also a key feature to reveal differentiation of the horizontal competition (Morrall 1994). Customers will not only lose their loyalty and lead to their leaving, but affect the overall image of the shops if they are not satisfied with the shops' service. Therefore, how to evaluate high reliability, optimize the quality of service for maintaining the service system is the primary key for the mainland tourists souvenir shops to win in a competitive operation.

Reliability is an important indicator of the measurement in quality, which is often applied in the manufacturing industry and service sectors. To establish or maintain a high reliability depends on the application of analysis tools which include Failure Mode and Effects Analysis (FMEA). In addition, the tool can prevent from the risk of system failure. For the mainland tourist souvenir shops' service system in the process, each service will likely cause failures and lead to customer complaints. The service projects' failure situation, their effect and cause are all essential and as observed improvement factors to pursue a high quality of service. If the service failure occurs during the process of service, the causes of failure must be analyzed and be improved to reduce the risk of failure. With view of above reasons, this study investigates the improvement of the reliability in mainland tourist souvenir shops service system and attempts to apply them in FMEA. In addition, this study also analyzes the impact of the mainland tourist souvenir shops' service system failure. The projects for the system are given a weighting score for severity of failure, occurrence of degree and difficulties checking level. Finally, this study constructs FMEA assessment model for flow of

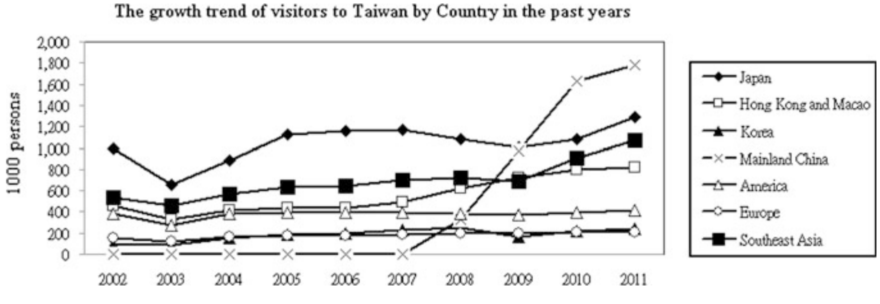


Fig. 1 The growth trend of tourists to Taiwan by country in the past years

the shops' service system and propose improvements to reduce the risk of failure of the service system and further optimize the reliability of the shops' service system.

2 Literature Review

2.1 Quality of Service

Service quality is the main form of customer satisfaction (Bitner 1990). Positive quality of service will improve service value and customer satisfaction (Rust and Oliver 1994). Customers would be willing to continue its transaction if the enterprise is providing good service (Keaveney 1995). Store atmosphere, the behavior of service staff, and merchandise display skills, it will affect the purchasing intention of tourists (Swanson and Horridge 2006). Chih et al. (2009) investigation gas station customer consumption behavior found that customer satisfaction can build up customer loyalty and customer satisfaction has a direct effect on customer loyalty.

2.2 Reliability

Weng (2011) pointed out that the "quality" and "reliability" is often confused, but in fact they are not the same. "Quality" means the production process, through the measure of actual quality performance with established quality standards for comparison, and to take the necessary production quality management decisions for which the quality difference. "Reliability" is on time considerations, in the setting of the use of environmental conditions or time conditions, and product or service can reach the required functional standard. In short, reliability is a product or service, whether in life or cycle process is normal, will be influenced by the reliability of the level of satisfaction on the quality of goods or services. It is increasing that uses reliability analysis to improve the quality of cases in service industry, failure mode and effects analysis (FMEA), and Fault Tree Analysis method is more used frequently.

2.3 Failure Mode and Effects Analysis

FMEA is a systematic method of reliability analysis, it is pointed out that the design and manufacturing of potential failure modes. It cans analysis the impact of failure for the system not only to give their assessment but take the necessary measures for system reliability problems (Hsu 2001). FMEA emphasis on prevention rather than corrective action after, can be applied in the system and at any stage of the product life cycle, such as the research and development stage of the system design, improve product reliability, maintainability and safety, as well as in the manufacturing of quality improvement (Hu 2008).

FMEA technology originated in the 1950s, the Grumman Aircraft Corporation, is mainly applied to the aircraft's main control system failure analysis. The United States Space Agency (NASA) used in the space program successfully in the 1960s. In 1970s, U.S. military also began to apply the FMEA technology, the FMEA operating procedures of the military standard MIL-STD-1692 and published in 1974. In 1980s, this standard was revised to MIL-STD-1692A, become important FMEA reference index (Hsu 2001). FMEA technology has already been widely used in the development of high-tech industries and traditional manufacturing or manufacturing stage. To the automotive industry, in 1993, General Motors, Ford and Chrysler, under the auspices of the U.S. quality control automobile branch of the Association and the Automotive Industry Action Group (AIAG), compile an effective operation manual "Potential Failure Mode and Effects Analysis Reference Manual", and can master the reliability. This technology with the QS 9000 quality system requirements as product development and process design tools in major automobile manufacturing center and its satellite factories (Chang et al. 2004).

FMEA is a tool for the analysis of safety and reliability, but also a proactive management technology. Because of its systemic thinking, simple and easy to use, it extended to the service system design and failure prevention services, even among the international standard ISO14001, OHSAS18001, TS16949 or technical specification in recent years (Hu 2008).

3 Research Methods

Study design is the primary work in research, the design process including decisions on the following: which variables to study, how to measure these variables, the method used to study, which is the object of the study, how to collect and analyze data, through the analysis of information, identify the best solution of the research problem (Jung 2008).

How to optimize the reliability of mainland tourist souvenir shops service is the main purpose of this study. Weng and Lin (2011) proposed FMEA execution steps are used for reference to construct FMEA assessment model in study. The following steps:

1. Understand the flow of mainland tourist souvenir shops service system.
2. Investigate all possible failure of the project on the system's degree of influence over the mainland tourist souvenir shops service system. Grading estimates and giving weights to the seriousness effects (severity, S), the likelihood that failure

associated with those effects will occur (occurrence, O), and an ability to detect the failure (detection, D). The assessment criteria are as follows:

(a) Severity (S): severity by failure to set the 10 level, the highest score of 10 points (very serious); level descending lowest score 1 point (non-hazardous).
(b) Occurrence (O): 10 level according to the frequency of failure occurs, a maximum score of 10 points (very high frequency); level descending, the lowest score 1 point (low frequency extremely).
(c) Detection (D): According the failure occurs be perceived of difficulty level set 10 rating, the highest score of 10 points (almost cannot be detected); level descending, the lowest scores 1 point (easily detected).

3. Using the assessment of risk priority number (RPN), RPN is a mathematical product of severity, occurrence, and detection, which can be expressed as follows:

$$RPN = S \times O \times D \tag{1}$$

The highest failure factor of RPN is the highest risk of failure cause to the system, it must be improvement priority.

4. Proposed recommendations to optimize the mainland tourist souvenir shops' service system reliability according to the findings.

4 Empirical Analysis

4.1 The Collection of Factors in Failure Service

The empirical Store H is one of the first five big mainland tourist souvenir shops. This study selects Store H for mainland tourists that have purchased. The research methods were conducted by simple random sampling and random interview on service failure to understand the reasons in September 2012. The reasons of service failure are summarized into two systems at Store H. The 10 failures of the projects are as follows:

1. Purchase system

A1 It's prone to chaotic situations under un-planning route for customer
A2 The stores few service personnel can not be in response to the majority of customers at the same time questions
A3 The service personnel are not cordial expression on face
A4 Customers have doubts about that try to eat merchandise stores provide few

A5 When the shelves selling merchandise sold out, failed to make up to provide customers with purchase quickly.

2. Checkout system

B1 Checkout must wait in line (takes more than 5 min)
B2 The cashier operates slowly to delay customer time
B3 The cashier is not cordial expression on face
B4 The cashier chats with other colleagues to poor customer perception
B5 Checkout barcode does not scan interpretation and must type the artificial verbatim.

4.2 The Statistics of Risk in Failure Service

The 10 failures of the projects are arranged as question items. The ‘simple random sampling’ is applied for collecting data on Store H over the mainland tourists that have purchased by depth interview in November 2012. Before the interview, the 10 failure items and the scoring criteria on the severity and occurrence are explained to customers. The mainland tourist rating information is collected by question-and-answer format immediately. The interview samples are 250 in total. The incomplete answers are excluded as invalid samples. Eventually, 213 samples are valid. In addition, the depth interview is also conducted on the manager and 12 employees at Store H to collect the data of score in 10 failure difficult detection score. Finally, the average value of severity, occurrence and detection are obtained, and the RPN of 10 failure items are also calculated. The statistics by RPN from large to small rearrange as shown in Table 1. The failure project No. 6 [Checkout must wait in line (takes more than 5 min)] RPN = 81.84 is the highest, it must be of the highest priority improvement project. Failure project No. 5 (When the shelves selling merchandise sold out, failed to make up to provide customers with purchase quickly) RPN = 71.38 is the second highest, it must be classified as the second priority improvement project, the order of other failure projects for improvement shown in Table 1.

FMEA assessment results via constructed in this study can be screened to the failure of the project must be the first priority to improve for No. 6 [Checkout must wait in line (takes more than 5 min)]. The improvement practices can be adopted to increase the number of POS and train the cashiers more skillful on operation to reduce customers waiting time, and avoid mainland tourists are unsatisfied due to long waiting periods. Improvement method proposed for other failure projects shown in Table 2.

Table 1 The order of priority to improve in failure projects

Priority	No	Failure project	RPN
1	6	Checkout must wait in line (takes more than 5 min)	81.84
2	5	When the shelves selling merchandise sold out, failed to make up to provide customers with purchase quickly	71.38
3	7	The cashier operates slowly to delay customer time	64.80
4	2	The stores few service personnel can not be in response to the majority of customers at the same time questions	60.59
5	3	The service personnel are not cordial expression on face	59.94
6	8	The cashier is not cordial expression on face	54.67
7	1	It's prone to chaotic situations under un-planning route for customer	54.12
8	9	The cashier chats with other colleagues to poor customer perception	51.83
9	10	Checkout barcode does not scan interpretation and must type the artificial verbatim	43.55
10	4	Customers have doubts about that try to eat merchandise stores provide few	28.70

Table 2 The improvement suggestions for failure projects

Priority	No	RPN	Improvement method
1	6	81.84	To increase the number of POS and train the cashiers more skillful on operation
2	5	71.38	To take the hot-selling goods enough, and designate staffs to fill up
3	7	64.80	To train the cashiers more skillful on operation
4	2	60.59	Can provide enough service staffs to respond the questions of customers at any time
5	3	59.94	To train the service staffs more courtesy and polite
6	8	54.67	To train the cashiers more courtesy and polite
7	1	54.12	To re-plan the purchasing route for customer and designate service staffs to guide
8	9	51.83	To set penalties and fines for the cashiers chat with colleagues during the operation
9	10	43.55	To repair scanning bar code machines and control barcode manufactured process
10	4	28.70	Increase the types of goods to try eating

5 Conclusions

The empirical result of assessment model shows that the service system failure of Store H must be prioritized to improve in project No. 6 [Checkout must wait in line (takes more than 5 min)]. This failure of the project is alike with the most of people in the process of buying behavior "impatient" and produces the same effect as unsatisfactory. It is often one of the main reasons to refuse to purchase again. This shows that the proposed model essentially ameliorate service level and effectively reduce the mainland tourist souvenir shops failure risks and enhance the reliability of service.

The FMEA has systemic thinking and with advantage of easily use. This evaluation model not only can provide reference for the mainland tourist souvenir shops, but also be widely used in the general souvenir shops.

References

Bitner MJ (1990) Evaluating service encounters: the effects of physical surroundings and employee responses. J Mark 54(2):69–82

Chang TM, Wu YW, Ho TP, Chiang JK (2004) The Application of "PFMEA" in manufacturing of automobile part. Hsiuping J 9:137–156

Chih WH, Chen JL, Pan MH (2009) Brand equity, service quality, perceived value, customer satisfaction and customer loyalty-an empirical study of Chinese petroleum corporation, Taiwan service stations. J Qual 16(4):291–309

Hsu SP (2001) A QFD and FMEA integrated model. Master dissertation, Department of Industrial Engineering and Management, Yuan Ze University, Taiwan

Hu KY (2008) Application of FMEA to reduce service failure. Tajen J 33:35–50

Jung TS (2008) Business research methods, 3rd edn. Wu Nan, Taipei

Keaveney SM (1995) Customer switching behavior in service industries: an exploratory study. J Mark 59(2):71–82

Morrall K (1994) Service quality: the ultimate differentiator. Bank Mark 26(10):33–38

Rust RT, Oliver RL (1994) Service quality: insights and managerial implications from the frontier, in theory and practice. In: Rust RT, Oliver RL (eds) Service quality: new directions. Thousand Oaks, Sage, pp 1–19

Sightseeing statistics chart (Taiwan Tourism Bureau) (2012) http://admin.taiwan.net.tw/public/public.aspx?no=315. Accessed 13 Aug 2012

Stafford MR (1996) Demographic discriminators of service quality in the banking industry. J Serv Mark 10(4):6–22

Swanson KK, Horridge PE (2006) Travel motivations as souvenir purchase indicators. Tourism Manag 27(4):671–683

Weng SJ (2011) Short introduction of reliability engineering. Qual Mag 47(1):44–47

Weng SJ, Lin KP (2011) Reliability engineering-introduction of FMEA. Qual Mag 47(2):32–34

The Effects of Background Music Style on Study Performance

An-Che Chen and Chen-Shun Wen

Abstract Due to the increasing popularity of personal digital devices, many students listen to music while they study. It is however a controversial issue whether music listening is helpful to study performance. This study investigates the effects of different types of background music on study performance among college students through lab experiments. Two major categories of study activities (i.e., reading comprehension and mathematical computation) are examined for four different treatments of background music style (i.e., soft music, rock music, heavy metal music, and no music). For each student subject, objective measures, such as test scores and heart rates, were recorded for all conditions of the experiment design. Subjective measures concerning treatment evaluations along with personal preference and behaviors on music listening were instrumented in the individual interviews after the experiments. Data analysis on the objective measures indicates that neither test scores nor heart rates of reading comprehension and mathematic computation for different styles of background music are with statistical significance. By further cross-referencing with the subjective measures, our results suggest that, for a better studying performance, college students may choose to listen to background music with preferred music for reading activities but non-preferred music for mathematic computation.

Keywords Background music · Study performance

A.-C. Chen (✉)
Ming Chi University of Technology, New Taipei City, Taiwan, Republic of China
e-mail: anche@mail.mcut.edu.tw

C.-S. Wen
Nanya Technology, New Taipei City, Taiwan, Republic of China
e-mail: s114202001@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_74,

1 Introduction and Background

Due to the increasing popularity of personal digital devices, many students listen to music while they study. It is however a controversial issue whether music listening is helpful to cognitive memory or study performance (Bellezza 1996; Pietschnig et al. 2010). Deems (2001) both found that students who normally listened to music while studying scored higher on reading comprehension tests compared to those who usually studied without any background music. Nittono et al. (2000) tested on 24 undergraduates performing a self-paced line tracing task with different tempos of background music and found that fast music accelerated performance compared with slow music. The study of Haynes indicated that studying to background music did reduce the math anxiety of college students.

On the other hand, Kiger (1989) reported that, for high school students, reading comprehension was best when material is learned in silence and worst in presence of high information-load music. Tucker and Bushman (1991) found that rock and roll background music decreased performance of undergraduate students on math and verbal tests, but not their scores on reading comprehension. Manthei and Kelly (1999) reported that the music had no statistically significant effect on the math test scores. Burns et al. (2002) suggested that different types of music have different effects on stress. While the analysis does not indicate that listening to classical or relaxing music decreases anxiety, it does suggest that hard rock music may compromise one's ability to relax. However, the test scores were not affected by the background music for students with different levels of anxiety. These studies suggest that background music act as a distracter to students trying to focus on studying.

Upon past research the influences of background music to learning performance may still be unclear and seems to have certain connections with personal preference. This present study therefore seeks to re-investigate the effects of different types of background music on study performance in terms of reading comprehension and math calculation through lab experiments and further linked with personal preference in music.

2 Method

This study investigates the effects of different types of background music on study performance through lab experiments. College students with non-music major are our target experiment subjects. Prior to the experiment, each student subject was requested to finish a questionnaire regarding demographic information (e.g., age, gender, and major), frequency of music listening while studying, and the preferred background music type.

In the experiment, two major categories of study activities (i.e., reading comprehension and mathematical computation) are examined for four different treatments of background music style (i.e., soft music, rock music, heavy metal music, and no music). In the reading comprehension sessions, subjects are asked to read several short essays (in Chinese) and answer the quiz questions following each essay. Mathematical questions on algebra and equation solving in fundamental high-school levels are instrumented for the math computation sessions. For each of the three background music types, two songs sampled from the pop music market in Taiwan are alternatively played to cover the entire experiment session. A within-subject completed randomized experiment design is therefore instrumented. That is, each student subject was tested on a set of all eight conditions (i.e., the combination of the two study categories with the four background music types) in random orders. Each experiment condition lasted for 30 min to ensure the sensitivity and validity of performance measures. These performance or objective measures, such as test scores (the percentages of the correct answers) and heart rate variation, were recorded for all conditions of the experiment design.

Subjective measures concerning treatment evaluations and cognitive influences were instrumented in the individual interviews after the experiments. The primary interests of these semi-structured post-experiment debriefings include possible distractions by lyrics or singer's image, positive or negative influences on attentions with different music types, and the major cognitive passageways behind those influences.

3 Results and Discussion

Twenty university students with non-music majors in Taiwan voluntarily participated in this study. Sixty percent were male (n = 12) and 40 % female (n = 8). The ANOVA results of gender and music type to test scores for reading comprehension and math computation show no significant effects except the gender effect to reading comprehension ($p = 0.008$). Figure 1 depicts the detailed data of gender differences in test performance under various types of background music. It is obvious that the test performance of female subjects is usually higher than that of male subjects for reading comprehension. This plot also suggests that, for reading comprehension in particular, the performance of females be less sensitive to music types while males perform better in listening to rock music or without any background music.

By further comparing the effects of music type across two study categories, as shown in Fig. 2, it is obvious that very limited variation in test performance was found across different types of background music for the reading comprehension sessions but the effect of music type to math computation showed a different pattern. For the math computation sessions in particular, the performance without background music was relatively poor while the performance of providing soft music was the best.

As to the measures of heart rate variation, which were the differences (in BPM) between the average HR of the last 5 min in each experiment session to that of the

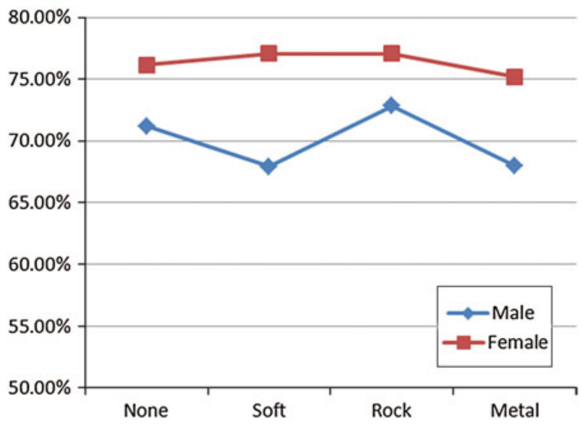


Fig. 1 Test performance of reading comprehension under different background music types

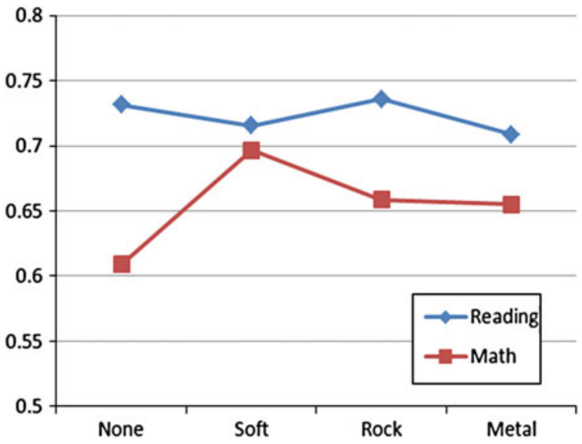


Fig. 2 Test performance under different types of background music

first five minutes, the ANOVA results show no statistical significance except the gender effect. By further examining the interaction plot shown in Fig. 3, it is obvious that male subjects generally demonstrated greater HR elevation than the females did. These data also suggest, mostly, the insignificant effects to heart rate variations across different background music types. But for male subjects in the math computation sessions, however, soft music showed a prominent HR elevation effect in contrast to other types of background music.

Therefore, in general, our analysis suggests that music type show any statistically significant effect on neither test performance nor heart rate elevation. This result rather concurs with both the findings reported in Manthei and Kelly (1999) and Haynes (2003). The analysis regarding the discrepancy between reading comprehension and math computation in our study, which is depicted in Fig. 2, shows similar patterns reported in Tucker and Bushman (1991). Our analysis on the post-experiment debriefings indicates that the lyrics in all music types and the

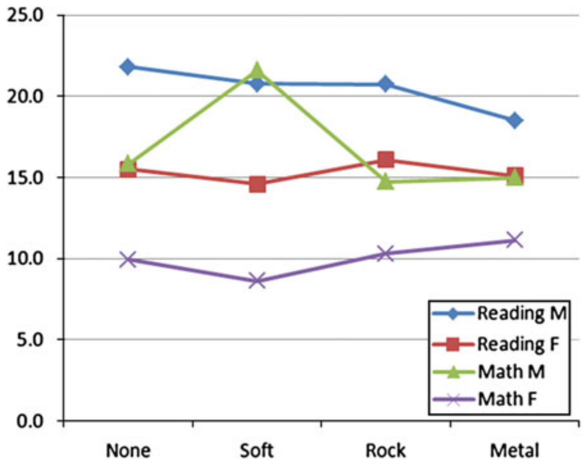


Fig. 3 The interaction plot for gender and music type to heart rate variation

noisy strong beats in rock and roll and heavy metal music acted as distractors to focused attentions in study activities. This result seems to well reflect the findings in Kiger (1989) and Burns et al. (2002) as well.

In order to investigate the individual preference effects demonstrated in Etaugh and Michals (1975) and Deems (2001), we cross-referenced the personal preference data from the pre-test questionnaires with the actual performance data collected in the experiments. Figure 4 shows the actual performance rankings of the preferred music type indicated by the individual subjects before the experiments. It is apparent that the results of two study categories did not share similar patterns. For reading comprehension, more than half (55 %) of subjects performed better (i.e., ranked best or second) when the type of background music provided was their personal preference. For math computation, in a reverse fashion, more than two-third of the test performance of the preferred music provided actually came in worse (i.e., third or worst ranking), compared to their non-preferred music. In the

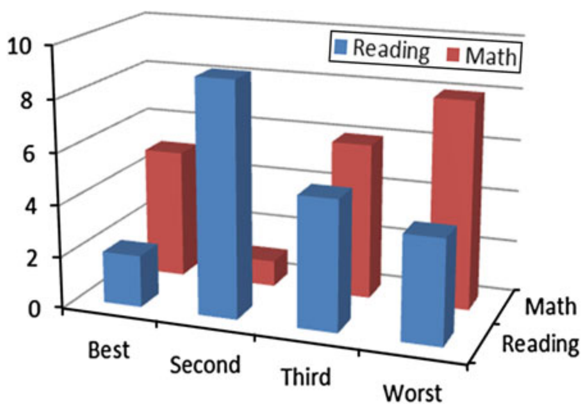


Fig. 4 Test performance rankings for individual preferred music types

post-experiment debriefings, several subjects reported that non-preferred music were in fact less distracting and therefore made the focused attention easier for study activities.

4 Conclusions

Data analysis on the objective measures indicates that neither test scores nor heart rates of reading comprehension and mathematic computation for different styles of background music are with statistical significance. Gender differences were found and the females seem to be less sensitive to the changes of background music types. By further cross-referencing with the subjective measures, our results suggest that, for a better studying performance, college students may choose to listen to background music with preferred music for reading activities but non-preferred music for mathematic computation.

References

Bellezza F (1996) Mnemonic methods to enhance storage and retrieval. In: Bjork E, Bjork R (eds) Memory. Academic Press, New York, pp 345–380

Burns JL, Labbé E, Arke B, Capeless K, Cooksey B, Steadman A, Gonzales C (2002) The effects of different types of music on perceived and physiological measures of stress. J Music Ther XXXIX(2):101–116

Deems DA (2001) The effects of sound on reading comprehension and short-term memory. Department of Psychology, MWSC

Kiger DM (1989) Effects of music information load on a reading comprehension task. Percept Mot Skills 69:531–534

Manthei M, Kelly SN (1999) Effects of popular and classical background music on undergraduate math test scores. Res Perspect Music Educ 1:38–42

Nittono H, Tsuda A, Nakajima Y (2000) Tempo of background sound and performance speed. Percept Mot Skills 90(3/2):1122

Pietschnig J, Voracek M, Formann AK (2010) Mozart effect- a meta-analysis. Intelligence 38(3):314–323

Tucker A, Bushman BJ (1991) Effects of rock and roll music on mathematical, verbal, and reading comprehension performance. Percept Mot Skills 72:942

Using Maple to Study the Multiple Improper Integral Problem

Chii-Huei Yu

Abstract Multiple improper integral problem is closely related with probability theory and quantum field theory. Therefore, the evaluation and numerical calculation of multiple improper integrals is an important issue. This paper takes the mathematical software Maple as the auxiliary tool to study some types of multiple improper integrals. We can obtain the infinite series forms of these types of multiple improper integrals by using integration term by term theorem. On the other hand, we propose some examples to do calculation practically. Our research way is to count the answers by hand, and then use Maple to verify our results. This research way can not only let us find the calculation errors but also help us to revise the original thinking direction because we can verify the correctness of our theory from the consistency of hand count and Maple calculations. Therefore, Maple can bring us inspiration and guide us to find the problem-solving method, this is not an exaggeration.

Keywords Multiple improper integrals · Integration term by term theorem · Infinite series forms · Maple

1 Introduction

As information technology advances, whether computers can become comparable with human brains to perform abstract tasks, such as abstract art similar to the paintings of Picasso and musical compositions similar to those of Mozart, is a natural question. Currently, this appears unattainable. In addition, whether computers can solve abstract and difficult mathematical problems and develop abstract

C.-H. Yu (✉)
Department of Management and Information, Nan Jeon Institute of Technology, No. 178, Chaoqin Road, Yanshui District, Tainan City 73746, Taiwan, Republic of China
e-mail: chiihuei@mail.njtc.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_75,

mathematical theories such as those of mathematicians also appears unfeasible. Nevertheless, in seeking for alternatives, we can study what assistance mathematical software can provide. This study introduces how to conduct mathematical research using the mathematical software Maple. The main reasons of using Maple in this study are its simple instructions and ease of use, which enable beginners to learn the operating techniques in a short period. By employing the powerful computing capabilities of Maple, difficult problems can be easily solved. Even when Maple cannot determine the solution, problem-solving hints can be identified and inferred from the approximate values calculated and solutions to similar problems, as determined by Maple. For this reason, Maple can provide insights into scientific research. Inquiring through an online support system provided by Maple or browsing the Maple website (www.maplesoft.com) can facilitate further understanding of Maple and might provide unexpected insights. For the instructions and operations of Maple, we can refer to (Abell 2005; Dodson and Gonzalez 1995; Garvan 2001; Richards 2002; Robertson 1996; Stroeker and Kaashoek 1999).

In this paper, we mainly study the multiple improper integral problem. This problem is closely related with probability theory and quantum field theory, and can refer to (Ryder 1996; Streit 1970). Therefore, the evaluation and numerical calculation of multiple improper integrals is an important issue, and can be studied based on (Edwards and Penney 1986, Chap. 16; Grossman 1992, Chap. 14; Larson et al. 2006, Chap. 14; Widder 1961, 6; Yu 2012a, b, c, 2013). In this paper, we determined the following two types of multiple improper integrals

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} (\ln x_m)^{p_m} \cdot \prod_{m=1}^{n} x_m^{a_m} \cdot \sin^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n \tag{1}$$

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} (\ln x_m)^{p_m} \cdot \prod_{m=1}^{n} x_m^{a_m} \cdot \cos^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n \tag{2}$$

where n is any positive integer, and $a_m, b_m > 0$, p_m are positive integers for all $m = 1, \ldots, n$. We can find the infinite series forms of these two types of multiple improper integrals; these are the main results of this study (i.e., Theorems 1 and 2). At the same time, we obtained two corollaries from these two theorems. Additionally, in several examples in which Theorems 1 and 2 were practically employed to determine the infinite series forms of these multiple improper integrals. The research methods adopted in this study involved finding solutions through manual calculations and verifying these solutions by using Maple. This type of research method not only allows the discovery of calculation errors, but also helps modify the original directions of thinking from manual and Maple calculations. Therefore, Maple provides insights and guidance regarding problem-solving methods.

2 Main Results

Firstly, we introduce some formulas and theorems used in this study.

Formulas:

(Available at http://en.wikipedia.org/wiki/Inverse_trigonometric_functions)

1. $\sin^{-1} y = \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} y^{2k+1}$, where $y \in R, |y| \leq 1$.
2. $\cos^{-1} y = \frac{\pi}{2} - \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} y^{2k+1}$, where $y \in R, |y| \leq 1$.

Differentiation term by term theorem (Apostol 1975, p 230). If, for all non-negative integer k, the functions $g_k : (a,b) \to R$ satisfy the following three conditions: (1) there exists a point $x_0 \in (a,b)$ such that $\sum_{k=0}^{\infty} g_k(x_0)$ is convergent, (2) all functions $g_k(x)$ are differentiable on open interval (a,b), (3) $\sum_{k=0}^{\infty} \frac{d}{dx} g_k(x)$ is uniformly convergent on (a,b). Then $\sum_{k=0}^{\infty} g_k(x)$ is uniformly convergent and differentiable on (a,b). Moreover, its derivative $\frac{d}{dx} \sum_{k=0}^{\infty} g_k(x) = \sum_{k=0}^{\infty} \frac{d}{dx} g_k(x)$.

Integration term by term theorem (Apostol 1975, p 269). Suppose that $\{g_n\}_{n=0}^{\infty}$ is a sequence of Lebesgue integrable functions defined on interval I. If $\sum_{n=0}^{\infty} \int_I |g_n|$ is convergent, then $\int_I \sum_{n=0}^{\infty} g_n = \sum_{n=0}^{\infty} \int_I g_n$.

Differentiation with respect to a parameter (Flatto 1976, p 405). Suppose $I = [a_{11}, a_{12}] \times [a_{21}, a_{22}] \times \ldots \times [a_{n1}, a_{n2}]$, and n-variables function $f(x_1, x_2, \ldots, x_n)$ is defined on I. If $f(x_1, x_2, \ldots, x_n)$and its partial derivative $\frac{\partial f}{\partial x_1}(x_1, x_2, \ldots, x_n)$ are continuous functions on I. Then

$$F(x_1) = \int_{a_{21}}^{a_{22}} \int_{a_{31}}^{a_{32}} \cdots \int_{a_{n1}}^{a_{n2}} f(x_1, x_2, x_3, \ldots, x_n) dx_2 dx_3 \ldots dx_n$$

is differentiable on the open interval (a_{11}, a_{12}), and its derivative

$$\frac{d}{dx_1} F(x_1) = \int_{a_{21}}^{a_{22}} \int_{a_{31}}^{a_{32}} \cdots \int_{a_{n1}}^{a_{n2}} \frac{\partial f}{\partial x_1}(x_1, x_2, x_3, \ldots, x_n) dx_2 dx_3 \ldots dx_n$$

Firstly, we determined the infinite series form of multiple improper integral (1).

Theorem 1 Assume n is any positive integer, and $a_m, b_m > 0, p_m$ are positive integers for all $m = 1, \ldots, n$. Then the n-tiple improper integral

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} (\ln x_m)^{p_m} \cdot \prod_{m=1}^{n} x_m^{a_m} \cdot \sin^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n$$
$$= (-1)^{\sum_{m=1}^{n} p_m} \cdot \prod_{m=1}^{n} p_m! \cdot \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1) \cdot \prod_{m=1}^{n} (2b_m k + a_m + b_m + 1)^{p_m+1}} \tag{3}$$

Proof If $0 \le x_m \le 1$, for all $m = 1, \ldots, n$, then

$$\prod_{m=1}^{n} x_m^{a_m} \sin^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) = \prod_{m=1}^{n} x_m^{a_m} \cdot \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} \left(\prod_{m=1}^{n} x_m^{b_m}\right)^{2k+1} \quad \text{(by formula (1))}$$
$$= \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} \cdot \prod_{m=1}^{n} x_m^{2b_m k + a_m + b_m} \tag{4}$$

Therefore,

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} x_m^{a_m} \cdot \sin^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n$$
$$= \int_0^1 \cdots \int_0^1 \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} \cdot \prod_{m=1}^{n} x_m^{2b_m k + a_m + b_m} dx_1 \ldots dx_n$$
$$= \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} \cdot \int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} x_m^{2b_m k + a_m + b_m} dx_1 \ldots dx_n. \tag{5}$$
(by integration term by term theorem)
$$= \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1)} \cdot \prod_{m=1}^{n} \left(\int_0^1 x_m^{2b_m k + a_m + b_m} dx_m\right)$$
$$= \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k(2k+1) \cdot \prod_{m=1}^{n} (2b_m k + a_m + b_m + 1)}$$

By differentiation with respect to a parameter and differentiation term by term theorem, differentiating each a_m by p_m times on both sides of Eq. (5), we obtained

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} (\ln x_m)^{p_m} \cdot \prod_{m=1}^{n} x_m^{a_m} \cdot \sin^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n$$
$$= (-1)^{\sum_{m=1}^{n} p_m} \cdot \prod_{m=1}^{n} p_m! \cdot \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k (2k+1) \cdot \prod_{m=1}^{n} (2b_m k + a_m + b_m + 1)^{p_m+1}}$$

In Theorem 1, substituting $x_m = e^{-t_m}$ (where $t_m > 0$ for all $m = 1, \ldots, n$), we obtained the following result.

Corollary 1 Suppose the assumptions are the same as Theorem 1. Then the n-tiple multiple improper integral

$$\int_1^{\infty} \cdots \int_1^{\infty} \prod_{m=1}^{n} t_m^{p_m} \cdot \exp - \left(\sum_{m=1}^{n} a_m t_m\right) \cdot \sin^{-1}\left[\exp - \left(\sum_{m=1}^{n} b_m t_m\right)\right] dx_1 \ldots dx_n$$
$$= \prod_{m=1}^{n} p_m! \cdot \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k (2k+1) \cdot \prod_{m=1}^{n} (2b_m k + a_m + b_m + 1)^{p_m+1}} \tag{6}$$

Using Theorem 1 and formula (2), we can easily determine the infinite series form of the multiple improper integral (2).

Theorem 2 If the assumptions are the same as Theorem 1, then the n-tiple multiple improper integral

$$\int_0^1 \cdots \int_0^1 \prod_{m=1}^{n} (\ln x_m)^{p_m} \cdot \prod_{m=1}^{n} x_m^{a_m} \cdot \cos^{-1}\left(\prod_{m=1}^{n} x_m^{b_m}\right) dx_1 \ldots dx_n$$
$$= (-1)^{\sum_{m=1}^{n} p_m} \cdot \prod_{m=1}^{n} p_m! \cdot \left[\frac{\pi}{2 \cdot \prod_{m=1}^{n} (a_m + 1)^{p_m+1}} - \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k (2k+1) \prod_{m=1}^{n} (2b_m k + a_m + b_m + 1)^{p_m+1}}\right] \tag{7}$$

In Theorem 2, substituting $x_m = e^{-t_m}$ (where $t_m > 0$ for all $m = 1, \ldots, n$), we obtained the following result.

Corollary 2 Suppose the assumptions are the same as Theorem 1. Then the n-tiple multiple improper integral

$$\int_1^{\infty}\cdots\int_1^{\infty}\prod_{m=1}^{n}t_m^{p_m}\cdot\exp-\left(\sum_{m=1}^{n}a_mt_m\right)\cdot\cos^{-1}\left[\exp-\left(\sum_{m=1}^{n}b_mt_m\right)\right]dx_1\ldots dx_n$$
$$=\prod_{m=1}^{n}p_m!\cdot\left[\frac{\pi}{2\cdot\prod_{m=1}^{n}(a_m+1)^{p_m+1}}-\sum_{k=0}^{\infty}\frac{\binom{2k}{k}}{4^k(2k+1)\prod_{m=1}^{n}(2b_mk+a_m+b_m+1)^{p_m+1}}\right] \tag{8}$$

3 Examples

In the following, aimed at the two types of multiple improper integrals, we propose two examples and use Theorems 1 and 2 to determine their solutions. On the other hand, we employ Maple to calculate the approximations of these multiple improper integrals and their infinite series forms for verifying our answers.

Example 1 By theorem 1, we determined the following double improper integral

$$\int_0^1\int_0^1(\ln x_1)^2(\ln x_2)\cdot x_1x_2^3\cdot\sin^{-1}\left(x_1^2x_2\right)dx_1dx_2$$
$$=-2\cdot\sum_{k=0}^{\infty}\frac{\binom{2k}{k}}{4^k(2k+1)\cdot(4k+4)^3(2k+5)^2} \tag{9}$$

We use Maple to verify our answer.

```
>evalf(Doubleint((ln(x1))^2*(ln(x2))*x1*x2^3*arcsin(x1^2*x2),x1=0..1,x2=
0..1),18);
```

$$-0.00126460806826573483$$

```
>evalf(-2*sum((2*k)!/(k!*k!*4^k*(2*k+1)*(4*k+4)^3*(2*k+5)^2),
k=0..infinity),18);
```

$$-0.00126460806826573482$$

Example 2 Using theorem 2, we obtained the following triple improper integral

$$\int_0^1 \int_0^1 \int_0^1 (\ln x_1)^3 (\ln x_2)^2 (\ln x_3) \cdot x_1^2 x_2 x_3^3 \cdot \cos^{-1}\left(x_1 x_2 x_3^2\right) dx_1 dx_2 dx_3$$
$$= 12 \cdot \left[\frac{\pi}{20736} - \sum_{k=0}^{\infty} \frac{\binom{2k}{k}}{4^k = (2k+1)(2k+4)^4 (2k+3)^3 (4k+6)^2} \right] \tag{10}$$

Also, we employ Maple to verify our answer.

```
>evalf(Tripleint((ln(x1))^3*(ln(x2))^2*(ln(x3))*x1^2*x2*x3^3*arccos(x1*x2*
x3^2),x1=0..1,x2=0..1,x3=0..1),14);
```

0.0017696990100762

```
>evalf(12*(Pi/20736-sum((2*k)!/(k!*k!*4^k*(2*k+1)*(2*k+4)^4*(2*k+3)^3*
(4*k+6)^2),k=0..infinity)),14);
```

0.0017696990100763

4 Conclusions

As mentioned, the integration term by term theorem, the differentiation term by term theorem, and the differentiation with respect to a parameter play significant roles in the theoretical inferences of this study. In fact, the applications of these theorems are extensive, and can be used to easily solve many difficult problems; we endeavor to conduct further studies on related applications.

On the other hand, Maple also plays a vital assistive role in problem-solving. In the future, we will extend the research topic to other calculus and engineering mathematics problems and solve these problems by using Maple. These results will be used as teaching materials for Maple on education and research to enhance the connotations of calculus and engineering mathematics.

References

Abell ML, Braselton JP (2005) Maple by example, 3rd edn. Elsevier Academic Press, Waltham

Apostol TM (1975) Mathematical analysis, 2nd edn. Addison-Wesley Publishing Co., Inc, Botson. Available at http://en.wikipedia.org/wiki/Inverse_trigonometric_functions

Dodson CTJ, Gonzalez EA (1995) Experiments in mathematics using Maple. Springer, New York

Edwards CH Jr, Penney DE (1986) Calculus and analytic geometry, 2nd edn. Prentice-Hall Inc, Upper Saddle River

Flatto L (1976) Advanced calculus. The Williams & Wilkins Co, Baltimore

Garvan F (2001) The maple book. Chapman & Hall/CRC, London

Grossman SI (1992) Calculus, 5th edn. Saunders College Publishing, Orlando

Larson R, Hostetler RP, Edwards BH (2006) Calculus with analytic geometry, 8th edn. Houghton Mifflin Harcourt, Botson

Richards D (2002) Advanced mathematical methods with maple. Cambridge University Press, Cambridge

Robertson JS (1996) Engineering mathematics with maple. McGraw-Hill, New York

Ryder LH (1996) Quantum field theory, 2nd edn. Cambridge University Press, Cambridge

Streit F (1970) On multiple integral geometric integrals and their applications to probability theory. Can J Math 22:151–163

Stroeker RJ, Kaashoek JF (1999) Discovering mathematics with maple: an interactive exploration for mathematicians, engineers and econometricians. Birkhauser Verlag, Berlin

Widder DV (1961) Advanced calculus. Prentice-Hall, Upper Saddle River

Yu CH (2012a) Evaluation of two types of multiple improper integrals, 2012 Changhua, Yunlin and Chiayi Colleges Union Symposium, Da-Yeh University, Taiwan

Yu CH (2012b) Application of maple on multiple improper integral problems, 2012 optoelectronics and communication engineering workshop. National Kaohsiung University of Applied Sciences, Taiwan

Yu CH (2012c) Evaluating multiple improper integral problems, 101 year general education symposium. National Pingtung University of Science and Technology, Taiwan

Yu CH (2013) Application of maple: taking the double improper integrals as examples, 2013 information education and technology application seminar. Overseas Chinese University, Taiwan

On Reformulation of a Berth Allocation Model

Yun-Chia Liang, Angela Hsiang-Ling Chen and Horacio Yamil Lovo Gutierrezmil

Abstract Over the last decade, Ports' operations have been a focal point for global supply chain management and logistics network structures around the world. The berth allocation problem (BAP) is closely related to the operational performance of any port. BAP consists of optimally assigning ships to berthing areas along the quay in a port. A good allocation of ships to berths has a positive impact on terminal's productivity and customer's satisfaction. Therefore, finding valid formulations which captures the nature of the BAP and accounts for the interest of ports operation management is imperative for practitioners and researchers in this field. In this study, various arrival times of ships are embedded in a real time scheduling system to address the berth allocation planning problem in a dynamic environment. A new mix integer mathematical formulation (MBAP) that accounts for two objectives—total waiting time and total handling time is proposed. The MBAP model is further evaluated in terms of computational time, and has demonstrated to be competitive compared to another well-known BAP formulation in the literature.

Keywords Berth allocation problem · Supply chain management · Ports operation management

Y.-C. Liang (✉) · H. Y. L. Gutierrezmil
Department of Industrial Engineering and Management, Yuan Ze University,
No. 135, Yuan-Tung Rd., Chungli 320 Taoyuan County, Taiwan, Republic of China
e-mail: ycliang@saturn.yzu.edu.tw

H. Y. L. Gutierrezmil
e-mail: s985458@mail.yzu.edu.tw

A. H.-L. Chen
Department of Marketing and Distribution Management, Taoyuan Innovation Institute of Technology, No. 141, Sec. 3, Jhongshan Rd., Chungli 320 Taoyuan County, Taiwan, Republic of China
e-mail: achen@tiit.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_76,

1 Introduction

In the past few years, the containerized maritime transportation has gained a crucial role in the trade of goods all over the world. The transshipment ports handle a large number of containers and require high levels of efficiency to stay its competitiveness. This has made the operation managers to endeavor their efforts in the stream linearization of the port's terminal activities and the efficient utilization of different resources. Generally, when a container ship arrives at a port, a part of the quay (a berth) is arranged to take care of the container. The quay cranes are in charge of loading and unloading the cargo which is moved from and to the yard by straddle carriers. The overall time a ship spends in port depends on the waiting time and the handling time at the berth where the ship is moored. Berths, therefore, seem one of the most important resources to be utilized for a cost-effective container terminal management. More so, a good berth allocation enhances not only terminal productivity and ship owners' satisfaction, but also produces a positive impact in any company's revenue levels.

The berth allocation problem (BAP) is an NP-Hard as noticed by Imai et al. (2001). The complexity of the problem from an optimization point of view has captured the attention of researchers who pursue to develop valid mathematical formulations and find efficient algorithms which provide good quality solutions in a practical amount of time. One of the most cited researches by Imai et al. (2001) presented the dynamic berth allocation problem where the arrival time of ships was already known; however, the arrival time assigned to a berth might be later than the time the berth became available. While the waiting time of a particular ship was represented by the departure of its predecessor minus the arrival time of the ship, the objective was to minimize the total of waiting and handling times.

Monaco and Sammarra (2007) reformulated the Imai et al. (2001) model, where the idle times per berth depends only on the berth and the ship sequence associated to. However, such idle times did not depend on the ship eventually scheduled to the position. The effectiveness of the Monaco and Sammarra (2007) model was proven by Buhrkal et al. (2011). Buhrkal et al. (2011) compared four mathematical models by three categories. The first category was based on Parallel Machine Scheduling; models proposed by Imai et al. (2001) and Monaco and Sammarra (2007) are in this category. The second category was based on the Multi-Depot Vehicle Routing Problem with Time Windows (MDVRPTW) and the third category was for the BAP formulated as a Generalized Set Partitioning problem (GSSP).

This research attempts to model the berth allocation problem in a way to balance the interest of the parties involved in the system. In other words, this study aims to minimize the handling time of ships served in a given time horizon and the waiting time for those ships have to spend before being moored in a berth. Different from other researches that have addressed the discrete berth allocation problem with dynamic arrival time of the ships (DBAP), the handling time of the vessels are not assumed to be integer.

The remaining paper is divided into four parts. Section 2 reviews previous approaches and models that addressed the berth allocation problem, and proposes a new mathematical model. Section 3 presents comparisons with existing models in the literature, and Sect. 4 draws the conclusions from the findings.

2 BAP Models

Efficiently allocating ships to berths and finding the best position for ships to be served in the service sequence of each berth has a positive impact in the operations of a port. Therefore, this section is devoted to review a main approach addressing the BAP and discusses a modified berth allocation problem (MBAP) model proposed in this study.

2.1 Monaco and Sammarra (2007) DBAP+ Model

When it comes to the berth allocation problem one of the most cited research is the one presented by Imai et al. (2001). The objective function pursues to minimize the total of waiting and handling times. The waiting time of a particular ship is represented by the departure of its predecessor minus the arrival time of the ship. Later Monaco and Sammarra (2007) presented a reformulation of the Imai et al. (2001) model. In their study, they assumed the idle times per berth depended only on the berth and the *kth* index of the ship sequence associated. However, such idle time did not depend on the ship eventually scheduled in the *kth* position. Taking that into consideration, proper changes in the objective function and constraints were made.

Furthermore, in Monaco and Sammarra (2007), the total quay dimension can be split into a finite number of berths (segment of the total quay) available for incoming ships to load or unload cargo. While having dynamic arrival times and different quay crane capacity, not all the vessels will be in the port at the beginning of the period; in fact, they will often arrive over time. As a result, the handling time of a ship is affected by its assigned berth which can serve only one ship at the time. In addition, not all berths might be ready for berthing activities at the beginning of the period; yet, they will eventually start operations. The former mentioned system is known as Discrete Berth Allocation Problem with Dynamic Arrival times ($DBAP^+$). The mathematical model of the $DBAP^+$ is as follows:

$$Min \sum_{i \in B} \sum_{j \in V} \sum_{k \in K} \left[(n-k+1)c_{ij} + s_i - a_j\right] x_{jki} + \sum_{i \in B} \sum_{k \in K} (n-k+1) y_{ki} \tag{1}$$

subject to

$$\sum_{i \in B} \sum_{k \in K} x_{jki} = 1, \forall j \in V \tag{2}$$

$$\sum_{j \in V} x_{jki} \leq 1, \forall i \in B, \forall k \in K \tag{3}$$

$$\sum_{h<k \in K} \left(y_{hi} + \sum_{l \in V} c_{li} x_{lhi} \right) - \sum_{j \in d} (a_j - s_i) x_{jki} + y_{ki} \geq 0, \forall i \in B, \forall k \in K \tag{4}$$

$$x_{jki} \in \{0, 1\}, \forall i \in B, \forall j \in V, \forall k \in K \tag{5}$$

$$y_{ki} \geq 0, \forall i \in B, \forall k \in K \tag{6}$$

Though the above model is similar to the one proposed by Imai et al. (2001), the number of constraints and variables related with the idle time are reduced because the idle time is handled as a two index variable. Therefore, when it comes to calculating the idle time in the objective function there is no need to account for the ships index anymore. Also, constraint (4) does not need the constraints that accounts for the ships index of the idle time.

2.2 MBAP

This study introduces a Modified Berth Allocation Problem model, which deals with the minimization of the total handling time of ships attended within a time horizon and the total waiting time those ships spend before being berthed. This objective allows schedules that are not only operationally efficient, but also capable of reducing an activity that does not add value to the customers (e.g., waiting for being served).

In MBAP, the main decision to be made is "where" and "when" the ships should be berthed. This naturally lends itself in a two-dimensional assumption. That is, all berths can handle any incoming ship; thus, the number of ships to be served, the arrival and handling time of the ships are known in advance. The handling time is defined to be the time when the ship is at the berth, while the service time is the total time the ship spends at the port (that includes the handling time plus any waiting time the ship experiences before being moored). Since all berths can handle any incoming ship, the time when a berth starts operation is given as well. The mathematical model introduced in this study share some characteristics from previous models from Monaco and Sammarra (2007) and Golias et al. (2009).

$$Min \sum_{i \in B} \sum_{j \in V} \sum_{k \in K} (n - k + 1)(h_{ij}) x_{ijk} + \sum_{i \in B} \sum_{k \in K} w_{ik} \tag{7}$$

subject to

$$\sum_{i \in B} \sum_{k \in K} x_{ijk} = 1, \forall j \in V \tag{8}$$

$$\sum_{j \in V} x_{ijk} \leq 1, \ \forall i \in B, \forall k \in K \tag{9}$$

$$y_{i1} \geq \sum_{j \in V} (a_j - s_i) x_{ij1}, \forall i \in B \tag{10}$$

$$y_{ik} \geq \sum_{j \in V} (a_j - s_i) x_{ijk} - \sum_{m < k \in K} \left(y_{im} + \sum_{l \in V} (h_{il}) x_{ilm} \right), \ \forall i \in B, \forall k \in K - \{1\} \tag{11}$$

$$w_{i1} \geq \sum_{j \in V} (s_i - a_j) x_{ij1}, \forall i \in B \tag{12}$$

$$w_{ik} \geq \sum_{m < k \in K} \left(y_{im} + \sum_{l \in V} (h_{il}) x_{ilm} \right) - \sum_{j \in V} (a_j - s_i) x_{ijk}, \forall i \in B, \forall k \in K - \{1\} \tag{13}$$

$$x_{ijk} \in \{0, 1\}, \forall i \in B, \forall j \in V, \forall k \in K \tag{14}$$

$$y_{ik} \geq 0, \forall i \in B, \forall k \in K \tag{15}$$

$$w_{ik} \geq 0, \forall i \in B, \forall k \in K \tag{16}$$

The objective is to minimize the sum of total handling and waiting time. Constraint (8) makes sure that every ship be assigned to a berth and a position in the service order. Constraint (9) does not allow a ship to be assigned to more than one berth and one position. Constraints (10) and (12) define the idle and waiting time respectively for ships scheduled in the first service position in every berth. Constraint (11) identifies the idle time of a given ship assigned to a specific berth and a position to be dependent of the completion time, which is equal to the handling time plus the time the berth is idle, of previous ships assigned to the same berth and the arrival time of the ship assigned to the current position. Constraint (13) defines the waiting time for any given ship scheduled at a determined berth and position. Constraint (14) denotes x as a binary variable which takes the value of 1 if a ship is assigned to a berth and a position in the service order and takes the value of zero otherwise. Constraints (15) and (16) define the idle and waiting time as continuous variables greater or equal than zero.

3 Model Comparisons

In this section the proposed MBAP model is compared with the DBAP+ model proposed by Monaco and Sammarra (2007) which has been proven to be one of the most efficient formulations. Besides, the MBAP model proposed in this research share some similarities with the DBAP+ model proposed by Monaco and Sammarra (2007) such as working with two index idle time variables. Therefore it will be interesting to test if the performance of both models will have similar performance in terms of computational effort. The mathematical models related to the instances of the problem were solved using the commercial package Gurobi optimizer 4.5. It was run on a computer Intel Core Duo 3.00 GHz and 2.00 GB of RAM.

The generation of the test instances was based on the characteristics of the ports of Singapore (Singapore), Kaohsiung (Taiwan) and Rotterdan (Netherlands). The information related to their number of berths and number of ships handled per month is available to the public online (World port source 2011). Consequently, the size of the instances was inspired by information gathered from those ports' terminals. It is worth to mention that those ports are some of the busiest ports in the world (Rosenberg 2011). Therefore, they provide valuable information to this research.

The inter-arrival time is exponentially distributed with arrival rate equal to 23.6, equivalent to 0.0422 ships per minute, or 2.53 ships per hour. That distribution was obtained from real data, inter-arrival rate, published online by the port of Kaohsiung in Taiwan (Kaohsiung harbor bureau 2011). In order to make a thorough analysis of the algorithms employed, it is intended to replicate different levels of operational pace. For that matter, the service rate (which is related to the handling time of the ships) is set proportionally higher or lower than the arrival rate (see Table 1 where LB and UB stand for the lower and upper bound parameters of the uniform distribution, respectively). On the other hand, the opening time of the berths was set based on the observation made in Cordeau et al. (2005). In the research it is pointed out that realistic opening times for the berths are 1/7–1/21 (expected proportion of ships present in the port) the amount of time from the arrival of the last ship with respect to the arrival time of the first ship taken into account in the time horizon plan. However, instead of setting a fix proportion for all berths, in this research the proportion varies uniformly

Table 1 Distribution and parameters of service rate

Uniform service rate as a percentage of the inter-arrival time with parameters [LB, UB]
[90, 150]
[85, 130]
[80, 110]
[60, 90]
[50, 80]

distributed from 1/7 to 1/21 which is more realistic yet the berths does not become all available at the same time.

In Table 2, it can be noticed that MBAP model outperforms the DBAP+ formulation in terms of computational time. As the instance becomes more complex the MBAP formulation presented in this research becomes more attractive. For example for instances of size 3 × 8 the difference in terms of performance is barely apparent between the two models. However, for instance 7 × 21 the MBAP formulation proposed is almost 30 times faster than the DBAP+ formulation over 5 instances. Furthermore, the DBAP+ model is not able to find an optimal solution within the 3 h run time limit set to Gurobi optimizer for instances 2, 3, 4, and 5 of size 9 × 30 while the MBAP formulation is able to solve the instances to optimality in less than 270 s for all instances of size 9 × 30.

The reason behind the superior performance of MBAP model in terms of CPU time is most likely related to the objective function taken into account and the constraints proposed. Given the similarities of the MBAP model and DBAP+ formulation, if both mathematical models had the same objective function then one model would converge to another. For instance, if it is pursued to minimize the total handling and waiting times with the DBAP+ model then constraint (11) has to be introduced yet that set of constraints defines the waiting times. Then it will be noticed that the DBAP+ has converged to the MBAP formulation. On the other hand, if the MBAP model employs the objective function of the DBAP+ model then constraint (11) becomes superfluous and therefore could be eliminated from the model. In that case the MBAP formulation reduces to the DBAP+ model.

Table 2 Comparison between MBAP and DBAP+ in terms of CPU time

Instance size	Instance ID	CPU time (s)	
		MBAP	DBAP+
3 × 8	1	0.156	0.375
	2	0.188	0.250
	3	0.188	0.219
	4	0.203	0.250
	5	0.313	0.265
7 × 21	1	5.359	273.516
	2	4.781	176.953
	3	3.594	100.969
	4	16.219	321.109
	5	8.453	304.094
9 × 30	1	51.875	3,465.484
	2	36.672	[a]
	3	61.703	[a]
	4	21.031	[a]
	5	263.438	[a]

[a] Instance not solved to optimality under pre-specified 3 h run time limit

4 Conclusions

This research focuses on the discrete berth allocation problem with dynamic arrival times, and proposes a new mixed integer formulation, named modified berth allocation problem, which pursues to deliver solutions with minimal total service time and total waiting times for the ships to be served during the horizon plan. The MBAP model not only presents a valid formulation of the discrete berth allocation problem with dynamic arrival times but also presents a worthy option for those terminals interested in having a low total handling time while offering a service with minimum waiting times for the ships to be served. The model was further evaluated in terms of computational time. The MBAP model has demonstrated to be competitive compared to another well-known formulation in the literature.

The objective function proposed in this research tries to account for two indicators, total waiting time and total handling time that are of special interest for any service provider. Without a doubt, every port is aware of its interest and priorities. Therefore, the decision maker would select an objective function which accounts for those metrics operations recognize as important. Furthermore, the decision maker has available optimal solutions in a relative short time for small instances of the problem. Since a port might consist of terminals of different sizes, exact methods are still viable (although the problem is NP-Hard) approaches for small enough terminals within a port.

References

Buhrkal K, Zuglian S, Ropke S, Larsen J, Lusby R (2011) Models for the discrete berth allocation problem: a computational comparison. Transport Res Part E 47:461–473

Cordeau J-F, Laporte G, Legato P, Moccia L (2005) Models and tabu search heuristics for the berth-allocation problem. Transport Sci 39:526–538

Golias M, Boile M, Theofanis S (2009) A lambda-optimal based heuristic for the berth scheduling problem. Transport Res Part C 18:794–806

Imai A, Nishimura E, Papadimitriou S (2001) The dynamic berth allocation problem for a container port. Transport Res Part B 35:401–417

Kaohsiung harbor bureau (2011) Vessel actual time of arrival, http://www.khb.gov.tw/english/. Accessed Sept 2011

Monaco MF, Sammarra M (2007) The berth allocation problem: a strong formulation solved by a Lagrangian approach. Transport Sci 41:265–280

Rosenberg M (2011) Busiest ports in the world. http://geography.about.com/cs/transportation/a/aa061603.htm. Accessed 5 Oct 2011

World port source (2011) Ports. http://www.worldportsource.com/. Accessed Sept 2011

Forecast of Development Trends in Cloud Computing Industry

Wei-Hsiu Weng, Woo-Tsong Lin and Wei-Tai Weng

Abstract This paper presents a study on the future development of Taiwan's Cloud Computing industry. The forecast of development trends was made through interviews and focus group discussions of industry professionals. We construct an analysis framework for analyzing value chain and production value for the emerging Cloud Computing industry. Based on the analysis of recent Cloud Computing business models and the value activities of Cloud Computing vendors, the result provides a reference for IT business developers and innovative vendors interested in entering the emerging Cloud Computing market.

Keywords Cloud computing · Industry development · Forecasting · Value chain · SWOT

1 Introduction

The Cloud Computing concept has made a major impact on the products, services and business models of the IT software and hardware industries (Armbrust et al. 2009; Buyya et al. 2008, Keahey and Freeman 2008). Cloud computing has therefore become the emerging concept and technology that has drawn the most

W.-H. Weng (✉) · W.-T. Lin
Department of Management Information Systems, National Chengchi University, Taipei city, Taiwan, Republic of China
e-mail: wh.weng@msa.hinet.net

W.-T. Lin
e-mail: lin@mis.nccu.edu.tw

W.-T. Weng
Department of Industrial Engineering and Management, Ming Chi University of Technology, Guangzhou, Taiwan, Republic of China
e-mail: wtweng@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_77,

attention from the IT software and hardware industries in the period of the 2008 global financial crisis. The sheer scope of the industry as well as the fact that it spans both the enterprise and consumer markets has led to much discussion on its future business potential as well (Katzan 2009; Foster et al. 2008). Nevertheless, Cloud Computing technologies and business models as well as the new products, services, competition and alliances that arise as a result offer an emerging market that is well worth monitoring.

Currently, major IT firms are exploiting possible business opportunity into Cloud Computing market (Vouk 2008; Sotomayor et al. 2008). The Taiwanese IT vendors are strong players worldwide in the manufacturing and integration of IT devices and services. To assist the Taiwanese IT vendors moving forward towards the emerging Cloud Computing market, this research aims to address the question of deriving future trends for the Taiwanese Cloud Computing industry.

2 Research Method

Qualitative analysis is employed instead of quantitative analysis, by way of expert panel, vendor interviews and focus groups.

2.1 Expert Panel

The expert panel from industry experts is to assist the convergence process of data analysis. To this objective, industrial experts panel of eleven people were selected. The panel consists of CEO, CIO and line of business managers from various domains of Taiwanese IT industry. All of them are from publicly listed firms. Their business domains include System Integration (SI), Independent Software Vendor (ISV), Internet Service Provider (ISV), device manufacturer, and data center operator. These are the major participants in the Cloud Computing industry. The main function of the Expert Panel is to help determining the research framework and deriving strategy. In particular, the following questions are discussed.

1. What are the possible Cloud Computing business models within the context of the Taiwanese IT industry and environment?
2. With regards to these business models, what is the value chain or value system of the Taiwanese Cloud Computing industry?
3. Within this value chain or value system, what are the business environments in terms of internal strengths and weaknesses, as well as external opportunities and threats of the IT firms?

4. Recognizing the internal and external business environments, what is the possible production value that could be estimated for the Cloud Computing industry?

2.2 Vendor Interviews and Focus Groups

Representative IT firms from Taiwan are selected as the objects of this study. The selection process is based on the rank of the revenue of the firms as well as their reputation in terms of technology innovation and market visibility. IT vendors of Taiwan enjoy high market share worldwide in the sectors such as computer, communication and consumer electronics manufacturing. Currently the Taiwanese vendors participate in Cloud Computing include IT device manufacturers, IT service providers, and Internet datacenter operators. We collect and analyze business proposal data of 66 Taiwanese IT vendors in cloud computing. The selection criteria are as follows.

1. Revenue of the firm is among the top five in its industry domain.
2. The firm has announced in public its vision, strategy, products or service toward Cloud Computing market.

Based on these criteria, representatives from 38 IT firms are selected for vendor interviews and focus groups. These firms are summarized in the following Table 1.

3 Development of Cloud Computing Industry

3.1 Development of Cloud Computing Business Models

Business model is a term often used to describe the key components of a given business. It is particularly popular among e-businesses and within research on e-businesses (Afuah and Tucci 2001). Despite of its importance, no generally accepted definition of the term ‘‘business model’’ has emerged. Diversity in the

Table 1 Selected cases for vendor interviews and focus groups

Business domain	Number of firms
Independent software vendor (ISV)	8
System integration provider (SI)	10
Telecom operator	4
Server and storage device manufacture	6
Networking device manufacture	4
Mobile device manufacture	6
Total	38

Table 2 Cloud computing business models

Service/product	Delivery model	Revenue model
Cloud user technology	IT vendor provides hardware and software products and technology for Cloud Computing client device, including client OS, user interface, middleware and applications	License
Software as a Service (SaaS)	Commercial application software are hosted by data center and accessed via internet service on a pay-as-you-go basis	Subscription
Platform as a Service (PaaS)	Software vendors provide APIs or development/deployment environment platforms for ISVs to develop cloud version software	Subscription
Infrastructure as a Service (IaaS)	Service providers provide the virtual computing environments for users, including virtual CPU, OS, storage and network	Subscription
Cloud infrastructure technology	IT service vendors provide technology, product or service to support enterprise or government agencies for implementing public or private cloud service	License

available definitions poses substantive challenges for delimiting the nature and components of a model and determining what constitutes a good model. It also leads to confusion in terminology, as business model, strategy, business concept, revenue model, and economic model are often used interchangeably. Moreover, the business model has been referred to as architecture, design, pattern, plan, method, assumption, and statement (Morris et al. 2003).

Several researches have proposed frameworks to identify business models. Morris et al. (2003) proposed a set of six questions for defining basic components of business models. In the context of Cloud Computing, Rappa (2004) described a framework to classify business models using the customer relationship as the primary dimension for defining categories. Using this approach, nine major categories are used to classify a number of different types of business models that have been identified in practice among web-based enterprises and also utility computing firms.

Business models of Cloud Computing are identified and summarized in Table 2.

3.2 *Development of Cloud Computing Value Chain*

Porter (1980, 1985, 1991) discusses the concept and framework of value chain analysis. The value chain provides a template for understanding cost position, because activities are the elemental unit of cost behavior. The value chain also provides a means to systematically understand the sources of customer value and conduct differentiation. Customer value is created when a firm lowers its customer's cost or enhances its customer's benefit. The term "value system" is

Table 3 Cloud computing vendors' value activities

Cloud computing sub-industries	Main value activities	Taiwanese vendor examples
Cloud user device	Entry into the cloud supply chain through smartphones, tablet, netbook PC, network communication equipment, and other products	Mainly smart mobile device manufactures, such as: HTC, Asus, Acer, D-Link, Gemtek
Cloud infrastructure equipment	Entry into the cloud supply chain through servers, storage equipment, power suppliers, and other branded products of OEM operations	Mainly server and storage device manufactures, such as: quanta, inventec, gigabyte, Delta electronics, infortrend, promise
Cloud service and data center operation	Provision of broadband service, data center services, and various XaaS services needed in cloud computing	Mainly cloud service provider and internet data center operators, such as: Chunghwa telecom, taiwan fixed network, FETnet, acer eDC, ASUS webstorage, GSS
Cloud infrastructure software and IT service	Assistance offered to cloud service and mobile device setup through system integration, software development, consultancy services, and other operations	Mainly system integrators and independent software vendors, such as: Systex, Data systems, the Syscom Group, Fortune Information Sysetms Corp., Tatung System Technologies Inc., Genesis Technology, Inc., Stark Technology Inc

sometimes employed when the concept of value chain is extended from intra-firm value activities to inter-firm value activities.

By examining the Cloud Computing business models obtained from the above sections, value activities can be identified and the Cloud Computing value chain can be extracted. IT vendors participating in the Cloud Computing value activities are classified into four clusters, which are identified as the major sub-industries of cloud computing. The value activities of these four clusters are summarized in the following Table 3.

4 Analysis on Forecasting Results

4.1 SWOT Analysis of Taiwan's Cloud Computing Industry

The SWOT analysis is an established method for assisting the formulation of strategy. SWOT analysis aims to identify the strengths and weaknesses of an organization and the opportunities and threats in the environment (Pickton and Wright 1998). The strengths and weaknesses are identified by an internal appraisal of the organization and the opportunities and threats by an external appraisal

Table 4 Competitiveness analysis of Taiwan's cloud computing industry

Strengths	Weaknesses
A. Possesses both hardware and software solutions and provides professional consultancy services experience B. Cooperated with the global leading companies for many years, and prices are flexible C. Possesses in-depth vertical domain knowledge, and localized Know-How as well	A. Customers are mostly large enterprises or government agencies; fewer dealings with SMEs and consumers B. Weak research and development of key software technologies such as virtualization and Big Data analytics
Opportunities	*Threats*
A. Open up the market of private cloud deployment B. Develop the SaaS model of software to attract new customers C. Cloud services governance, including security, auditing, and quality control D. Enterprise mobile application software and services	A. Global leading companies lead technologies and standards B. Part of the business is replaced by emerging cloud services C. Industries rise in the emerging markets such as Mainland China, India, and others

(Dyson 2004). Having identified these factors strategies are developed which may build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats (Weihrich 1982).

By applying the analysis method of Weihrich (1982), the SWOT matrix of Taiwan's Cloud Computing industry is derived as follows (Table 4).

4.2 Forecast of Taiwan's Cloud Computing Production Value

With the gradual development of the cloud market, the number of Taiwanese companies in the cloud computing industry and their scale has gradually expanded, while production value has increased annually. At present, vendors of smartphones, tablets, netbooks, servers, network communication equipments, data centers, system integration, and software solution have actively participated in the development. With the continued cloud service development and the combined market effects brought about by the trend of digital conversion, the production value is expected to achieve steady growth through 2018, as shown in Table 5.

Table 5 Production value of Taiwan's cloud computing industry (Unit: USD Million)

Cloud computing sub-industries	2013	2014	2015	2016	2017	2018
Cloud user device	12,025	14,312	16,785	18,937	21,278	23,786
Cloud infrastructure equipment	1,937	2,052	2,188	2,305	2,487	2,650
Cloud service and data center operation	365	453	536	665	745	842
Cloud infrastructure software and IT service	144	166	180	205	223	248
Total production value	14,471	16,983	19,689	22,112	24,733	27,526
YoY growth (%)	–	17.36	15.93	12.31	11.85	11.29

5 Conclusions

The cloud computing industry in accordance with the value activities are divided into four sub-industries, namely, the cloud infrastructure software and IT service industries, the cloud service and data center operation industry, the cloud infrastructure equipment industry, as well as the cloud user device industry. The internal strength and weakness, the external opportunity and threat, as well as the production value forecast, are analyzed and presented.

Vendors interested in exploring the market opportunities of Cloud Computing can use this analysis process and outcome of this research as a reference for their strategic planning, and avoid many unnecessary trial and error efforts. In particular, with a clear picture of the Cloud Computing business model and value chain, vendors can position themselves more precisely for a market sector of their competitive advantage.

Acknowledgments The authors gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Afuah A, Tucci CL (2001) Internet business models and strategies: text and cases. McGraw-Hill, Boston

Armbrust M, Fox A, Griffith R, Joseph A, Katz, R, Konwinski A, Lee G, Patterson D, Rabkin A, Stoica I, Zaharia M (2009) Above the clouds: a Berkeley view of cloud computing, Technical Report. No.UCB/EECS-2009-28, University of California at Berkley, USA

Buyya R, Venugopal S, Yeo CS (2008) Market oriented cloud computing: vision, hype and reality for delivering IT services as computing utilities. In: Proceedings of the 10th IEEE international conference on high performance computing and communications

Dyson RG (2004) Strategic development and SWOT analysis at the University of Warwick. Eur J Oper Res 152:631–640

Foster I, Zhao Y, Raicu I, Lu S (2008) Cloud computing and grid computing 360-degree compared. In: Proceedings of the IEEE grid computing environments workshop 1–10

Katzan H Jr (2009) Cloud software service: concepts, technology, Economics. Service Sci 1(4):256–269

Keahey K, Freeman T (2008) Science clouds: early experiences in cloud computing for scientific applications. Workshop on cloud computing and its applications 2008 (CCA08), Chicago, Illinois, USA

Morris M, Schindehutte M, Allen J (2003) The entrepreneur's business model: toward a unified perspective. J Bus Res 58:726–735

Pickton DW, Wright S (1998) What's SWOT in strategic analysis? Strategic Change 7(2):101–109

Porter ME (1980) Competitive Strategy. Free Press, New York

Porter ME (1985) Competitive Advantage. Free Press, New York

Porter ME (1991) Towards dynamic theory of strategy. Strateg Manag J 12(Winter):95–117

Rappa MA (2004) The utility business model and the future of computing services. IBM Syst J 43(1):32–42

Sotomayor B, Montero RS, Llorente IM, Foster I (2008) Capacity leasing in cloud systems using the Opennebula engine, workshop on cloud computing and its applications 2008 (CCA08), Chicago, Illinois, USA

Vouk MA (2008) Cloud computing–issues, research and implementations. J Comput Inf Technol 16(4):235–246

Weihrich H (1982) The TOWS matrix: a tool for situational analysis. Long Range Plan 15(2):54–66

Self-Organizing Maps with Support Vector Regression for Sales Forecasting: A Case Study in Fresh Food Data

Annisa Uswatun Khasanah, Wan-Hsien Lin and Ren-Jieh Kuo

Abstract Many food stores face the same problem, "how many products should we make and how much ingredients should we order?" For most managers, they cannot predict a specific quantity of sales for upcoming week. If their prediction is not accurate, it will cause lots of products waste or the opposite, products shortage. Fresh food products have time limit. When consumers buy food, they would first consider if the foods are fresh or has been expired. As a result, customer demand forecasting is an important issue in food product market. With the recent development of artificial intelligence models, several methods have been employed in order to conduct forecasting model to be more effective than the conventional one. This research presents a two-stage forecasting model. The noise detecting and the removing will be considered first, and then all data will be clustered to increase the accuracy and practicability of the model.

Keywords Clustering · Forecasting · Self-organizing maps · Support vector regression

---

A. U. Khasanah (✉) · W.-H. Lin · R.-J. Kuo
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei city, Taiwan, Republic of China
e-mail: M10101816@mail.ntust.edu.tw

W.-H. Lin
e-mail: M10101004@mail.ntust.edu.tw

R.-J. Kuo
e-mail: rjkuo@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_78,

1 Introduction

Food products have time limit. When consumers buy food products, they would consider whether the foods are fresh or not for the first time, and the other factors will be considered next. So, this is why expiry dates become important issues in food industry, especially in fresh food business. Products can be categorized by its expiry dates. They can be categorized into long-term products (can be kept for over one year) and perishable products (can only be kept for less than 15 days).

As sales forecasting can predict consumer demand before the sale begins, it can be used to determine the required inventory level to meet this demand and avoid the problem of under stocking. In addition, sales forecasting can have implications on corporate financial planning, marketing, client management and other areas. Therefore, improving the accuracy of sales forecasting has become an important issue in business operation.

During the last few years, many scholars have developed different kinds of forecasting techniques to increase the forecasting accuracy. Among these methods, regression models and autoregressive moving average model techniques are classified as traditional methods, which are criticized by researchers for their weakness of non-linear fitting capability.

Differential evolution (DE), a recent optimization technique, has been considered as a novel evolutionary computation technique, and outperformed other evolutionary computation techniques such as genetic algorithm (GA), particle swarm optimization (PSO). The advantages of DE are not only it is easy to be implemented but also it requires few parameters. DE has been successfully employed in many real work applications such as pattern recognition, classification and multi-objective optimization. But, only few researchers use DE algorithm for SVR parameters optimization in forecasting problem.

In this study, we apply DE algorithm to select the appropriate parameters in support vector regression model for improving the model's forecasting accuracy, preceded by clustering the data using self-organizing maps (SOM) before performing the forecasting step. We apply both of those methods to compare the forecasting result between clustered data and the non-clustered one.

2 Literature Review

Artificial neural networks (ANNs), such as support vector regression (SVR), have been found to be useful techniques for sales/demand forecasting due to their ability to capture subtle functional relationships among the empirical data even though the underlying relationships are unknown or hard to be described, and unlike traditional time series forecasting model, such as ARIMA and multivariate regression analysis (MARS), they do not require strong model assumptions and can map any nonlinear function without a priori assumption about the properties of the data. Fildes et al. in (2008), Alahakoon and Halgamuge (2000) proves coupled with superior performance in constructing nonlinear models.

However, Chang et al. in (2006) and Wang et al. in (2009) have mentioned that no matter what kind of data, some noise may influence the forecast result a lot. It seems data preprocessing become more and more important. Dash et al. in (1995) and Chang et al. in (2000) have applied different methods to select key factors in their forecasting system.

Furthermore, in the recent years, hybrid system is widely developed in different areas and has many positive performances as shown by Chen in (2003) and Marx-Gómez et al. (2002). Chang et al. in (2006) have developed various hybrid methods in dealing with the sales forecasting problems in different industrial sectors.

Cheng et al. (2009) have developed a hybrid model by integrating K-mean cluster and fuzzy neural network (KFNN) to forecast the future sales of a printed circuit board factory. This sales forecasting model is designed with the purpose of improving the forecasting accuracy and providing timely information to help managers make better decisions.

Wang and Lu have developed a demand forecasting model which noise detecting and removing task will be considered first, and then all data will be clustered to increase the accuracy and the practicability of the model. In their research, a hybrid forecasting model which combines ICA, GHSOM, and SVR algorithm is proposed. The GHSOM clusters input data into several disjoined clusters and each cluster contains similar objects. Next, an individual SVR model for each cluster is constructed and the final forecasting results can be obtained.

3 Methodology

3.1 Self-organizing Maps

The SOM architecture was originally motivated by the topological maps and the self organization of sensory pathways in the brain. It is a kind of unsupervised learning neural network. The main focus of SOM is to summarize information while preserving topological relationship. The objective of SOM is to represent high dimensional input patterns with weight vectors that can be visualized in a usually two dimensional (2D) lattice structure (Kuo et al. 2012). Each unit in the lattice structure is called neuron and adjust neuron are connect to each other, which gives the clear topology of how the network fits itself to the input space. Input layer and the output layer are connected with weight and this weight will be update during the training. A cluster can be defined as a group of neurons with short distances between them and long distance to the other neurons.

There are several procedures that must be followed to apply this method (Alahakoon and Halgamuge 2000).

1. Set up network parameters (learning rate, neighborhood radius).
2. Set up connecting weight matrix, w, randomly.
3. Input a training sample's input vector, x.
4. Select the winning output node using Euclidean distance. The winning neuron is denoted as wc.

$$|x - wc| = \min|x - wi| \tag{1}$$

5. where i is the position for ith weight.
6. Updating weight

$$wij(new) = wij(old) + a[xi - wij(old)] \tag{2}$$

7. Repeat step 3–5 until all training samples have been presented.
8. Shrink learning rate and neighborhood radius.
9. Repeat step 3–7 until the termination criteria is satisfied.
10. Error measurement

$$\sum_p \left(\min_j d_j^p\right) d_j^p = \sqrt{\sum_i \left(X_i^p - W_{ij}\right)^2} \tag{3}$$

3.2 Support Vector Regression

The basic concept of SVR is introduced. A nonlinear mapping $\varphi(.) : \Re^n \rightarrow \Re^{n_h}$ is defined to map the input data (training data set) $\{(x_i, y_i)\}_{i=1}^N$ into a so-called high dimensional space (which may have infinite dimensions), $\Re^{n_h}$. Then, in the high dimensional feature space, a linear function, *f*, is used to formulate the nonlinear relationship between input data and output data. This linear function, called SVR function, is defined as Eq. (4),

$$f(x) = w^T \varphi(x) + b \tag{4}$$

The purpose of SVR method is minimizing the empirical risk through Eq. (5),

$$R_{emp}(f) = \frac{1}{N}\sum_{i=1}^{N} \Theta_\varepsilon(y_i, w^T\varphi(x_i) + b) \tag{5}$$

Where $\Theta_\varepsilon(y_i, w^T\varphi(x_i) + b)$ is the ε-insensitive loss function and it can be explain more as shown in Eq. (6),

$$\Theta_\varepsilon(y_i, w^T\varphi(x_i) + b) = \begin{cases} |w^T\varphi(x_i) + b - y_i| - \varepsilon, & if\ |w^T\varphi(x_i) + b - y_i| \geq \varepsilon \\ 0, & otherwise \end{cases} \tag{6}$$

in addition, $\Theta_\varepsilon(y_i, w^T\varphi(x_i) + b)$ is employed to find out the optimum hyper plane on the high dimensional feature space to maximize the distance separating the training data into two subsets. Thus, the SVR focuses on finding the optimum hyper plane and minimizing the training error between the training data and the ε-insensitive loss function. Then, the SVR minimize the overall errors through Eq. (7)

$$\underset{w,b,\xi^*,\xi}{Min}\ R_\varepsilon(w, \xi^*, \xi) = \frac{1}{2}w^T w + C\sum_{i=1}^{N}(\xi_i^* + \xi_i) \tag{7}$$

with the constraints

$$\begin{aligned} y_i - w^T\varphi(x_i) - b \le \varepsilon + \xi_i^*,\ i = 1, 2, \ldots, N \\ -y_i + w^T\varphi(x_i) + b \le \varepsilon + \xi_i,\ i = 1, 2, \ldots, N \\ \xi_i^* \ge 0,\ i = 1, 2, \ldots, N \\ \xi_i \ge 0,\ i = 1, 2, \ldots, N \end{aligned}$$

Training errors above ε are denoted as ξ_i^*, whereas training errors below ε are denoted as ξ_i. After the quadratic optimization problem with inequality constraints is solved, the parameter vector w in Eq. (8) is obtained,

$$w = \sum_{i=1}^{N}(\beta_i^* - \beta_i)\varphi(x_i) \tag{8}$$

where β_i^*, β_i are obtained by solving a quadratic program and are the Lagrangian multipliers. Finally, the SVR function is obtained as Eq. (9) in the dual space,

$$f(x) = \sum_{i=1}^{N}(\beta_i^* - \beta_i)k(x_i, x_j) + b \tag{9}$$

where $k(x_i, x_j)$ is called the kernel function, and the value of the kernel equals the inner product of two vectors, x_i and x_j in the feature space $\varphi(x_i)$ and $\varphi(x_j)$, respectively; so, $K(x_i, x_j) = \varphi(x_i) \circ \varphi(x_j)$. Any function that meets Mercer's condition can be used as the kernel function. The most used kernel functions are the Gaussian radial basis functions (RBF) with a width of $\sigma : K(x_i, x_j) = \exp(-0.5||x_i - x_j||^2/\sigma^2)$.

4 Results

The first step in this study is to cluster the data with SOM. The number of cluster can be represented by the topological size. Topology size is an important factor to be decided, however, there is no theory which can exactly determine and solve this

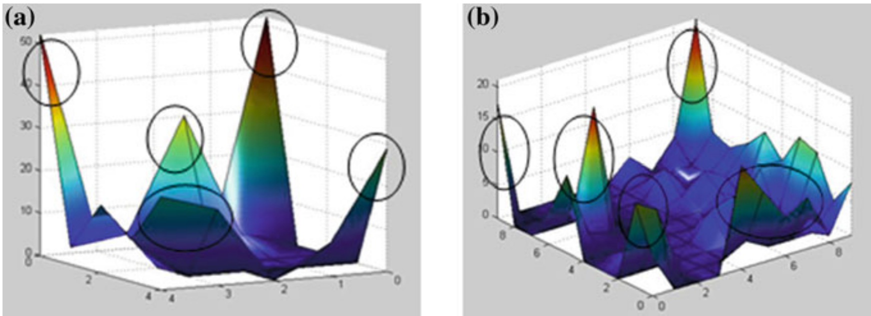


Fig. 1 **a** 5 × 5, **b** 10 × 10 topological clustering results

problem. In the preliminary test, different sizes of topology are tested and compared to see the effect of this difference in the result.

The data is nine months "mochi" sales data, and it includes 262 days. There are several factors to be considered: holiday, temperature, humidity, indicator for the occurrence of rain or drizzle, snow or ice pellets, thunder, and fog.

Figure 1 represents the clustering result when 5 × 5 and 10 × 10 topology sizes are applied. The number of clusters can be determined by the number of peaks than can be seen. The bigger the topology size, there will be more peaks appear. Just like what it has been shown in Fig. 1 there is more peaks appear in 10 × 10 than in 5 × 5 topology. But, overall it can be concluded that there are five high peaks. For several topology sizes that have been tested, in general they all show five peaks.

The error measurement for each topology also computes through Eq. (3). Figure 2 represents the MAD comparisons for each topology. It can be seen that the bigger the topology size, the smaller the MAD. High topology size will produce small MAD, but sometime the number of cluster is more difficult to determine because there will be so many peaks.

Fig. 2 MAD comparison

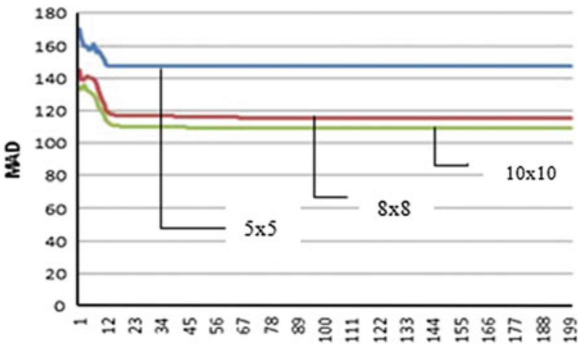
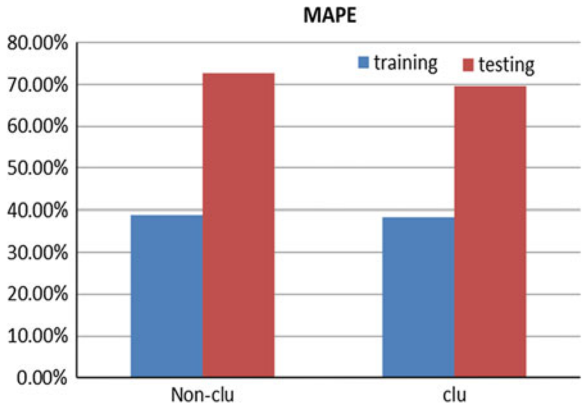


Fig. 3 Forecasting result comparing



The second step is to forecasting step using SVR. In the forecasting method, two models are compared. The first model is conducted without clustering the data and the forecasting model is constructed by considering all of the factors. The eight day sale is predicted by using the previous seven days. The second model is constructed by applying five clustered data. In this model, the forecasting is constructed for each cluster.

Performance evaluation using MAPE is conducted to show the forecasting result. The MAPE value for non-clustered data and clustered data respectively are 38.8 and 38.5 % for training, and 72.7 and 69.84 % for testing. From this result, it can be concluded that clustered data has smaller percentage error compare with non-clustered one even the differences is not so much. It is because, when we clustered the data, the variance error within the cluster is smaller than the non clustered one, and the variance error will become smaller when more topology size is applied. In the other word, for example if there are 10 high sales value among the 262 data, in non clustered model those 10 data will be compared with the other 252, so the 10 high sales data will be not very significant. But, in clustered model those 10 data will be compared with smaller number data in a cluster. Because, it has been said before that in clustered model, the forecasting method is conducted in each cluster.

In this case, the error testing is still very big. This problem is caused by the daily data is quite difficult to predict. By considering several factors that may be influenced the mochi's sales, make this kind of forecasting is more difficult to be done. There are lots of uncertainties Fig. 3.

5 Conclusion

This study constructs a forecasting model by comparing the non clustered data and the clustered one use SOM and SVR. From the experimental result, the clustered data gives better forecasting result than non clustered data. It is proved by the MAPE value.

In the clustering issues using SOM, it is important to define the topology size. There is no rule of thumbs to decide the topology size. Finally, it must be decide by the analyzer. And in the forecasting issues, it is important to do preprocessing data. Data clustering is one this step. It is important to know how the data looks like, and it is also important to recognize what kinds of factor that can influence the data and the forecasting result due to minimize noise. So, finally accurate forecasting result can be obtained. To forecast daily data is more difficult to conduct, because there will be more uncertainties to be considered.

References

Alahakoon D, Halgamuge SK (2000) Dynamics self-organizing maps with controlled growth for knowledge discovery. IEEE Trans Neural Netw 11(3):601–604

Chang PT, Huang LC, Lin HJ (2000) The fuzzy Delphi method via fuzzy statistic sand membership function fitting and an application to the human resources. Fuzzy Sets Syst 112:511–520

Chang PC, Wang YW, Liu CH (2006) Combining SOM and GA-CBR for flow time prediction in semiconductor manufacturing factory. Lect Notes Comput Sci, pp 777–767

Chang PC, Liu CH, Fan CY (2009) Data clustering and fuzzy neural network for sales forecasting: a case study in printed circuit board industry. Knowl Based Syst J

Chen T (2003) A fuzzy back propagation network for output time prediction in a wafer fab. Applied Soft Comput 2(3):211–222

Dash PK, Liew AC, Rahman S (1995) Peak load forecasted using a fuzzy neural network. Electric Power Syst Res 32:19–23

Fildes R, Nikolopoulos K, Crone SF, Syntetos AA (2008) Forecasting and operational research: a review. J Oper Res Soc 59(9):1150–1172

Kuo RJ, Wang CF, Chen ZY (2012) Integration of growing self-organizing map and continuous genetic algorithm for grading lithium-ion battery cells. Appl Soft Comput J

Marx-Gómez J, Rautenstrauch C, Nürnberger A, Kruse R (2002) Neural-fuzzy approach to forecast returns of scrapped products to recycling and remanufacturing. Knowl-Based Syst 15:119–128

Wang YW, Liu CH, Fan CY (2009) The hybrid model development of clustering and back propagation network in printed circuit board sales forecasting. Opportunities Challenges Next-Generation Appl Intell, pp 213–218

State of Charge Estimation for Lithium-Ion Batteries Using a Temperature-Based Equivalent Circuit Model

Yinjiao Xing and Kwok-Leung Tsui

Abstract This study investigates battery state-of-charge (SOC) estimation under different temperature conditions. A battery modeling approach is developed aiming to improve the accuracy of the SOC estimation when ambient temperature is taken into account. Firstly, a widely used equivalent circuit model with the one-order resistance-capacitor (RC) network is modified to capture battery dynamics at different temperatures. Secondly, since the open-circuit voltage verse SOC (OCV-SOC) incorporated into the battery model is also influenced by the temperature, OCV-SOC-Temperature (OCV-SOC-T) table is constructed to replace the original table based on our experimental data. The experiments with two dynamic load tests, dynamic stress test (DST) and federal urban driving schedule (FUDS) are run on the battery. The purpose of DST profile is to identify the battery model, while FUDS data is used to emulate the operation conditions and evaluate the performance of our proposed model by unscented Kalman filtering. Finally, the comparative results indicate that our temperature-based model provide more accurate SOC estimation with root mean square estimated errors than the original model without regard to temperature dependence.

Keywords Lithium-ion batteries · State-of-charge estimation · Equivalent circuit model · Unscented Kalman filtering · Dynamic load tests

Y. Xing (✉) · K.-L. Tsui
Department of Systems Engineering and Engineering Management,
City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong SAR
e-mail: yxing3@student.cityu.edu.hk

K.-L. Tsui
e-mail: kltsui@cityu.edu.hk

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_79,

1 Introduction

Batteries are receiving a large amount attention as the major energy storage device in electric vehicles (EVs) and uninterruptible power supplies (UPS). In order to guarantee a safe, reliable and effective operation of a battery-powered system, the key information of a battery should be monitored, and provided to the end users through the battery management system (BMS). The major functions in BMS include state-of-charge (SOC), state-of-health (SOH) and remaining useful performance (RUP) (Xing et al. 2011). For EV drivers, one of the top concerns is running out of the cars on the road. In other words, an accurate battery gauge indicator is significant for users on residual range of EV. However, battery SOC cannot be measured directly but must be estimated according to measurable parameters, such as current, terminal voltage, ambient temperature, internal resistance etc. In particular, when the battery is operated under different conditions, for example, dynamic loadings and different ambient temperatures, the performance of the battery SOC estimator is subjected to challenge. Thus, it is necessary to develop an effective and robust method to estimate battery SOC under different working conditions.

The existing methods for SOC estimation can be categorized into three types, including Coulomb counting, black box modeling, and a combination of coulomb counting method with model-based estimation. The Coulomb counting approach is a definition-based method for SOC estimation. It accumulates the charge flowing in and out of a battery directly from the initial time. However, the initial SOC is difficult to determine. In addition, this method is an open-loop estimator. The measurement errors due to current sensors and noise disturbances will cause accumulating errors (Charkhgard and Farrokhi 2010). Thus, the recalibration methods were widely employed for offline adjustment, such as open-circuit voltage (OCV) table. Secondly, the black box modeling methods were discussed in Hansen and Wang (2005), Singh et al. (2006), Li et al. (2007), Cheng et al. (2011). They mainly refer to neural networks-based, fuzzy-based, support vector-based estimators. This modeling method is time consuming. The robustness of the model will suffer from the uncertainty of the new dataset. Thirdly, a model-based filtering method combined with Coulomb counting approach is being popular and studied in Plett (2004), Junping et al. (2009), Roscher and Sauer (2011), Sun et al. (2011), Dai et al. (2012). The models refer to electrochemical models (first principle model) and equivalent circuit models. Equivalent circuit model is preferred in today's BMSs because it is easy to implement on the online system.

However, the existing methods did not take into account temperature dependence of battery modeling. There are two facets involved. One is that model parameters vary with temperature; the other is that the OCV-SOC function in the equivalent circuit model is temperature dependent. In this paper, we put forward a temperature-based equivalent circuit model incorporated with OCV-SOC-Temperature (OCV-SOC-T) to estimate the SOC of lithium-ion batteries. Our work proceeds as follow. Experiments are introduced in Sect. 2. Our methodology combining the proposed model with unscented Kalman filtering is followed by Sect. 3. The results of SOC estimation are shown in Sect. 4 to demonstrate the performance of our proposed model in comparison with that of the original model without regard to temperature effects.

2 Experiments

Lithium-ion batteries (LiFePO4) with the nominal capacity of 1.1 Amp-hours were run in our lab to simulate the practical operation. Battery monitoring system was used to control battery charge/discharge, measure the battery data. Each test as follows was tested from 0 to 50 °C at an interval of 10 °C. Three kinds of tests were run on our test samples.

Driving stress test (DST) profile was tested for model identification. It is similar to a pulse discharge regime that simulates the expected demands of an EV battery (Hunt 1996). Since a standard DST cycle only lasts for 360 s, the discharge process includes several cycles when our test sample discharge from a fully charge at 3.6 V (100 % SOC) to empty at 2 V (0 % SOC). FUDS profile was tested for evaluating the performance of our proposed method because it is a more complicated dynamic current profile to simulate the practical operation data. DST and FUDS data tested at 20 °C are shown in Fig. 1.

The OCV-SOC relationship for is significant for SOC recalibration. However, it is temperature dependent (Johnson et al. 2001; Plett 2004; Roscher and Sauer 2011). In other words, a normal OCV-SOC tested at room temperature will cause large errors for the SOC inference. Figure 2 shows OCV curves form 30 % SOC to 80 % SOC at different temperatures. It can be seen that the same OCV i.e. 3.3v

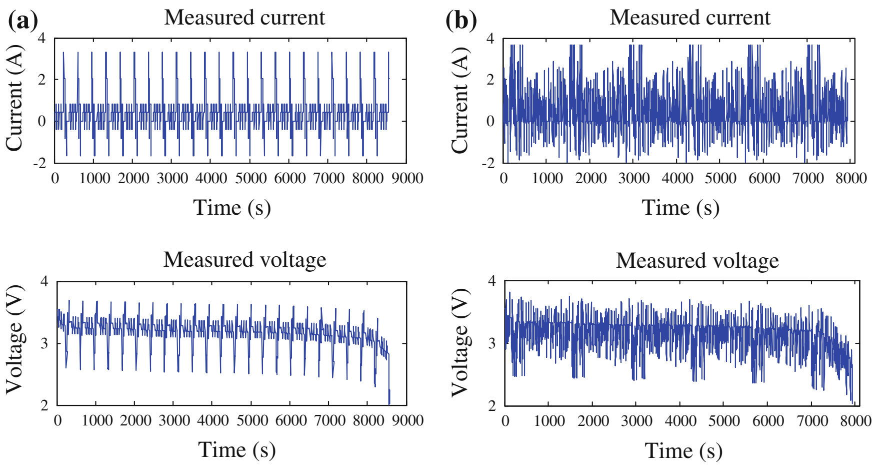


Fig. 1 Dynamic load test profile tested at 20 °C

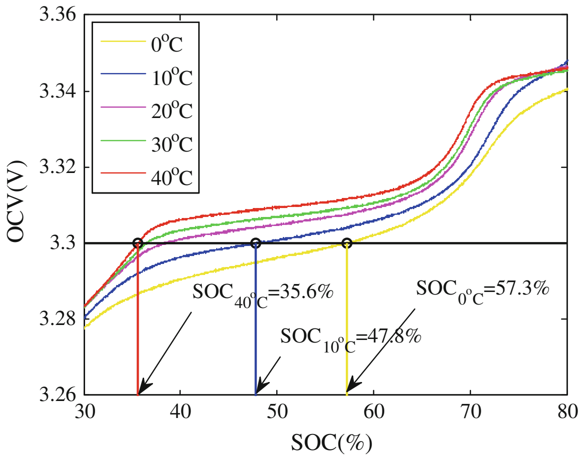


Fig. 2 SOC differences at the OCV of 3.3 V at different temperatures

corresponds to different SOC values at different temperatures. Thus, to minimize the deviation of the OCV-SOC at different temperatures, we tested the OCV curve from 0 to 50 °C at an interval of 10 °C. OCV-SOC-Temperature (OCV-SOC-T) will replace the original OCV-SOC relationship.

3 Methodology

3.1 Battery RC Model and Model Identification

A typical one-order resistance–capacitance (RC) model was employed in our study. It is a well-behaved model, and has been widely used to capture LiFePO4 dynamics (Hu et al. 2011; Roscher and Sauer 2011; He et al. 2012). Its schematic diagram is shown in Fig. 3.

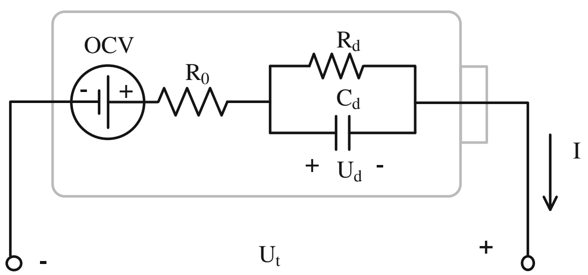


Fig. 3 Schematic diagram of LiFePO4 model

Table 1 Statistical list of the battery model

Temperature (°C)	R_0	R_p	C_p	MAE	RMSE
0	0.263	0.115	400.2	0.00132	3.4E-03
10	0.229	0.090	618.5	0.00083	2.1E-03
20	0.217	0.076	820.4	0.00061	1.5E-03
25	0.194	0.070	889.8	0.00047	8.6E-04
30	0.177	0.061	986.4	0.00040	6.0E-04
40	0.151	0.050	1139.1	0.00037	5.6E-04
50	0.176	0.0426	1340.1	0.00036	5.2E-04

$$\begin{cases} \dot{U}_d = \dfrac{I}{C_d} - \dfrac{U_d}{C_d R_d} \\ U_t = OCV(SOC) - U_d - I \times R_0 \end{cases} \tag{1}$$

where U_t is the measured terminal voltage of the battery, I is the load current with a positive value at discharge and a negative value at charge, R_0 is the ohmic resistance, C_d and R_d are the polarization capacitance and resistance, respectively. U_d is the voltage across the C_d.

As mentioned in Sect. 2, the sequence of current and terminal voltage of DST at the given temperature was used to fit model using least square. The specific OCV-SOC- T i.e. OCV-SOC-40 °C was selected. For the OCV inference in Eq. (1), the accurate SOC at time k should be obtained. Since the battery was discharged from 100 % SOC, the accumulative SOC can be calculated. Accordingly, model parameters were fitted as shown in Table 1.

Mean absolute modeling error (MAE) and root mean square modeling error (RMSE) are used to evaluate the goodness of fit of the model. Here, modeling error refers to the deviation between the measured terminal voltage ($U_{t,k}$) and the estimated terminal voltage ($\widehat{U}_{t,k}$). Table 1 demonstrates that the model can fit the measured data well with small MAEs and RMSEs taking into account temperature. Additionally, model parameters vary with temperature. Thus, a temperature-based model, TRC model, was proposed as follows.

$$\begin{cases} \dot{U}_d &= \dfrac{I}{C_d(T)} - \dfrac{U_d}{C_d(T) R_d(T)} \\ U_t &= OCV(SOC, T) - U_d - I \times R_0(T) \end{cases} \tag{2}$$

3.2 Unscented Kalman filtering for State Estimation

The online SOC estimation has strong nonlinearity. In order to improve the estimation accuracy, unscented Kalman filtering (UKF) was employed for battery SOC estimation. The characteristics of UKF is based on unscented transformation, which could avoid the weakness using Taylor series expansion like extended Kalman filtering (EKF) (Wan and Van Der Merwe 2000, 2001). Incorporating with the discrete form of Eq. (2) and Coulomb counting principle, a state-space model for UKF estimation can be formulated in Eqs. (3) and (4).

State function:

$$\mathbf{x}_{k+1} = \begin{bmatrix} SOC_{k+1} \\ U_{d,k+1} \\ R_{0,k+1} \end{bmatrix} = \mathbf{A}_k \begin{bmatrix} SOC_k \\ U_{d,k} \\ R_{0,k} \end{bmatrix} + \mathbf{B}_k I_k + \begin{bmatrix} \omega_{SOC,k} \\ \omega_{U_d,k} \\ \omega_{R_0,k} \end{bmatrix} \tag{3}$$

Measurement function:

$$\mathbf{y}_k = U_{t,k} = OCV(SOC_k, T) - I_k R_{0,k} - U_{d,k} + \xi_k \tag{4}$$

where $\mathbf{A}_k = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \exp(-\Delta T/C_p R_p) & 0 \\ 0 & 0 & 1 \end{bmatrix}, \mathbf{B}_k = \begin{bmatrix} -\Delta T/C_n \\ R_d[1 - \exp(-\Delta T/C_p R_p)] \\ 0 \end{bmatrix}$, k is the time, C_n is the nominal capacity of the battery. ΔT is the sampling period of 1 s in our test, ω_{SOC}, ω_{U_d}, ω_{R_0}, ξ are zero man while stochastic process.

4 Results

Based on our proposed temperature-based model as Eq. (2), the sequence of FUDS data tested at different temperatures was used to evaluate the performance of our developed method. FUDS profile is applied to emulate the operation conditions. A comparison was made by using RC and TRC models at different temperatures. Initialized parameters, including the initial guess of SOC_0, measurement covariance and process noise, were set the same for these two estimators. Figure 4a and b compare the estimated results based on these two models. For both of these two figures, the initial guess of SOC was set at 30 %, while the initial SOC was 80 %. Figure 4a is the estimated results when the battery operated at a relatively high temperature i.e. 40 °C. Figure 4b is the results at a low temperature i.e. 10 °C.

According to the estimated results, several conclusions can be obtained as follows. Firstly, the estimated SOC based on TRC model was much more close to the true SOC than RC model. Without the knowledge of the true initial SOC value, our method still can quickly track and converge to the true SOC. Secondly, there were large estimated errors at low temperature, especially using RC model. That means, the estimation based on RC model would not be able to capture the battery dynamics. Finally, Fig. 4b show that the estimated errors based on TRC model would be relatively large when the SOC is between 40 and 60 %. The reason is that the OCV curve is flat in this stage. Thus, a small deviation from the OCV inference will cause the fluctuation of the estimated SOC.

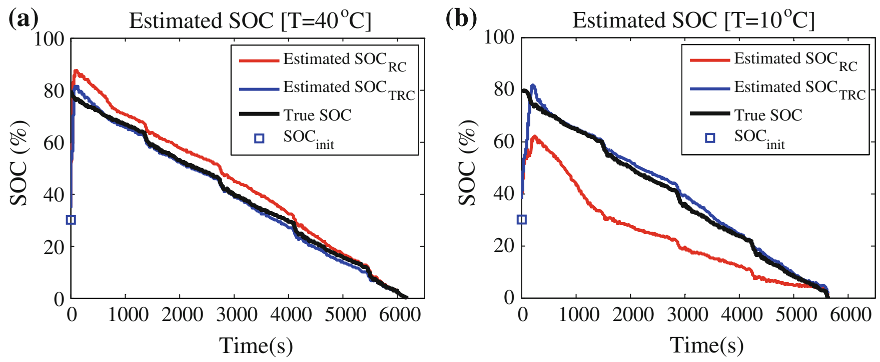


Fig. 4 True and estimated SOC at two temperatures

5 Conclusions

State of charge (SOC) estimation is one of significant functions in a battery management system. It does not only indicate residual range for battery recharge, but also provides information to avoid overcharge and over-discharge for a long battery life. However, when the battery is operated under different working conditions i.e. different temperatures, the existing methods for SOC estimation is subjected to challenge.

In this paper, we discussed temperature effects on SOC estimation based on our test data. To address this problem, a temperature-based battery model (TRC model) incorporated with the OCV-SOC-Temperature table was put forward to improve the accuracy of the SOC estimation by unscented Kalman filtering. Experimental results demonstrated that our model could provide more accurate SOC estimation with smaller root mean square estimated errors than the original model (RC model) without regard to temperature dependence. In addition, TRC model would perform better at high temperature than at low temperature. Therefore, in order to improve the SOC estimation at low temperature, a more accurate model to capture battery dynamics is worthy to investigate for further study.

References

Charkhgard M, Farrokhi M (2010) State-of-charge estimation for lithium-ion batteries using neural networks and EKF. IEEE Trans Ind Electron 57:4178–4187

Cheng C-S, Chen P-W, Huang K-K (2011) Estimating the shift size in the process mean with support vector regression and neural networks. Expert Syst Appl 38:10624–10630

Dai H, Wei X, Sun Z, Wang J, Gu W (2012) Online cell SOC estimation of Li-ion battery packs using a dual time-scale Kalman filtering for EV applications. Appl Energ 95:227–237

Hansen T, Wang C-J (2005) Support vector based battery state of charge estimator. J Power Sources 141:351–358
He H, Xiong R, Guo H (2012) Online estimation of model parameters and state-of-charge of LiFePO4 batteries in electric vehicles. Appl Energ 89:413–420
Hu X, Li S, Peng H (2011) A comparative study of equivalent circuit models for Li-ion batteries. J Power Sources 198:359–367
Hunt G (1996) USABC electric vehicle battery test procedures manual.
Johnson VH, Pesaran AA, Sack T, America S (2001) Temperature-dependent battery models for high-power lithium-ion batteries. National Renewable Energy Laboratory, City of Golden
Junping W, Jingang G, Lei D (2009) An adaptive Kalman filtering based state of charge combined estimator for electric vehicle battery pack. Energ Convers Manage 50:3182–3186
Li IH, Wang WY, Su SF, Lee YS (2007) A merged fuzzy neural network and its applications in battery state-of-charge estimation. IEEE Trans Energ Convers 22:697–708
Plett GL (2004) Extended Kalman filtering for battery management systems of LiPB-based HEV battery packs: Part 2. Modeling and identification. J Power Sources 134:262–276
Roscher MA, Sauer DU (2011) Dynamic electric behavior and open-circuit-voltage modeling of LiFePO4-based lithium ion secondary batteries. J Power Sources 196:331–336
Singh P, Vinjamuri R, Wang X, Reisner D (2006) Design and implementation of a fuzzy logic-based state-of-charge meter for Li-ion batteries used in portable defibrillators. J Power Sources 162:829–836
Sun F, Hu X, Zou Y, Li S (2011) Adaptive unscented Kalman filtering for state of charge estimation of a lithium-ion battery for electric vehicles. Energy 36:3531–3540
Wan EA, Van Der Merwe R (2000) The unscented Kalman filter for nonlinear estimation. In: Adaptive systems for signal processing, communications, and control symposium 2000. AS-SPCC. The IEEE 2000. pp 153–158, IEEE
Wan EA, Van Der Merwe R (2001) The unscented Kalman filter. Kalman Filtering Neural Netw, Wiley, 221–80
Xing Y, Ma EWM, Tsui KL, Pecht M (2011) Battery management systems in electric and hybrid vehicles. Energies 4:1840–1857

Linking Individual Investors' Preferences to a Portfolio Optimization Model

Angela Hsiang-Ling Chen, Yun-Chia Liang and Chieh Chiang

Abstract When optimizing a portfolio, individual investors today already knew potential returns from the capital are often offset by the amount of risk willing to take; hence, to lower the risk associated with the investment, they'll have to diversify through a pool of portfolio from different asset classes (such as stocks, bonds, mutual funds, and cash, etc.). Since most studies have disregarded preferences of individual investors and selections of different asset classes in model formulations, this study provides a systematic approach to set priorities among multi-criteria and trade-off among objectives for Taiwanese individual investors. For that, the Analytic Network Process (ANP) is suggested to determine an asset allocation scheme tailored to the specific requirements of individual investors. Such scheme is then applied to the Markowitz model of portfolio optimization. The Variable Neighborhood Search (VNS) algorithm is constructed to build an efficient frontier of multiple portfolios which offer investors more alternatives on asset selections.

Keywords Asset allocation · Portfolio optimization · Analytic network process · Variable neighborhood search

A. H.-L. Chen (✉)
Department of Marketing and Distribution Management, Taoyuan Innovation Institute of Technology, No. 414, Sec. 3, Jhongshan E. Rd., Chungli 320, Taoyuan County, Taiwan, Republic of China
e-mail: achen@tiit.edu.tw

Y.-C. Liang · C. Chiang
Department of Industrial Engineering and Management, Yuan Ze University, No 135 Yuantung Rd., Chungli 320, Taoyuan County, Taiwan, Republic of China
e-mail: ycliang@saturn.yzue.du.tw

C. Chiang
e-mail: s995433@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_80,

1 Introduction

Long-term investors have known to diversify investment through a pool of portfolio amongst different asset classes in order to minimize the unacceptable risk and maximize the expected profit. Academic interests on diversification began and have grown since Markowitz (1952) first proposed a mean–variance model. Today, many attempts have been made to linearize Markowitz's model (Chang et al. 2000) and to include other various realistic constraints (Markowitz et al. 2000; Soleimani et al. 2009; Anagnostopoulos and Mamanis 2011; Golmakani and Fazel 2011; Lwin and Qu 2013).

According to Markowitz model, investors are better off to buy a large number of different securities, but to manage a portfolio with a large number of different securities is rather weary and expensive for any investors. Moreover, in Matarazzo (1979) individuals with extensive financial and mental capabilities often make different investment decisions from those with fewer capabilities. Konno (1990) observed that most investors actually buy portfolios apart from the efficient frontier as a result of different views on attributes, e.g. the number of securities in a portfolio, holding periods, and profit growth, etc. Several papers have provided insight into the preferences of the investors and the characteristics of the investment opportunities (Ballestero 1998; Bronson et al. 2007; Charouz and Ramik 2010; Chen et al. 2011; Le 2011).

Since both investor preferences and portfolio optimality are desirable attributes, this study proposes three distinct and useful contributions to the problem of portfolio selection and optimization. First, the risk and diversification of various asset classes match investor preferences by developing a set of suitable and diversified weights using the Analytical Network Process (ANP). Second, portfolio selection is optimized with a cardinality-constrained mean–variance (CCMV) model in Chang et al. (2000) and its computation has been proven to be NP-hard (Moral-Escudero et al. 2006). As well, the realistic constraints are introduced, its computational complexity elevates as well. For that, the Variable Neighborhood Search (VNS) used to overcome challenges faced by deterministic optimization methods. Finally, this study concludes by validating the model with empirically available data and deriving the best combination of portfolios assigned to different financial assets. We hope, with evidence mounting, our study can better meet the modeling needs of investors other than of the standard variety.

2 Problem Formulation

The model of portfolio optimization is worked out in light of the recommendation of financial advisors and finance theory (Khaksari et al. 1989; Puelz and Puelz 1992; Bolster et al. 1995; Bodie and Crane 1997). We consider a four-level hierarchical decision system (Fig. 1). Such hierarchy aims to find investor

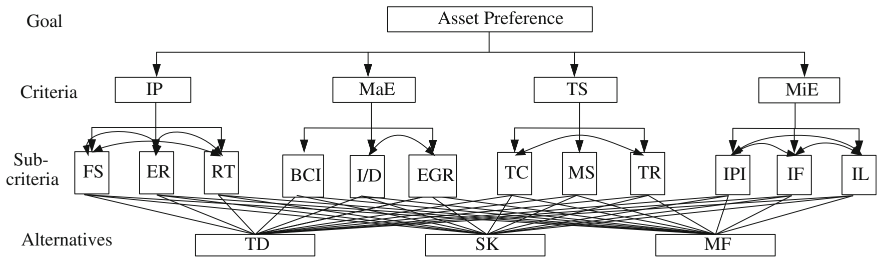


Fig. 1 A four-level hierarchical decision system

preferences among different asset classes—*fix income securities* (e.g. term deposit, TD), *mutual funds* (MF), and *company equities* (e.g. stocks, SK). Major criteria and attributes are listed in Table 1. The array of possible outcomes is the weightings of the tree assets held in investor's portfolio.

Table 1 Definitions for attributes and sub-elements of investment preferences

Criterion/attribute	Definition
Investor's profile (*IP*)	
Financial status (FS)	The financial position and goals that an investor maintains
Expected return (ER)	The rate of return that an investor desires to achieve for his/her investment
Risk tolerance (RT)	The level of risk that an investor is willing to take for the possibility of incurring a loss
Macroeconomic environment (*MaE*)	
Business cycle indicator (BCI)	An economic indicator that shows the recurring and fluctuating levels of economic activity over a long period of time
Inflation/deflation (I/D)	The overall general price movement (upward/downward) of goods and services in an economy
Economic growth rate (EGR)	A measure of economic change that a nation's GDP goes from one period to another in percentage terms
Trade situation (*TS*)	
Transaction costs (TC)	Expenses incurred in the process of carrying out a transaction
Market scale (MS)	The marketability of the financial securities that is relevant
Trade regulation (TR)	Certain financial requirements, restrictions and guidelines, handled by either a government or non-government organization
Microeconomic environment (*MiE*)	
Industrial production index (IPI)	An economic indicator, highly sensitive to interest rates and consumer demand, measures changes in output for the manufacturing, mining, and utilities
Industrial forecasting (IF)	The trend in which the demographics, socio-cultural, economic, technological, regulatory, and natural environments of an industry will continue to grow
Industrial lifecycle (IL)	The distinct stages of an industry include introduction, growth, maturity, and decline

While the target preferences (i.e. weightings) of the asset classes are defined, we use a CCMV model to find optimal portfolios for each asset class for a single period of investment. Due to the page limitation, the details of the model can be found in Chang et al. (2000). The two objectives (i.e. risk and return) are interdependent and formulated as follows:

$$\min\left(\lambda\sum_{i=1}^{N}\sum_{j=1}^{N}w_iw_j\sigma_{\text{ij}}-(1-\lambda)\sum_{i=1}^{N}w_i\mu_i\right). \quad (1)$$

In Eq. (1), each asset has associated a real valued expected return (per period) (μ_i) and each pair o assets has real valued covariance (σ_{ij}). Values of $\lambda(0<\lambda<1)$ represent an explicit trade-off between risk and return. At $\lambda=0$, the optimal solution consists of maximum expected return (μ_i) regardless of the risk (σ_{ij}) involved; whereas, at $\lambda=1$, the optimal solution becomes minimum risk regardless of the return involved. Also, three additional constraints were adopted: the cardinality constraint imposes a limit K on a desired number of assets in the portfolio (i.e. $\sum_{i=1}^{N}z_i=K$); the budget constraint insures the proportions held of asset i in the portfolio add up to one (i.e. $\sum_{i=1}^{N}w_i=1, 0\le w_i\le 1$); the quantity constraint defines upper and lower limits for each asset in the portfolio (i.e. $\varepsilon_i z_i\le w_i\le\delta_i z_i$).

3 Methodology

3.1 Analytical Network Process

When it comes to solve multi-criteria decision problems, the well-known Analytical Hierarch Process (AHP) by Saaty assumes its functional independence on upper and lower parts of alternatives or criteria. Nevertheless, many real-life decision-making involves the interaction and dependence of several alternatives and criteria; thus, the ANP becomes more appropriate. The process utilizes pairwise comparisons of the "n" alternatives and/or criteria (C_n), forming a 'supermatrix (W_{ij})' to deal with component dependence and feedback. Within this supermatrix, the criteria is further decomposed into the sub-elements ($C_i=\{e_{i1},\ldots,e_{in}\}$), where $\{e_{i1},\ldots,e_{in}\}$ denotes the components of sub-elements and eigenvector solutions. The final priority weights are derived by the limiting matrix, multiplying the supermatrix by itself until Cesaro summability occurs. Due to the page limitation, the details of this method can be found in several Saaty's works (Niemira and Saaty 2004).

3.2 Variable Neighborhood Search

VNS, one of metaheuristics for solving combinatorial optimization problems, is based on the strategy of a systematic change of neighborhood structure (Mladenovic and Hansen 1997). Applications have been rapidly pertained to many fields, and references can be found in (Hansen et al. 2010). This study contains a single weighted objective so the single objective VNS algorithm is employed here, but the archive of Pareto front, i.e. the efficient frontier, will be built up to store the non-dominated solutions. The procedures are as follows:

Stage 1. Set up a set of predefined neighborhood structures (U_k, $k = 1, 2, 3$)

Stage 2. (Initialization) Randomly generate 1,000 solutions, and each owns K assets. For each asset K, determine the corresponding s_i value, which is used for weight calculation, and the weight w_i, which represents the proportion held of asset i, according to Chang et al. (2000).

Stage 3. (Local Search) Within the chosen neighborhood, randomly generate 50 neighboring solutions and select one among them. For its associated s_i value, add a random number ranging between (−0.1, 0.1) in the first neighborhood, (−0.2, 0.2) in the second neighborhood, and (−0.3, 0.3) in the third neighborhood. For s_i value less than zero will be replaced by any unselected asset; otherwise, update the value. All neighboring solutions will be used to update the efficient frontier.

Stage 4. Accept the solution when its objective function value at *stage* 3 is better than its base solution. Note that whenever a neighborhood structures generates a better solution, the search start over; otherwise, the same base solution will be used for next neighborhood.

Stage 5. (Termination) At the stopping criterion equal to the total number of evaluations in this study), stop the algorithm; otherwise, return to *stage* 3.

4 Computational Results

To illustrate the use and advantages of the combined ANP and CCMV model in portfolio optimization, we present empirical data obtained from Taiwanese investors and Taiwan financial markets. For determining the relative importance between these elements in Table 1, a series of pair-wise comparisons with Saaty's nine-point scale is made. Then the geometric mean method is used to aggregate their assessments, expressed in the form as the unweighted supermatrix. The unweighted supermatrix is then multiplied by the priority weights from the clusters, yielding the weighted supermatrix.

Next, in order to evaluate the weights of elements, the limiting process method of the powers of the supermatrix was employed. The solution is derived by the power method process generating the limiting matrix (shown in Fig. 2). Indeed, the

W =

	IP	MaE	TS	MiE	FS	ER	RT	BCI	I / D	EGR	TC	MS	TR	IPI	IF	IL	TD	SK	MF
IP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.126	0.224	0.096
MaE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.066	0.313	0.106
TS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.248	0.169
MiE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.311	0.124
FS	0.236	0.000	0.000	0.000	0.236	0.236	0.236	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ER	0.043	0.000	0.000	0.000	0.043	0.043	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RT	0.206	0.000	0.000	0.000	0.206	0.206	0.206	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BCI	0.000	0.149	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I / D	0.000	0.157	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EGR	0.000	0.157	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TC	0.000	0.000	0.183	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.234	0.234	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MS	0.000	0.000	0.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.259	0.259	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TR	0.000	0.000	0.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000
IPI	0.000	0.000	0.000	0.133	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000
IF	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000
IL	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.000	0.000	0.000
TD	0.000	0.000	0.000	0.000	0.126	0.126	0.126	0.069	0.063	0.063	0.061	0.061	0.052	0.056	0.051	0.051	0.000	0.000	0.000
SK	0.000	0.000	0.000	0.000	0.224	0.224	0.224	0.284	0.314	0.314	0.243	0.243	0.310	0.284	0.306	0.306	0.000	0.000	0.000
MF	0.000	0.000	0.000	0.000	0.096	0.096	0.096	0.096	0.108	0.108	0.178	0.178	0.124	0.118	0.126	0.126	0.000	0.000	0.000

Fig. 2 The limiting supermatrix

calculations of the supermatrix can be easily solved by using the professional software named "super decisions," and then the overall normalized priorities were obtained: W = $\{IP, MaE, TS, MiE\} = \{0.439, 0.173, 0.184, 0.204\}$, $W_{IP} = \{FS, ER, RT\} = \{0.487, 0.089, 0.424\}$, $W_{MaE} = \{BCI, I/D, EGR\} = \{0.321, 0.340, 0.339\}$, $W_{TS} = \{TC, MS, TR\} = \{0.418, 0.464, 0.117\}$, and $W_{MiE} = \{IPI, IF, IL\} = \{0.285, 0.357, 0.357\}$, and $A = \{TD, SK, MF\} = \{0.173, 0.574, 0.253\}$. These ANP results provide the relative importance weights for every factor in the model. The most considered factor is investor's profile (*IP*) due to the highest priority of 0.439. Among the alternatives, the rank is *SK* (i.e. stocks), *MF* (mutual fund), and *TD* (term deposit). Their weights are used as priorities in final portfolio optimization formulation. $(TD, SK, MF) = (w_1, w_2, w_3) = (0.173, 0.574, 0.253)$, where w_j are the values of the three asset classes in our investment portfolio.

Now that the investor's preferences have been determined, the VNS algorithm coded in Borland C++ 6.0 is applied to optimize a structure-judgmental portfolio for each asset classes (i.e. stocks and mutual funds). Our sample consists of 731 stocks from all the sectors listed in the TSE and 258 mutual funds currently traded in the market. The study period includes the years 2007–2011, and the closing prices were recorded in a weekly basis. The stopping criteria are set to 1,000 N, where N represents the total number of assets in each class. The λ value is increased from 0 with increment of 0.02; thus, a total number of 51 λ values is considered. For both asset classes, we set different values of K (i.e., 5, 10, 15, and 20), references to the desired number of assets in the portfolio. The upper (δ_i) and lower (ε_i) limits of the weights are 1.0 and 0.01, respectively.

To illustrate our proposed model in action, we assume a base-line investor who prefers a more conservative allocation, lower level of risk and would like to maintain a portfolio of 10 assets in each of asset classes. Therefore, via the VNS, we generate a recommended portfolio for both stocks and mutual funds (Tables 2 and 3).

Table 2 A recommendation of a stock portfolio at K = 10

Stock no.	Weights (%)	Stock no.	Weights (%)	Stock no.	Weights (%)
512	1.057	502	1.005	418	1.014
28	26.785	385	1.006	619	1.009
657	22.763	466	21.174	215	1.013
45	23.174				

Table 3 A recommendation of a mutual fund portfolio at K = 10

MF no.	Weights (%)	MF no.	Weights (%)	MF no.	Weights (%)
233	1.000	201	1.004	108	43.604
166	12.797	251	1.015	208	1.055
203	2.055	150	1.018	205	34.637
91	2.815				

5 Conclusions

In this work, we have proposed an investor's preference framework in portfolio selection problem. Moreover, we consider selections of different investment instruments (i.e. asset classes) in formulating portfolio selection model. As few studies consider preferences of individual investors, and even fewer investigate portfolio selection with different investment instruments, our study shows potential to meet the needs of investors.

References

Anagnostopoulos KP, Mamanis G (2011) The mean-variance cardinality constrained portfolio optimization problem: an experimental evaluation of five multiobjective evolutionary algorithms. Expert Syst Appl 38:14208–14217

Ballestero E (1998) Approximating the optimum portfolio for an investor with particular preferences. J Oper Res Soc 49:998–1000

Bodie Z, Crane DB (1997) Personal investing: advice, theory, and evidence from a survey of TIAA–CREF participants. Financ Anal J 53:13–23

Bolster PJ, Janjigian V, Trahan EA (1995) Determining investor suitability using the analytic hierarchy process. Financ Anal J 51:63–75

Bronson J, Scanlan M, Squires J (2007) Managing individual investor portfolios, CFA level III candidate body of knowledge. CFA Institute, Charlottesville

Chang TJ, Meade N, Beasley JE, Sharaiha YM (2000) Heuristics for cardinality constrained portfolio optimization. Compu Oper Res 27:1271–1302

Charouz J, Ramík J (2010) A multicriteria decision making at portfolio management. Ekonomika A Manage 2:44–52

Chen AHL, Cheng K, Lee ZH (2011) The behavior of Taiwanese investors in asset allocation. Asia-Pacific J Bus Admin 3:62–74

Golmakani HR, Fazel M (2011) Constrained portfolio selection using particle swarm optimization. Expert Syst Appl 38:8327–8335

Hansen P, Mladenović N, Pérez JAM (2010) Variable neighborhood search: methods and applications. Annals Oper Res 175:367–407

Khaksari S, Kamath R, Grieves R (1989) A new approach to determining optimum portfolio mix. J Portfolio Manage 15:43–49

Konno H (1990) Piecewise linear risk function and portfolio optimization. J Oper Res Soc Jpn 33:139–156

Le SV (2011) Asset allocation: an application of the analytic hierarchy process. J Bus Econ Res (JBER) 6:87–94

Lwin K, Qu R (2013) A hybrid algorithm for constrained portfolio selection problems. Appl Intell 1–16. doi:10.1007/s10489-012-0411-7

Markowitz HM (1952) Portfolio selection. J Financ 7:77–91

Markowitz HM, Todd GP, Sharpe WF (2000) Mean-variance analysis in Portfolio choice and capital markets. Frank J. Fabozzi Series: book, vol 66. Wiley, Hoboken

Matarazzo J (1979) Wechsler's measurement and appraisal of adult intelligence, 5th edn. Oxford University Press, New York, pp 449–454

Mladenović N, Hansen P (1997) Variable neighborhood search. Comput Oper Res 24:1097–1100

Moral-Escudero R, Ruiz-Torrubiano R, Suárez A (2006) Selection of optimal investment portfolios with cardinality constraints. In: Evol Comput 2006 (CEC 2006) IEEE Congress on. July 2006, 2382–2388

Niemira MP, Saaty TL (2004) An analytic network process model for financial-crisis forecasting. Intl J Forecast 20:573–587

Puelz AV, Puelz R (1992) Personal financial planning and the allocation of disposable wealth. Financ Serv Rev 1:87–99

Soleimani H, Golmakani HR, Salimi MH (2009) Markowitz-based portfolio selection with minimum transaction lots, cardinality constraints and regarding section capitalization using genetic algorithm. Expert Syst Appl 36:5058–5063

Models and Partial Re-Optimization Heuristics for Dynamic Hub-and-Spoke Transferring Route Problems

Ming-Der May

Abstract The major advantages of hub-and-spoke network are the reduction of the number of routes and the effect of economies of scale, which can effectively save the shipping cost of the transportation industry. In the landside pick-up services of the international express industry, the application of such a model has achieved high efficient transit operations. The entire operational area is divided into numbers of partitions. Each partition sets up a station as the cargo collection place (meeting point). Vehicle routes meet here to consolidate goods that collected from customers into truckload shipment and transfer those to regional centers by larger trucks. In this study, the dynamic vehicle routing problem are extended to this type of hub-and-spoke network architecture, which make it different from the Vehicle Routing Problem (VRP), and is formulated as the Dynamic Hub-and-Spoke Problem with Transferring Route (DHSPTR). Test problems with dynamic pickup flows of export goods under H-S networks are designed to evaluate the proposed hybrid ACO solution methods. Partial re-optimization heuristics are realized by ACO for its ability to keep the solution status while new demands keep coming during the process and are inserted to existing routes dynamically.

Keywords Dynamic vehicle routing · Hub-and-spoke · Partial re-optimization · Ant colony optimization

1 Introduction

Generally, international express carriers set up a regional warehouse in the airport of some given market area, and dividing the large region into several smaller sub-regions. For example, if Taiwan is one of the major market regions of some

M.-D. May (✉)
Lung Hwa University of Science and Technology, No.300, Section1, Wanshou Road, Guishan Shiang, Taoyuan County, Taiwan, Republic of China
e-mail: mdmay@mail.lhu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_81,

international express carrier, thus one or some sub-regions may be clustered within this area. Each sub-region might be served by one or several transshipping points (TP) to handle the pickup or delivery of goods. In the end of every work days or some given deadline, the carrier has to transfer all collected cargos to regional warehouse in the airport for the followed international transportation processes. This operational framework is shown as in the Fig. 1.

In this framework, there are three participants within it, which are the regional warehouses in the airport, TPs, and customers. These three players are interacted in two stages. In the first stage, customer orders are collected to TPs. One or more vehicles (ex. pickup truck or van) route to customers to collect parcels and back to the TP. In the second stage, express carriers transfer collected freights at TPs to the airport warehouse. Such two stages collecting and transferring networks are quite common for LTL or express carriers, and are able to save the operation cost dramatically when the customer demands are large enough.

In this paper, we develop transshipment route models that consider three major decisions simultaneously. Phase (I) is planning interior operation paths which connect carrier's regional hub to every TPs, and phases (II) is the selection of TPs, finally, the phase (III) is the routing to every customers assigned to each TP. The transferring routes path from the single central hub to every TP is also considered. One dynamic solution framework is proposed for these models to select TPs and routing paths dynamically based on the arrival of new orders. Afterward the numerical testing results would be described and followed with some conclusion remarks in the end.

The concrete definition of DVRP was first addressed by Psaraftis (1988), who was discussion the meaning, characteristic of DVRP and solving strategy of it. A new review study by Pillac et al. (2013) is recommended for the further knowledge about DVRP. The MDVRP consists of constructing a set of vehicle routes in such a way that: (1) each route starts and ends at the same depot, (2) each customer is visited exactly once by a vehicle, (3) the total demand of each route does not exceed the vehicle capacity Q, (4) the total duration of each route (including travel and service time) does not exceed a preset limit L and (5) the total routing cost is minimized (Renaud et al. 1996). Generally, the objective of the MDVRP is to

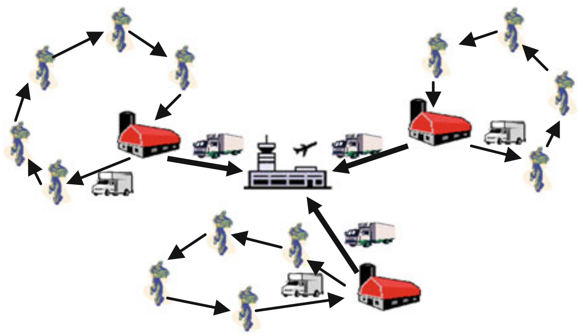


Fig. 1 Operational framework of pickup service for express carriers

minimize the total delivery distance or time spent in serving all customers. Every customer is visited by a vehicle based at one of several depots.

Irnich (2000) examined a 'Multi-Depot Pickup and Delivery Problem with a Single Hub and Heterogeneous Vehicles' (MDPDPSH), where pickup always means to load something at a location and deliver it to the hub, and delivery is always defined as loading some goods at the hub and deliver it to a location. Their work is inspired by a practical problem at the Deutsche Post AG, Germany's post service. The MDPDPSH is one subproblem, the ground feeding problem, in the design process of the global area transportation network. Crevier et al. (2007) consider a 'Multi-Depot Vehicle Routing Problem with Inter-Depot Routes' (MDVRPI) that arises from a real-life grocery distribution problem in the Montreal area. They mention that several similar applications are encountered in the context where the route of a vehicle can be composed of multiple stops at intermediate depots in order for the vehicle to be replenished.

Transshipping problem is gathering more and more attention in recent years. The similar and classical problem is Hub-and-Spoke (H/S) problem, which can reduce transportation cost by transshipping with hubs. But Zäpfel and Wasner (2002) argued that hybrid direct shipment and transshipping will be more efficient than only direct shipment or transshipping. Wasner and Zapfel (2004) further pointed out that using transshipping operation can reduce the number of depots and operating cost.

Above literatures show related topics like MDVRP and H/S problem have been studied well and have obvious results in each area, but either DVRP are limited to single depot or MDVRP are limited on static scenario. Therefore, this study will focus on integrating DVRP, MDVRP and transshipping problem.

The ant colony optimization (ACO) algorithm is one of the metaheuristics for combinatorial problem, and was proposed by Dorigo (1992). ACO can be seen as multiagent systems in which each single agent is inspired by the behavior of a real ant. The dynamic memory structure, which incorporates information on the effectiveness of previously obtained results, guide the construction process of initial solution, and resume the re-optimization process if the problems is interrupted and changed during the running process.

2 Operational Framework of Express Pick Service

In this section, we introduce the operational processes in pickup procedure of local express carriers. Generally, express carriers set up a regional warehouse in their market region, and dividing the large region into several smaller sub-regions. For example, if the Taipei city area is the major market region of one local express carrier, thus one or some administrative districts may be cluster into the sub-regions. Each sub-region will be served by a small transshipping post to pickup or delivery. However, they will transfer the collected cargos to the regional warehouse for the followed transportation processes. The operational framework has been shown in the Fig. 1.

In this framework, there are three levels, which are the warehouses, transshipping points, and customers. These three levels are operated in two stages. First, customer orders are collected to transshipping points in stage 1. One or more vehicles route to every customers to collect parcels and back to the transshipping point. In the stage two, express carriers transfer collected freight from transshipping points to regional warehouse. Some local carriers dispatch a truck especially for direct shipping between transshipping point and regional warehouse. Although this method is easy to implement, the efficiency and flexibility for serving customers would be getting worse if the demand is varied. Because a large truck is often adopted to do line haul from transshipping post to the regional warehouse. That usually leads to low utilization rate and increased operational cost. Moreover, the transshipping operation processed in the end of every business day that cumulate the cargos into truck load will defer customers collected before the midday to the next day. So it seems to have some problems in existing transshipping framework, that is the purpose of this study to try to improve and solve in our proposed models and dynamic transferring framework. These will be discussed in next section.

3 Models and Formulation

As mentioned above, this study focus on the pickup operation of local express service providers, and consider the customer demand appeared in real time. There are three levels and two stages in the considered serving framework. Briefly, the first level is the customers, the transshipping point and warehouse (or hub) is at the second and the third level respectively. The stage (I) is routing network from the transfer post to every customers that have been assigned to this transshipping point, and the stage (II) is interior operation, i.e. no customers involved, for paths connecting the hub and every transshipping point. The proposed models are based on Warehouse Location Routing Problem (WLRP) which presented by Perl and Daskin (1985) and Ambrosino and Scutella (2005) respectively, and DVRPTW which presented by Shieh and May(1998). Some new variables and constrain are created to formulate this problem and some assumptions in these two models are made and will be described later.

The purpose of this model is to reduce transshipping cost. For this reason, only one big truck moves back and forth between the regional hub and tranship point, and may route several times a day. In this way, we have assumed that: (1) Customers can assign to any transshipping point, and the customers appear in real time; (2) Cargos are transferred from a small vehicle to a big truck at the transshipping points; (3) The small vehicles site in transshipping points and the big trucks site in regional hub; and (4) Vehicles do pickup operations to collect demand to accumulated to the vehicle’s capacity, if so, the vehicle will be back to the transshipping point. Again, the big truck travel to all transshipping points to collect the cargos and move back to the hub.

3.1 Multi-Depot and Routing Transshipment

The route starts from the hub to each transshipping point with big truck. For this reason, we need to adjust and define additional notation as follows.

$V_1 = \{1,\ldots,v_1\}$: set of vehicles which route form the hub to transshipping points;

$V_2 = \{1,\ldots,v_2\}$: set of vehicles which route form transshipping points to customers;

$R = \{1,\ldots,m + H\}$: $TP \cup H$;

TCgh:the cost of routing from node g to node h, $\forall g, h \in R; g \neq h$

Qk1: capacity of vehicle k1, $\forall k_1 \in V_1$;

Qk2: capacity of vehicle k2, $\forall k_2 \in V_2$;

sgk1: start service time of node g by vehicle k1; $\forall g \in R$;

shk1: start service time of node h by vehicle k1; $\forall h \in R$;

sgk2: start service time of node g by vehicle k2; $\forall g \in Y$;

shk2: start service time of node h by vehicle k2; $\forall h \in Y$;

t1gh: travel time from node g to node h including service time of node g, $\forall g, h \in R$; $g \neq h$;

t2gh: travel time from node g to node h including service time of node g, $\forall g, h \in Y$; $g \neq h$;

$[a_{1g}, b_{1g}]$: *time window of routing from hub;*

$[a_{2g}, b_{2g}]$: *time window of routing from transshipping poitn;*

The DHSPTR is formulated in the following.

$$Min \sum_{j \in TP} VC_j \left(\sum_{i \in C} D_i y_{ij} \right) + \sum_{k \in V_1} \sum_{g \in R} \sum_{h \in R} TC_{gh} r_{ghk1} + \sum_{k \in V_2} \sum_{g \in Y} \sum_{h \in Y} C_{gh} x_{ghk2} \quad (1)$$

$$\sum_{k \in V_1} \sum_{h \in Y} r_{ihk} = 1, \quad \forall i \in TP, \quad (2)$$

$$\sum_{k \in V_2} \sum_{h \in Y} x_{ihk} = 1, \quad \forall i \in C, \quad (3)$$

$$\sum_{g \in TP} r_{hgk_1} - \sum_{g \in TP} r_{ghk_1} = 0, \quad \forall h \in R, \forall k_1 \in V_2, \quad (4)$$

$$\sum_{g \in C} x_{hgk_2} - \sum_{g \in C} x_{ghk_2} = 0, \quad \forall h \in Y, \forall k_2 \in V_2, \quad (5)$$

$$\sum_{g \in TP} \sum_{h \in H} r_{ghk1} \leq 1, \quad \forall k_1 \in V_1, \quad (6)$$

$$\sum_{g \in C} \sum_{h \in TP} x_{ghk_2} \leq 1, \quad \forall k_2 \in V_2, \tag{7}$$

$$\sum_{h \in H} \sum_{g \in R} r_{ghk_1} = 1, \quad \forall k_1 \in V_1, \tag{8}$$

$$\sum_{h \in R} \sum_{g \in H} r_{hgk_1} = 1, \quad \forall k_1 \in V_1, \tag{9}$$

$$\sum_{g \in TP} \sum_{h \in Y} x_{ghk_2} = 1, \quad \forall k_2 \in V_2, \tag{10}$$

$$\sum_{h \in Y} \sum_{g \in TP} x_{hgk_2} = 1, \quad \forall k_2 \in V_2, \tag{11}$$

$$\sum_{i \in C} \sum_{j \in TP} D_i y_{ij} \sum_{h \in R} r_{jhk_1} - Q_{k1} \leq 0, \quad \forall k_1 \in V_1, \tag{12}$$

$$\sum_{i \in C} D_i \sum_{h \in Y} x_{ihk_2} - Q_{k2} \leq 0, \quad \forall k_2 \in V_2, \tag{13}$$

$$\sum_{h \in Y} x_{ihk_2} + \sum_{h \in Y} x_{jhk_2} - y_{ij} \leq 1, \quad \forall i \in C, \forall j \in TP, \forall k_2 \in V_2, \tag{14}$$

$$s_{1gk} + t_{1gh} - K(1 - r_{ghk_1}) \leq s_{1hk}, \quad \forall g, h \in R, \forall k_1 \in V_1, \tag{15}$$

$$s_{2gk} + t_{2gh} - K(1 - x_{ghk_2}) \leq s_{2hk}, \quad \forall g, h \in Y, \forall k_2 \in V_2, \tag{16}$$

$$a_{1g} \leq s_{1gk_1} \leq b_{1g}, \quad \forall g \in R, \forall k_2 \in V_2, \tag{17}$$

$$a_{2g} \leq s_{2gk_2} \leq b_{2g}, \quad \forall g \in Y, \forall k_1 \in V_1, \tag{18}$$

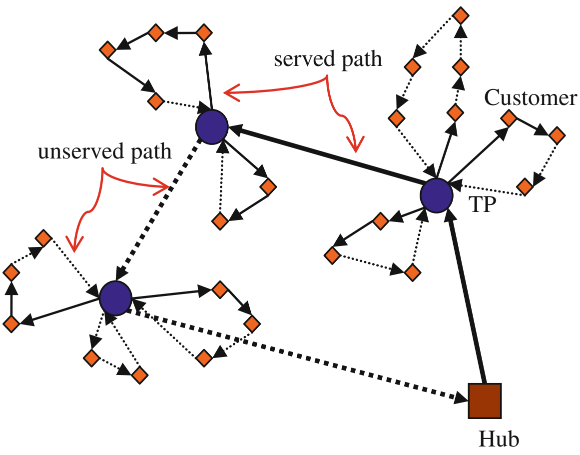
$$r_{ghk_1} \in \{0, 1\}, \quad \forall g, h \in R, \forall k_1 \in V_1, \tag{19}$$

$$x_{ghk_2} \in \{0, 1\}, \quad \forall g, h \in Y, \forall k_2 \in V_2, \tag{20}$$

$$y_{ij} \in \{0, 1\}, \quad \forall i \in C, \forall j \in TP, \tag{21}$$

The objective function (1) is minimizing total cost of pickup and transshipping operation, and the meaning of constrains are also similar to the related constrains in the above DHSPTR formulation. The framework of this DHSPTR is depicted as Fig. 2.

Fig. 2 Operation framework of DHSPTR



4 Computational Test

In order to investigate the performance of our models, we do some computational tests in some instances as shown in Table 1. To test our two models, we randomly generate 6 instances, and try to find how the transshipping point (TP) numbers affect their results, so we set TP about 2–3, and number of customers are given from 3 to 10; the vehicles are given by 3 and 5. The demand of the customers set form 1 to 25; the routing cost is generated randomly, transshipping cost is also generated randomly. Finally, time window is generated in interval [0,180] for early time and [10, 190] for later time. To ensure both the arrival and departure to be at TP within reasonable time, we set time window of every TP as [0,200].

Table 1 The instances data for computational test

Problem number	Number of TP	Number of customer	Number of vehicle	Number of constraints	Number of variables
1	2	5	3	216	167
2	2	7	5	542	431
3	2	10	5	908	755
4	3	5	3	279	219
5	3	7	5	674	534
6	3	10	5	1086	892

5 Conclusions

In this paper, we consider the actual operation of local express carriers. In order to solve the dynamic customer demand in real time, we have presented mathematical programming formulations that determine customer's assignment, routing, and transshipping in the same time. We develop ACO with dynamic framework to carry out solution. However, this research has provided stable basis for further development, and how to solve instants efficiently will be the major subjects for the future work.

References

Ambrosino D, Scutella MG (2005) Distribution network design: new problems and related models. Eur J Oper Res 165(3):610–624
Crevier B, Cordeau JF, Laporte G (2007) Multi-depot vehicle routing problem with inter-depot routes. Eur J Oper Res 176:756–773
Dorigo M (1992) Optimization, learning and natural algorithms (in Italian), PhD Thesis, Department of Electronics, Politecnico di Milano, Italy
Irnich S (2000) A multi-depot pickup and delivery problem with a single hub and heterogeneous vehicles. Eur J Oper Res 122(2):310–328
Pillac V, Gendreau M, Guéret C, Medaglia AL (2013) A review of dynamic vehicle routing problems. Eur J Oper Res 225:1–11
Psaraftis HN (1988) Dynamic vehicle routing problems. In: Golden BL, Assad AA (eds) Vehicle routing: methods and studies. Elsevier, North-Holland, pp 223–248
Renaud J, Laporte G, Boctor FF (1996) A tabu search heuristic for the multi-depot vehicle routing problem. Comput Oper Res 23:229–235
Wasner M, Zapfel G (2004) An integrated multi-depot hub-location vehicle routing model for network planning of parcel service. Int J Prod Econ 90(3):403–419
Zäpfel G, Wasner M (2002) Planning and optimization of hub-and-spoke transportation networks of cooperative third-party logistics providers. Int J Prod Econ 78(2):207–220

Hazards and Risks Associated with Warehouse Workers: A Field Study

Ren-Liu Jang and An-Che Chen

Abstract This study evaluated risk factors of manual material jobs performed in the field using questionnaire and NIOSH 1991 lifting guide. Discomfort assessment survey was used to investigate the risk of musculoskeletal injury in the warehousing operations. The questionnaire contains basic personal information, medical history, working hour and discomfort symptoms of the body such as pain, soreness, numbness at the end of the working day. Work analysis and ergonomic evaluation was also conducted to understand how workers engaged in their work. The results found the musculoskeletal risk factors for workers in warehouses were the overweight of objects lifted, awkward postures, static working postures, and long working duration. Awkward working postures such as lifting involved forward bending or twisting would increase the risk of lower back pain. Static working postures such as prolonged sitting or standing were also associated with the occurrence of low back pain and other discomfort.

Keywords Manual material handling · Biomechanics · Warehouse

1 Introduction

The main operations of warehouses are to manipulate the flow of goods and quick response to customer demand. Although most operations in warehouses are designed toward automation considering on cost and efficiency, it is difficult to run warehouses fully automation without involving manual handling. For example,

R.-L. Jang (✉) · A.-C. Chen
Department of Industrial Engineering and Management, Ming Chi University of Technology, Hsinchu County, Taiwan, Republic of China
e-mail: renliuj@mail.mcut.edu.tw

A.-C. Chen
e-mail: anche@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_82,

picking up the goods from shelves to pallets, manual handling is still the most efficient way.

The manual material handling was the main cause for workers to develop musculoskeletal injury. The National Association of Wholesale Grocers of America and the International Foodservice Distribution Association found that 30 % of occupational injuries of the warehousing personnel were back sprain and strain (Waters 1993). Studies showed that manual lifting jobs were related to back injuries and was the primary cause of back injuries in 54 % of all cases studied. Compared with other workers in warehouses, order selectors had a very high incidence rate of lower back injuries, particular when handling frequency was high (Waters 1993; Waters et al. 1995) .

Order selectors had a higher risk in musculoskeletal disorders because of many factors which resulted in fatigue and high metabolic rate and hardly keeping up with the pace of work. The study found that order selectors' workload exceeded the metabolism and biomechanical standards, mainly due to shelf height, workplace layout and long working hours (Waters et al. 1993). There were 50 % of 38 retail pickers reported at least injured once within 12 months in which at least 18 % of them were back injuries. Another similar report, 63 % of the workers reported at least injured once within 12 months and 47 % of them report at least injured once on back (Waters 1993; Waters et al. 1995).

Work-related low-back disorders (LBDs) are still the major cause of compensation costs. The relative contributions between personal, workplace, organizational and environmental variables to the development and severity of LBDs remain unclear. Dempsey et al. (1997) investigated the personal variables associated with LBDs in industrial populations. The results suggested that age, gender, injury history, relative strength, smoking, and psychosocial variables be studied further. The personal variables: height, weight, pathologies, genetic factors, maximum oxygen uptake, and absolute strength were unlikely to produce significant effects.

Xu et al. (1997) found that physically hard work, frequently twisting or bending, standing up, and concentration demands were the risk factors for the occurrence of low back pain, even after the following variables: age, sex, educational level, and duration of employment in a specific occupation were controlled.

Macfarlane et al. (1997) found those whose jobs involved lifting/pulling/pushing objects of at least 25 lbs, or whose jobs involved prolonged periods of standing or walking had an increased risk of a new episode of low back pain. Occupational activities such as working with heavy weights or lengthy periods of standing or walking, were associated with the occurrence of low back pain.

Bongers et al. (1993) studied psychosocial factors at work and musculoskeletal disease, and concluded that monotonous work, high perceived work load, and time pressure were related to musculoskeletal symptoms. The data also suggested that low control on the job and lack of social support by colleagues were positively associated with musculoskeletal disease. In addition, stress symptoms were often associated with musculoskeletal disease, and some studies indicated that stress symptoms did contribute to the development of this disease.

Besides the weight of object to be lifted, the locations of stacking items, and the sizes of the items would affect how order selectors appropriately handled the items. Awkward postures would result in high compressing forces on spinal disc (Marras et al. 1999).

2 Methods

This study evaluated risk factors of manual material jobs performed in the field using questionnaire and NIOSH 1991 lifting guide. Discomfort assessment survey was used to investigate the risk of musculoskeletal injury in the warehousing operations. The questionnaire contains: basic personal information, medical history, working hour and discomfort symptoms of the body such as pain, soreness, numbness at the end of the working day. Work Analysis and ergonomic evaluation was also conducted to understand how workers engaged in their work. In ergonomic evaluation, there was a videotaping on the order fulfillment process, from activities performed at the warehouse to activities performed at the shipping sites. Biomechanical evaluations of compressing force on low back were performed using the revised NIOSH lifting equation.

2.1 Respondents

95 workers participated in this survey from 8 local logistic centers. There were 29 female and 66 male. 62 % of female worked in the warehouse sector and 34 % worked in the management department; 67 % of male worked in the warehouse sector and 33 % worked in the shipping sector.

The female workers' average age ranged from 26 to 40 years, with an average of 33. Height ranged from 149 to 168 cm, with an average of 157. Weight ranged from 49 to 60 kg, with an average of 55. The male workers' average age ranged from 26 to 35 years, with an average of 32.7. Height ranged from 164 to 177 cm, with an average of 171. Weight ranged from 67 to 74 kg, with an average of 69.

3 Results

3.1 Respondents Background

Female respondents' seniority in laborious work was 8.5 years on average. The average working time was 8.6 h and the average sleeping time 7 h. 31 % of respondents were engaged in labor work more than 10 years and 38 % between

5 and 10 years. 59 % of respondents working at their current positions for more than five years and 38 % less than three years.

Male respondents' seniority in laborious work was 7.5 years on average. The average working time was 9.3 h and the average sleeping time 6.5 h. 38 % of respondents were engaged in labor work more than 10 years and 26 % between 5 and 10 years. 33 % of respondents working at their current positions for more than five years and 56 % less than three years.

3.2 Discomfort Assessment Survey

Medical history showed that eight female respondents (27 %) had been injured, and four had fully recovered. 29 male respondents (44 %) had been injured, and fifteen had fully recovered.

The response of three major questions in DAS was analyzed.

Q 1: In the past 12 months, have you experienced any discomfort, fatigue, numbness, or pain that relates to your job by body location?

65.5 % of female respondents experienced discomfort on shoulder and hand and 62 % on low back; 65.2 % of male respondents experienced discomfort on shoulder and 57.6 % on neck and low back.

Q 2: How often (daily, weekly, monthly) do you experience discomfort, fatigue, numbness, or pain in the region of the body?

41.7 % of female respondents experienced discomfort daily on legs and feet and 38.9 % on low back; 42.2 % of male respondents experienced discomfort daily on feet and 42.1 % on low back. 70 % of female respondents experienced discomfort weekly on low leg and 69.2 % on feet; 71.4 % of male respondents experienced discomfort weekly on low leg and 68.4 % on neck.

Q 3: On average, how severe (affecting work and daily living) is the discomfort, fatigue, numbness, or pain in this region of the body?

72.2 % of female respondents experienced discomfort affecting work and daily living on low back and 70 % on arms; 73.7 % of male respondents experienced discomfort affecting work and daily living on low back and 69.8 % on shoulder.

Regardless of gender, low back, followed by shoulder and neck were the body parts most frequently affected and experienced discomfort, fatigue, numbness or pain within 12 months. Low back, hand/wrist, and feet were the most responded locations for experienced discomfort daily. Above 50 % of respondents reported every discomfort of body part would affect work and daily living no matter what location being experienced discomfort.

3.3 Work Analysis

The workers in the warehouse sector were mainly order selectors. When picking a case from shelves, they normally would slide or rolled cases to the front edge of pallets before lifting to avoid reaching across pallets to lift and always pick up the cases in front and at waist height first. The workers in the management department were data-entry workers, which was sedentary work. The workers in the shipping sector were drivers who used pallet jacks to move the pallet of goods directly to delivery trucks.

The hazards and risks associated with workers were found that:

1. The NIOSH lifting criteria showed that most of the case lifting tasks exceeded the recommended weight limit (RWL).
2. The depth on the shelf exceeded the normal reach limit of the order selectors. Extended reaches for heavy cases may significantly increase the risk for musculoskeletal injuries.
3. Awkward positions of the hand, wrist, forearm, shoulder and low back increased the risk for experiencing discomfort, fatigue, numbness and pain during and after the work.
4. Awkward postures such as lifting involved forward bending or twisting increased the risk of lower back injuries.
5. Long work hours with only few short breaks resulted in more discomforts in body parts, particularly on legs and feet.

4 Conclusions

This study evaluated risk factors of manual material jobs performed in the field using questionnaire and NIOSH 1991 lifting guide. The results found the musculoskeletal risk factors for workers in warehouse were the overweight of objects lifted, awkward postures, static work postures, and long work duration. To reduce workers' exposures to hazards and risks, the following guidelines are recommended:

1. Reduce the weight of loads such as putting fewer items in the container or using a smaller and/or lighter-weight container.
2. Avoid manually lifting or lowering loads to or from the floor. Pallet loads of materials are located at a height that allows workers to lift and lower within their power zone which is between knee height and waist height.
3. Minimize the distances loads are lifted and lowered.
4. Clear spaces to improve access to materials or products being handled. Easy access allows workers to get closer and reduces reaching, bending, and twisting.

5. Adjust work schedules, work pace, or work practices. Provide recovery time (e.g., short rest breaks).
6. Plan the work flow to eliminate unnecessary lifts.
7. Alternate lifting tasks for workers with non-lifting tasks to reduce the frequency of lifting and the amount of time on perform lifting tasks.

Acknowledgments This work was supported by Institute of Occupational Safety and Health of Republic of China. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Bongers PM, de Winter CR, Kompier MA, Hildebrandt VH (1993) Psychosocial factors at work and musculoskeletal disease. Scand J Work, Environ Health 19:297–312

Dempsey PG, Burdorf A, Webster BS (1997) The influence of personal variables on work-related low-back disorders and implications for future research. J Occup Environ Med 39:748–759

Macfarlane GJ, Thomas E, Papageorgiou AC, Croft PR, Jayson MIV, Silman AJ (1997) Employment and physical work activities as predictors of future low back pain. Spine 22:1143–1149

Marras WS, Granata KP, Davis KG, Allread WG, Jorgensen MJ (1999) Effects of box features on spine loading during warehouse order selecting. Ergonomics 42(7):980–996

Waters T, Putz-Anderson V, Barron S, Fine L (1993) National Institute for Occupa-tional Safety and Health, Big Bear Grocery Warehouse, Columbus, Ohio, HETA 91-405-2340

Waters T, Putz-Anderson V, Barron S, Fine L (1995) National Institute for Occupa-tional Safety and Health, Kroger Grocery Warehouse, Nashville, Tennessee, HETA 93-0920-2548

Waters TR (1993) Work workplace factors and trunk motion in grocery selector tasks. In: Proceedings of the human factors and ergonomics society 37th annual meeting. Human Factors and Ergonomics Society, Santa Monica, pp 654–658

Xu Y, Bach E, Orhede E (1997) Work environment and low back pain: the influence of occupational activities. Occup Environ Med 54:741–745

Green Supply Chain Management (GSCM) in an Industrial Estate: A Case Study of Karawang Industrial Estate, Indonesia

Katlea Fitriani

Abstract Increasing the pollution drive government and people consider about environment, therefore green issues become the hot topic lately, especially industrial sector. There are two reasons drive the industries to consider for applying green aspect in their supply chain, which are regulation, Financial and supply chain pressure. This paper intends to introduce the GSCM pressure, describe the GSCM practices, performance in Karawang city, Indonesia and compare the result with previous literature. Survey questionnaire is be conducted in which consist of 3 sections and using five-point scale. The questions are be mainly based on literature review and developed to the conceptual circumstance. The factorial analysis is be used to aggregate the factors, then multiple regression analysis is used to know the relation for each variable. The research provides that Karawang has not considered the GSCM pressure yet. Industries are considering carrying out GSCM practice like improving the quality of environment friendly goods. However, those practices are not enough to prevent their pressure. Nevertheless, those practices did not give huge affect to the performance, especially operation performance.

Keywords Green supply chain management · Operations management · Manufacturing industries · GSCM performance · Factor analysis · Multiple regression analysis

1 Introduction

SCM is a relation from supplier, manufacturer, transportation, distributor until consumer. There are many things which effect SCM. Such as consumer need, efficiency, quality and responsiveness (Zelbst et al. 2010) and lately Environment

K. Fitriani (✉)
School of Business and Management Institut Teknologi Bandung, Jl Ganesha No 10, Bandung, Indonesia
e-mail: katlea.fitriani@sbm-itb.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_83,

(Green et al. 2012). People also became more aware about environment. People do not only need quality good and service, they also need cleaner production which can produce safe product. Recently, the objective of manufacturers is not about how to minimize cost but also to apply the cleaner production, like waste disposal and decreasing the use of hazardous material.

Indonesia will be the next manufacturer country in the future. Many Factories will be built to fulfill the demand of the customer. This is will be good opportunity for Indonesia economy. However, Indonesia will face some environmental issue regarding this problem. The pressure will push Indonesia to apply GSCM practice. Thus, Indonesia government, especially Ministry of Environment has established PROPER Project to overcome this matter. This project rated the pollution which has been produced each factories in Indonesia. Ministry of Environment will publish the result and the factories must fulfill the minimum rate of allowed pollution (Anon 2011a, b, c, d). In addition, Indonesia president also established president regulation No 61 2011 about decreasing greenhouse gas emissions (RAN-GRK). This regulation made for fulfilling Indonesia commitment to decrease 26 % gas emissions (Anon 2011a, b, c, d). Karawang is regency in West Java, Indonesia. This area is well-known as Industrial area. Many manufacturers are built their factories in there. Thus, it makes Karawang as one of the highest pollution city in Indonesia.

Because of that overview, this paper aims to introduce the GSCM pressure, practice and performance in Karawang Industrial Area, Indonesia. This paper also showed the comparison among GSCM in China and Japan to give deeper understand. Based on that objective, this paper took four hypotheses which are:

H1. Manufacturers in Karawang Industrial area, Indonesia have thought that the pressures are important to their management especially the Indonesia government regulation about environment, so they need to implement GSCM practice.
H2. Manufacturers in Karawang Industrial area, Indonesia have already considered applying GSCM practice especially to improve the quality of environmental friendly goods.
H3. Most of manufacturers in Karawang, Indonesia measure the company's success from their capabilities to improve the product quality.
H4. All GSCM pressures influence Green production and marketing practice the most.
H5. All GSCM practice in Karawang did not affect manufacturers performance.
H6. Manufacturers in Indonesia, especially in Karawang are lag behind than China and Japan for face the environment pressure or to apply GSCM practice.

2 Literature Review

(Sarkis 1999a, b) said that Supply Chain Management (SCM) is a system which consists of in-bound logistic, production, distribution and reverse logistic. Another literature mentioned that SCM is a relation within the raw material supplier, manufacture, transportation, distribution including the financial and information flow of good and service (Wang and Gupta 2011a, b). Planning and controlling the systems are also mentioned in SCM definition (Wang and Gupta 2011a, b). SCM is an integration from supplier supply raw material until deliver good and service to customer. In other word, SCM consist of four factors which are Raw material, Production, Distribution and Customer.

Because of many environmental issues, people started aware about environment. Balancing financial and environment become new purpose of SCM. To make SCM become green, (Rao 2002) integrated of the green purchasing from supplier to consumer, TQM based environment point, zero waste, Life cycle analysis, and green marketing. (Zhu and Sarkis 2004) defined GSCM as a green purchasing from supplier to customer including the reverse logistic in close-loop net-work. In simple way, GSCM has same function as SCM but in GSCM put environmental point to balancing the chain.

3 Method

This paper used questionnaire to collect the data from respondent. The questionnaire is made based on previous literature (Zhu et al. 2005) and modified by the writer. The questionnaire consists of three sections which are GSCM pressure, practice and performance. In first section, there are 12 questions about some pressure that affects to each company to apply GSCM practice. This section is answered using five-point Liker t-scale (1 = Not very important, 2 = Not important, 3 = Not thinking about it, 4 = Important, 5 = Extremely important). Second section consists of 30 questions about GSCM practice that might be applied by some companies. This section is also answered using five-point liker t-scale (1 = not considering, 2 = planning to consider it, 3 = currently considering it, 4 = starting to carried out, 5 = successfully carried out). Last section consists of 20 questions about some performance indicator that might be measured by companies. The questions are answered also using five-point liker t-scale (1 = not very important, 2 = not important, 3 = not thinking about it, 4 = important, 5 = very important). The questionnaire is made using Indonesia language, so to avoid confusing the respondent, each variable from (Zhu et al. 2005) is developed to some questions. The questionnaire also provided briefly explanation about each five-point liker t-scale, so the respondents can distinguish the differences.

Based on research in China (Zhu et al. 2005) and Japan (Zhu et al. 2010) used large companies as their sample. (Barney 1991) said that large manufacturers in

China and Japan have carried out GSCM practice very well. Larger manufacturers have more financial capabilities to implement GSCM practice in their production. Large manufacturers also get the affect of environmental pressure directly, so to meet the standard of environment requirement, they need to be more care about implement GSCM practice (Russo and Fouts 1997). Because of those issues, this paper use large manufacturers in Karawang as the sample. This Paper also will use high pollution industries to show the affect GSCM clearly. High pollution industries are assessed as one of the effect of increasing pollution and waste in Indonesia.

Based on those requirements, the writer took list of manufacturers in Karawang, Indonesia from BPS (Bank of Statistic Data in Indonesia) West Java about the Medium–Large Manufacturers in Karawang. There are several industries, but the writer just used 53 industries which meet the requirement. Those 53 industries are large manufacturers which can be shown from their amount of employee and production cost. The industries also are high pollution industries which can be shown from the type of industries, such as textile, chemical, plastic, paper and spare part industries.

The writer sent the questionnaire using email to 53 industries. The questionnaires are filled by the production manager because they understand more about the production process in the manufacturers. Out of 53 questionnaires sent, 34 questionnaire gave response (64.15 % respond rate). The manufacturers which respond the questionnaires are six textile manufacturers, four Plastic manufacturers, four chemical manufacturers, four paper manufacturers, three Semiconductor manufacturers, two heavy equipment manufacturers, a hair product manufacturer, a food manufacturer and ten spare part manufacturers.

Before using the factor analysis, reliability and validity test need to be held in the questionnaire data. In this paper, the author used the level of cronbach's alpha. The data will be consistent and valid if the level of cronbach's alpha is above 0.7 (Nunnally 1978a, b). In Pressure factor, all 12 variables are reliable and valid. Practice factor has seven variables to be removed to make the data reliable and valid. In performance factors need to remove six variables to make the data reliable and valid.

4 Result and Discussion

The evaluation just compare the mean score each factor which has determined by using factor analysis. First, The GSCM pressure is divided into two factors, which are Standard Regulation Pressure and Supply Chain Pressure. Manufacturers in Karawang, Indonesia have not taken those pressures as important issue which can make those manufacturers implement GSCM practices. It is shown in the mean score of each factor GSCM pressure. The highest mean score is Standard Regulation pressure which only can reach 3,279 (3 = not thinking about it) and the lowest score is Supply chain pressure, which is 3,015. However, based on the result, variable ‘standard for exporting product’ got the highest mean score which is 3,884 (4 = important). It means industries started to get the pressure from importer to produce environment-friendly product. Therefore, importers establish some standard for the product which will be imported to protect their customers in their country. Based on the result, H1 is rejected because the manufacturers in Karawang have not considered those pressures as booster to implement GSCM practice yet. Furthermore, Manufacture’s in Karawang are more caring about the Standard for exporting product than the Indonesia government regulation.

Second, GSCM practice found three factors, which are Green Production and Marketing, Environmental Design and Management, and Internal Green Processing. Manufacturers in Karawang are in the stage to ‘considering it now’. Green production and marketing got the highest mean which 2,772 (3 = considering it now), especially for ‘improving the quality of environmental friendly goods’, which has mean score 3,088 (3 = considering it now). The lowest mean score is ‘Internal green processing’ which has mean score 2,512 (2 = Planning to consider it). Some manufacturers do not corporate with consumer for designing environment friendly goods. Those manufacturers just developed it by themselves based on the environment standard. It is shown that variable has the lowest mean score. Overall, Manufacturers in Karawang have not carried out GSCM practices, they are still in the level of considerate it. However most manufacturers have considered improve the quality of environmental friendly goods. Thus, H2 is accepted.

Last, the performance variables that company measure is divided into three factors, which are Operation Performance, Environment Performance and Production Performance. The manufacturers in Karawang are taking care more about production performance. The manufacturers rank increasing of production cost as the measurement whether the company can performs better. Increasing of production can affects in two ways, it can make the product price getting higher and also decreasing of the company benefits. Production performance has the highest mean score, 3, 294 (3 = not thinking about that). The lowest mean score is Operation performance 3, 1 (3 = not thinking about that). The operation performance consists of improving the product quality, 3,912 (4 = important). Some of manufacturers still do not consider about that point to measurement of company performance. Based on the over view, H3 is accepted.

The first regression is between GSCM pressure factors as independent variable and GSCM Practice factors as dependent variable. There are three times regressions from two factors pressure which might be had significant correlation with three factors practice. As can be seen in the result of multiple regression analysis, the independent variable affected the dependent variable if the significant coefficient is less than 0.05. The standard regulation and supply chain pressure gave significant correlation through the green production and marketing practice. It is shown from the significant coefficient, which are 0.032 and 0.020. It means that the standard regulation and supply chain pressure has affected 34.6 and 37.8 % to the green production and marketing practice.

In other hand, GSCM pressure did not all affect in the GSCM practice. The result showed that only Supply chain Pressure could affected in the environmental design and management practice. It is shown from the significant coefficient, which is 0.002. The supply Chain pressure affected 51.2 % environmental design and management practice. Otherwise, internal green processing could be affected 36.6 % by regulation pressure. Only regulation pressure has significant correlation to internal green processing practice, 0.035. Based on that result, H5 is accepted.

Then the regressions between GSCM practice as the independent variable and performance as the dependent variable are applied. There are 3 times regressions between three factor GSCM practices which might be had significant correlation with three factors performance. Based on the SPSS result, there are no any significant correlations from the GSCM practices which can affect the operation performance. All the significant coefficients are higher than 0.05. However green production and marketing practice affected 72.7 % to the environment performance with the significant coefficient, 0.00. The environmental design and management has affected 58.2 % to the production performance with the significant coefficient, 0.00. H5 stated that all GSCM practice in Karawang did not affect the performance. Based on the table V result, H5 is rejected. Because some GSCM practice factors could affect the performance of the manufacturers.

This comparison is to seek the level of GSCM practice in Karawang, Indone-sia compare to China (Zhu et al. 2005) and Japan (Zhu et al. 2010). To give clear explanation, the writer put an ISO 14001 issue because ISO 14001 is a system and certification for companies about their environment action. ISO 14001 Certificate is needed to know how far a company's green action. The manufacturer and the supplier should have ISO 14001 certificate. In Karawang, Indonesia, both manufacturers and suppliers are still considering to get it now. It can be shown in the mean score in table II which have same score, 2,941 (3 = Considering it now). Surprisingly, China is in the same level with manufacturers in Karawang Indonesia. China manufacturers and suppliers are still considering to get ISO 14001 certificate. It is shown by the mean score in the previous paper (Zhu et al. 2005), which are 3.36 and 3.18 (3 = considering it now). In other hand, Japan manufacturers have successfully implemented it. Japan suppliers are still starting to get ISO 14001 certificate. The mean score for this point are 4.89 (5 = successfully implemented) and 4.00 (4 = Starting to implemented) (Zhu et al. 2010). The GSCM practices of manufacturers in Karawang, Indonesia are still left far behind if comparing it with the level of GSCM practice in China and especially Japan. Thus H6 is accepted.

5 Conclusion

The awareness of environment issue has not effect so much to manufacturers in Karawang. Although, Karawang is less awareness, it does not mean that Karawang Industrial area does not face any pressure about environment issue. Manufacturers in Karawang face pressure from importers who require some standard to export products to them. This makes Manufacturers must play smart to overcome this issue. If manufacturers in Karawang do not follow the requirement, they must prepare to lost opportunity to get high foreign income. Moreover, Indonesia government regulation must be considered. Recently, government is aggressively doing environment action, like establishing rule about decreasing carbon emission or ministry of the environment's PROPER project. Thus, next 2–3 years, Indonesia will feel the pressure directly.

Deeper research using more samples with broadly area of research can give clearer overview about GSCM in Indonesia. Moreover, the type of manufacturers can be extended, not only Medium-Large manufacturers, but also Small-Medium manufacturers. The comparison between GSCM in Medium–Large manufacturers and Small–Medium manufacturers can be seen.

Acknowledgments The most sincere appreciation dedicated to my parent who always support every time I lost hope. This research was possible thanks to the participation from all company in Karawang, Indonesia. I also want to say thank you to Prof Dermawan Wibisono and Mr Gatot Yudoko for all suggestions and advices.

References

Journal article

Barney J (1991) Firm resources and sustained competitive advantage. J Manage 17(1):99–120

Green KW Jr, Zelbst PJ, Meacham J, Bhadauria VS (2012) Green supply chain management practice: impact on performance. Supply Chain Manage: Int J 17(3):290–305

Rao P (2002) Greening the supply chain: a new initiative in South East Asia. Int J Oper Prod Manage 22(6):632–655

Russo M, Fouts P (1997) A resource based perspective on corporate environmental performance and profitability. Acad Manag J 40(3):534–559

Anon (2011a) Peraturan Presiden Republik Indonesia Nomor 61 Tahun 2011: Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca, Jakarta: s.n

Anon (2011b) PROPER. [Online] Available at: http://www.menlh.go.id/proper. Accessed 23 Apr 2013

Nunnally J (1978a) Psycometric theory. McGraw-Hill, New York

Sarkis J (1999a) How green is the supply chain? Practice and research. Graduate School of Management, Clark University, Worcester

Wang H-F, Gupta SM (2011a) Green supllhain management : product life cycle approach. McGraw-Hill, Chicago

Zelbst P, Green KJ, Sower V, Abshire R (2010) Relationships among market orien-tation, JIT, TQM, and agility. Ind Manage Data Syst 110(5):637–658

Zhu Q, Geng Y, Fujita T, Hashimoto S (2010) Green supply chain management in leading manufacturers: case study in Japanese large companies. Manage Res Paper 33(4):380–392

Zhu Q, Sarkis J (2004) Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. J Oper Manag 22(3):265–289

Zhu Q, Sarkis J, Geng Y (2005) Green supply chain management in China: pressures, practice and performance. Int J Oper Prod Manage 25(5):449–468

Journal Article Only by DOI

Sarkis J (1999b) How green is the supply chain? Practice and research, Graduate School of Management, Clark University, Worcester

Anon (2011c) Peraturan Presiden Republik Indonesia Nomor 61 Tahun 2011 : Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca, Jakarta: s.n

Book and chapter

Nunnally J (1978b) Psycometric theory. McGraw-Hill, New York

Wang H-F, Gupta SM (2011b) Green Supllhain management: product life cycle approach. McGraw-Hill, Chicago

Online document (no DOI available)

Anon (2011d) PROPER. [Online] Available at: http://www.menlh.go.id/proper/. Accessed 23 Apr 2013

Limits The Insured Amount to Reduce Loss?: Use the Group Accident Insurance as an Example

Hsu-Hua Lee, Ming-Yuan Hsu and Chen-Ying Lee

Abstract Property-Liability insurance Industry pays much attention to the loss ratio of accident insurance. From 2005 to 2011, average loss ratio is 45.24 % in Property-Liability insurance industry and 34.31 % in Life insurance Industry. Most important to achieve the maximum benefit for reducing losses based on the minimum cost of underwriting for property-liability insurer's underwriters. The purpose of this research is to examine limit insured amount can reduce the loss or not and whether business quality control by underwriting system. We complied data on group accident insurance from a Property-Liability Company in Taiwan from 2009 to 2010. There are 4,504 samples in group features. We use χ^2 test, test analysis and ordered logistic regression verify the relevance of the insured amount and loss, business quality control effect and the factor impact the loss. The results of the analysis show that the there was a correlation between insured amount and loss, business quality control that effectively reduce medical loss, Variables of AD&D, MR/AD&D and DHI/AD&D have a significant influence for the loss. The result of the analysis not only help underwriter to adjust underwriting guidelines but also reduce loss amount. Moreover, our results have practical implications for the Property-Liability insurance industry in Taiwan.

Keywords Property-liability insurance · Underwriting system · Group accident insurance · Orded logistic regression · Business quality control

H.-H. Lee (✉) · M.-Y. Hsu
Graduate Institute of Management Sciences, Tamkang University, No.151, Yingzhuan Rd., Tamsui, New Taipei City 25137, Taiwan, Republic of China
e-mail: Hxl120@gmail.com

M.-Y. Hsu
e-mail: a6827609@ms18.hinet.net

C.-Y. Lee
Department of Insurance and Finance, Chihlee Institute of Technology, No.313, Sec.1,Wunhau Rd., Banciao, Taipei City, Taiwan, Republic of China
e-mail: chenying0207@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_84,

1 Introduction

As to the loss rate of group accident insurance, the average loss rate of group accident insurance for the property-liability insurance industry was 65 %, which was higher than that for life insurance industry (45 %) by 20 %. After the property-liability insurance industry began participating in the accident insurance market, was business quality control (underwriting) sacrificed with the percentages of market leaders and business growth? This is an issue worthy of study.

This study probed into the following three topics: T-1: Do high-insured amount lead to choose high loss? T-2: Does business quality management help lower the loss? T-3: What factors impact the loss? We use χ^2 test to illustrate T-1, use the decision rule to verify T-2 and using Ordered Logistic Regression analysis to analyze the factors of loss. According to the reimbursement data of case property-liability insurance company, the 1606 claim cases with a total claim amount of NT$57,497,011 in 2009 were significantly reduced to 899 claim cases with a total reimbursement amount of NT$32,098,480 in 2010. This was the effect of the case property-liability insurance company practicing precise business screening and quality management in 2010.

For previous underwriting research are concentrated in information asymmetry adverse selection and moral hazard phenomenon of something more than the presence or absence authentication. How to resolve this phenomenon is not taking a step forward of the proposed method, this study attempts to introduce a further view. The underwriters deep-rooted notion that, reduce the insured amount will be able to reduce losses, this study will challenge this argument.

The results suggest that the insured amount related to loss and business quality management helps to reduce the loss. MR and DHI/ADD have a positive relationship; MR/ADD has negative effect of losses.

This paper is constructed as follows: The first section of the article is an introduction. The second section, literature review is explore underwriting, asymmetric information and methodology for quality control in underwriting system. The third section describes the methodology to examine the hypotheses from a case insurance company. The results for various analyses are presented following each of these descriptive sections. Finally, conclusions are presented and suggestions are made for future studies.

2 Literature Review

The insurers' risk includes market risk, credit risk, business risk, underwriting risk, liquid risk and event risk (Report of Solvency Working Party 2002). According to the research of Ryan et al. (2001), from 1969 to 1998, in the U.S. there were 683 events where the insurer failed to pay off. The percentage of events with insurance underwriting risk was 42 %. Thus, underwriting risk is the most significant risk source of the insurers. Luthard and Wiening (2006) defined underwriting as the selection of the insured, the setting of coverage, the decision of the conditions of the insured and the examination and decision-making of business. Dorfman (1998) suggested that the purpose of underwriting is to match the actual loss of insurance companies with the expected loss and avoid the adverse selection of risk.

Group insurance means a corporation of at least five persons, which formation is not for the sole purpose of purchasing insurance, takes out insurance in insurance companies to cover the risk of financial loss caused by diseases, injury, or the death and retirement of the group members and their relatives. In order to have a precise research scope, the researcher focused on samples of group accident insurance.

Arrow (1963) first proposed asymmetric information theory. Rothschild and Stiglitz (1976) and Shavell (1979) applied asymmetric information theory to their studies on insurance and suggested that asymmetric information in the insurance market will cause adverse selection and moral hazard. The related research has mainly focused on automobile insurance and various kinds of life insurance. (Li et al. 2004) suggested that these two kinds of insurance have individual attributes that are close to group attributes.

From the perspective of asymmetric information, group accident insurance assessors are certainly a party receiving asymmetric information. In the acquisition of insurance information, salespersons collect the clients' information and pass it to the underwriters as a reference. However, since the information may be incomplete, the underwriters may be inexperienced, or there may be a lack of samples or analysis in the returned statistics, there can be errors in decision making. After taking out insurance, the individuals participating in group accident insurance may change and the risk is dynamic. There will be various errors from the start to the end of the period of insurance.

Rothschild and Stiglitz (1976) suggested that with asymmetric information, the party having more information makes selections based on personal interest and harms the right of the party with less information. This is known as adverse selection. However, De Meza and Webb (2001) proposed advantage selection and suggested that insurance companies' information asymmetry is reflected on the types of risk and risk preference. Individuals who are risk averse will purchase insurance and be concerned about personal risk factors. Thus, the probability of accidents is low and the insurers can acquire benefits above quota. (Wang et al. 2008) suggested that in a well-developed insurance market, asymmetric information will disappear because of a powerful underwriting system.

In studies on the construction of insurance assessment, (Lee and Ting 2004) evaluated the underwriting system of automobile insurance using the Logit model and the GANN model and demonstrated that the evaluation performance of these two models was at least 80 %. Shih (2004) explored the adverse selection and moral hazard of labor with occupational fatality insurance in Taiwan and realized that labor has adverse selection when taking out insurance and there is moral hazard in the application for payment. Among literatures on rate factors, (Chou et al. 2010) used logistic regression to examine the business of personal accident insurance in one property-liability insurance company and demonstrated that age, place of accident, occupation and place significantly influence the factors for the loss ratio.

Regarding the group insurance of one life insurance company. (Chen et al. 2008) used logistic regression to establish the discriminant claim model and explored the factors of claim using regression analysis. It was found that the precision of the discriminant reimbursement rate constructed by logistic regression was 81.7 %.

3 Research Method

3.1 Data and Research method

1. Data

The research data consisted of group insurance policies and the claim of one property-liability insurance company in Taiwan in 2009 and 2010. The regions of were across Taiwan. The number of samples was 2,373 in 2009 and 2,150 in 2010. After the elimination of invalid samples, the number was 2,362 in 2009 and 2,143 in 2010. The explanatory variables included death and dismemberment insured amount (AD&D), medical expense insured amount (MR), the percentage of medical insurance expense amount in death and dismemberment (MR/AD&D), the daily hospitalization indemnity insured amount (DHI), and the percentage of daily hospitalization indemnity insured amount in death and dismemberment (DHI/AD&D). The variables for validating reimbursement included the loss frequency, loss severity and loss ratio. In order to lower the gap among the variables, the variables were classified according to the degree of risk. Operational definitions of variables are shown in Table 1. In addition, the descriptive statistics of the variables are listed in Table 2.

2. Variables

Explanatory variables: Regarding insured amount, the setting of life insured amount should be appropriate. With low life insured amount, the employees will lack a guarantee, while high coverage will cause moral hazard. The setting of group insurance coverage is not based on group members' decisions; instead, it relies on employees' salary, positions, working years or fixed amounts. There should be no adverse selection or moral hazard. However, since there can be errors in the setting of group insurance that are caused by external factors, an examination is necessary. For the insured, those with higher risk will select higher insured amount. However, the underwriters hope that people with higher risk will select lower insured amount. The balance of the two parties will be the insured amount. Although death and dismemberment loss severity is high, the loss frequency is low. Medical insurance loss severity is low and the loss frequency is much higher than that for death and dismemberment. Thus, the insured will lower the amount of death and dismemberment insurance coverage or increase the amount of medical insurance coverage. Underwriters will adopt a percentage of the medical insured amount in the death and dismemberment insured amount in

Table 1 Operational definition of variables

Variable		Operational definition
Explanatory variables	AD&D	X <= 1,000,000, V = 1; 1,000,000 < X <= 3,000,000, V = 2;X > 3,000,000, V = 3
	MR	X = 0, V = 1; X <= 20,000, V = 2;X > 20,000, V = 3
	MR/AD&D	X = 0 %, V = 1; 0 % < X <= 2 %, V = 2; X > 2 %, V = 3
	DHI	X = 0, V = 1; X <= 1,000, V = 2; X > 1,000, V = 3
	DHI/AD&D	X = 0, V = 1; 0 % < X <= 0.001, V = 2; X > 0.001, V = 3
Explained variables	Loss frequency	X = 0, V = 1; X <= 3, V = 2; X > 3, V = 3
	Loss severity	0, V = 1; 0 < X <= 500,000, V = 2; X > 500,000, V = 3
	Loss ratio	0, V = 1; 0 < X <= 100 %, V = 2; X > 100 %, V = 3

Table 2 Descriptive statistics

Variables		2009					2010				
		N	Min	Max	Mean	S.D.	N	Min	Max	Mean	S.D.
Explanatory variables	ADD	2373	1	3	2.02	0.25	2150	1	3	1.37	0.55
	MR	2373	1	3	1.85	0.57	2150	1	3	1.90	0.48
	MR/ADD	2366	1	3	1.77	0.46	2148	1	3	1.87	0.44
	DHI	2373	0	3	2.01	0.62	2150	1	3	1.85	0.52
	DHI/ADD	2366	1	3	1.81	0.40	2148	1	3	1.80	0.45
Explained variables	Loss frequency	2373	0	3	1.27	0.50	2150	1	3	1.21	0.44
	Loss severity	2373	0	3	1.26	0.46	2150	1	3	1.21	0.42
	Loss ratio	2370	1	3	1.32	0.59	2150	1	3	1.22	0.47
Valid N (listwise)				2,366					2,148		

order to find the adverse selection of the insured when taking out insurance. Explained variables: Loss frequency is the number of losses during the insurance period. If a group has high loss frequency, it means that the group neglect to pay attention to its risk management on behalf of the group. For this type of business, the underwriters will be taken out of business or measures to reduce the insured amount. Loss severity, the characteristics of the accident is the loss of low frequency, the magnitude of such losses. For individual business, the magnitude of such losses and can not prove that this business is bad business. But on the whole, the loss of a large range of cases accumulated as the underwriters to develop underwriting guideline and an important underwriting experience. The loss ratio is equal to loss amount/insured amount. To the individual, high loss rate means that the profit contribution of the business of insurance companies is negative. For these businesses, Underwriters had to understand the exact cause. Indeed own business poor quality, it will increase premiums to reflect reasonable price to the customers.

3.2 *Research Model*

T-1 χ^2 test for independent

$$\chi^2 = \sum_{i=1}^{a} \sum_{j-1}^{b} \frac{(o_{ij} - e_{ij})^2}{e_{ij}}$$

T-2 Decision Rule

Decision	Population	
	H_0 is true	H_0 is false
Accept H_0	Correct decision	False acceptance
Reject H_0	False rejection	Correct decision

T-3 Ordered Logistic Regression was employed to Verify assumptionslog $\left(\frac{P(y \le j|x)}{1-P(y \le j|x)}\right) = \beta_j - \sum_{k=1}^{K} \beta_k x_k$, j = 1, low risk ranking; j = 2, middle risk ranking; j = 3, high risk ranking. x_k, the kth independent variable.

4 Empirical Results and Analysis

T-1: Do high-insured amount lead to choose high loss?

Table 3 shows the relation insured amount and loss. Apart from 2010 AD&D of the *P* value was larger, and the rest are very small. It means that there is connected between the insured amount and the loss.

Table 3 The relation of insured amount and loss

Loss *p*-value	Loss frequency		Loss severity		Loss ratio	
Amount	2009	2010	2009	2010	2009	2010
ADD	0.00	0.12	0.00	0.00	0.00	0.08
MR	0.00	0.00	0.00	0.00	0.00	0.00
MR/ADD	0.00	0.00	0.00	0.00	0.00	0.00
DHI	0.00	0.00	0.00	0.00	0.00	0.00
DHI/ADD	0.00	0.00	0.00	0.00	0.00	0.00

Table 4 Decision rule–insured amount and loss

Type of insurance	Type of claim	Low amount high loss		Correction decision		High amount low loss	
		2009 (%)	2010 (%)	2009 (%)	2010 (%)	2009 (%)	2010 (%)
ADD	Claim frequency	3.20	14.65	23.09	56.56	73.70	28.79
	Claim severity	1.81	14.42	24.61	56.84	73.58	28.74
	Loss ratio	7.30	15.02	19.16	56.23	73.54	28.74
MR	Claim frequency	3.23	2.42	42.23	31.91	54.45	65.67
	Claim severity	2.28	1.77	45.39	32.73	54.81	65.86
	Loss ratio	6.92	3.21	38.95	31.07	54.14	65.72
MR/ADD	Claim frequency	3.89	2.42	43.87	32.26	52.24	65.32
	Claim severity	2.41	1.77	45.39	32.73	52.20	65.50
	Loss ratio	7.61	3.21	40.28	31.42	52.11	65.36
DHI	Claim frequency	2.82	3.95	35.31	34.28	61.86	61.77
	Claim severity	1.39	3.26	36.76	34.84	61.85	61.91
	Loss ratio	5.78	4.56	33.67	33.63	60.55	61.81
DHI/ADD	Claim frequency	3.17	4.00	39.86	34.78	56.97	61.22
	Claim severity	1.69	3.26	41.46	35.47	56.85	61.27
	Loss ratio	7.31	4.66	35.84	34.12	56.85	61.22

T-2: Does business quality management help lower the loss?

Table 4 shows the effects of business quality management. Correct rate, only the AD&D has significantly improved, and the rest showed a downward. In particular, MR, MR/AD&D is even more evident. High insured amount and low losses (False rejection), in underwriting too strict. The one hand, allows the company to generate underwriting profits, but because of reduced premium cash inflow. The ratio was significantly reduced have AD&D, significantly improved MR, DHI. Therefore, AD&D, MR and DHI have a considerable impact on the business quality control.

T-3: What factors impact the loss?

1. Validation of loss frequency

Table 5 shows the factor affect loss frequency. As to the effects of business quality management, MR, DHI/ADD had a positive effect and MR/ADD had a negative effect.

Table 5 The factor affect loss frequency

Parameter estimates—loss frequency		2009					2010				
		Est.	Std.	Wald	df	Sig.	Est.	Std.	Wald	df	Sig.
Threshold	lossfre = 1	4.80	0.74	41.92	1	0.00	3.16	0.37	72.30	1	0.00
	lossfre = 2	7.43	0.75	97.48	1	0.00	6.14	0.42	215.33	1	0.00
Location	ADD	−0.41	0.25	2.67	1	0.10	−0.09	0.11	0.64	1	0.42
	MR	0.53	0.16	10.77	1	0.00	−0.13	0.34	0.15	1	0.70
	MR/ADD	0.39	0.23	2.95	1	0.09	0.76	0.37	4.27	1	0.04
	DHI	−0.07	0.12	0.31	1	0.58	−0.37	0.27	1.89	1	0.17
	DHI/ADD	1.53	0.28	29.06	1	0.00	0.77	0.31	6.34	1	0.01

Table 6 Factors affect loss severity

Parameter estimates–loss severity		2009					2010				
		Est.	Std.	Wald	df	Sig.	Est.	Std.	Wald	df	Sig.
Threshold	loss severity = 1	4.98	0.74	44.80	1	0.00	3.06	0.37	68.05	1	0.00
	loss severity = 2	8.64	0.77	124.62	1	0.00	7.07	0.49	209.95	1	0.00
Location	ADD	−0.30	0.25	1.38	1	0.24	−0.10	0.11	0.88	1	0.35
	MR	0.44	0.16	7.12	1	0.01	−0.15	0.34	0.19	1	0.66
	MR/ADD	0.47	0.23	4.14	1	0.04	0.76	0.37	4.28	1	0.04
	DHI	−0.06	0.12	0.23	1	0.63	−0.30	0.27	1.29	1	0.26
	DHI/ADD	1.52	0.28	28.60	1	0.00	0.67	0.30	4.86	1	0.03

Table 7 Factor affect loss ratio

Parameter estimates–loss ratio		2009					2010				
		Est.	Std.	Wald	df	Sig.	Est.	Std.	Wald	df	Sig.
Threshold	lossratio = 1	4.82	0.73	43.43	1	0.00	3.07	0.37	69.20	1	0.00
	lossratio = 2	6.43	0.74	76.30	1	0.00	5.51	0.40	192.38	1	0.00
Location	ADD	−0.34	0.25	1.81	1	0.18	−0.10	0.11	0.75	1	0.39
	MR	0.41	0.16	6.51	1	0.01	−0.17	0.34	0.25	1	0.62
	MR/ADD	0.46	0.23	4.07	1	0.04	0.79	0.37	4.62	1	0.03
	DHI	−0.06	0.12	0.28	1	0.60	−0.29	0.27	1.20	1	0.27
	DHI/ADD	1.52	0.28	29.44	1	0.00	0.65	0.30	4.68	1	0.03

2. Validate of loss amount

Table 6 shows the factor affect loss severity. As to the effects of business quality management, MR, DHI/ADD had a positive effect and MR/ADD had a negative effect.

3. Validate of loss ratio

Table 7 shows the factor affect loss ratio. As to the effects of business quality management, MR, DHI/ADD had a positive effect and MR/ADD had a negative effect.

5 Conclusion and Future Studies

Regarding T-1, Can see that the insured amount is indeed related losses, but can not be further evidence of the high insured amount will lead to high losses. Regarding T-2, Further AD&D significantly improved the probability lead to high losses in high insured amount. The business quality management lowers the effect of loss. However, as to T-3, the factors affect loss were MR, MR/ADD, DHI/ADD. This study explores the correlation between insured amount and losses. The research method is including independent test, decision rule and Ordered Logistic Regression, the region is Taiwan and the data includes 2 years. Increasing the research data periods of free premium rate insurance and validating them by other methods will allow the study of this field to be more complete.

References

Chen C-H, Lin M-C, Gong Y-C (2008) An empirical study on the compensation ratio of group insurance. J Risk Manag 10(2):133–155

Chou PL, Yao CH, Shih PH (2010) An analysis on risk factors of personal injury insurance in property-liability insurance industry. J Underwriters 19:29–60

de Meza D, Webb DC (2001) Advantage selection in insurance market. Rand J Econ 32:249–262

Dorfman MS (1998) Introduction to risk management and insurance. Prentice Hall, Upper Saddle River

Lee WC, Ting J (2004) The construction of the physical damage automobile insurance underwriting system: empirical study in Taiwan. Insur Monograp

Li C-S, Chi C, Yeh JH (2004) The inconsistency between asymmetric information theory and empirical evidence in insurance markets. Insur Monogr 20(2):99–112

Report of Solvency Working Party (2002) International Association of Insurance

Rothschild M, Stiglitz J (1976) Equilibrium in competitive insurance markets: an essay on the economics of imperfect Information. Q J Econ 90(4):629–649

Ryan JP, Archer Lock PR, Czernuszewicz AJ, Gillot NR, Hinton PH, Ibeson D, Malde SA, Paul D, Malde SA, Paul D, Shah N (2001) Financial condition assessment. Inst Actuaries Fac Actuaries

Shih Yang (2004) Note on union workers participating in occupational injury insurance: the perspective of adverse selection and moral hazard. Insur Issue Practices 3(1):53–76

Wang JL, Chung C-F, Tzeng LY (2008) An empirical analysis of the effects of increasing deductibles on moral hazard. J Risk Insur 75(3):551–566

Manipulation Errors in Blindfold Pointing Operation for Visual Acuity Screenings

Ying-Yin Huang and Marino Menozzi

Abstract We developed a self-testing device for screening visual acuity, in which patients used a joystick to enter the responses. Since patients kept fixation of the test chart throughout the test, the joystick was operated blindfold. Pointing errors as function of the orientation of the Landolt ring were computed by analyzing records of 457 patients. In 97 % of errors, patients misestimated the orientation of the Landolt ring by 45°, which is the orientation next to the one presented. Mismatches in counter clockwise direction were 3 times more frequent as in clockwise direction. Findings are compared to results recorded in 25 subjects who performed acuity tests by reporting verbally the orientation of presented Landolt rings. In the verbal reporting condition, error rates for orthogonal and diagonal orientations were similar. We suggest considering the limited accuracy of motor response as a major issue in the blindfolded operation of a joystick which is used in combination with a vision screener. Furthermore we suggest a statistical procedure accounting for manipulation errors in an acuity test. The combination of previous findings (Menozzi 2013, 1995) to findings reported here suggests that computerized screening devices enabling self-testing are a reliable and convenient method for large scale vision screenings.

Keywords Vision screening · Blindfolded pointing · Manipulation · Acuity test

Y.-Y. Huang (✉)
Department of Management, Technology and Economics and Department of Health Sciences and Technology, Ergonomics of Information Media Research Group, ETH Zurich, Scheuchzerstrasse 7, CH-8092 Zurich, Switzerland
e-mail: yingyinhuang@ethz.ch

M. Menozzi
Department of Health Sciences and Technology, Ergonomics of Information Media Research Group, ETH Zurich, Scheuchzerstrasse 7, CH-8092 Zurich, Switzerland
e-mail: mmenozzi@ethz.ch

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_85,

1 Introduction

Medical screenings of physiological functions have become widespread in the occupational health sector. Depending on the country and on the workplace, medical screenings are performed as part of entrance requirements in many different occupations. Also screenings are applied repeatedly during employment in order to detect adverse health effects of workplace hazards. Occupational medical screenings are important workload in personnel involved in occupational health. From a personal communication of physicians of a Swiss pharmaceutical company we have learned that a large size company may perform as many as 10,000–20,000 medical screening tests per year. Since usually the resources allocated to the occupational screening process are of limited nature, the question arises on how screenings can be accomplished within a given time frame and with respecting quality measurement. A frequently adopted strategy to fulfill mentioned requirements is to adopt a two phase screening. In a first phase the total population is screened by means of a coarse test of a short duration. Patients failing the coarse test are sent to a detailed examination which is performed in a second phase. As has been shown by Krueger (1991), a two phase screening strategy may save an important amount of time when compared to a detailed examination of the total population. A further improvement of efficiency in large scale screenings may be achieved by using fully computerized devices enabling patients to perform sophisticated tests by themselves without the need of personnel for administering the tests. As we were able to show for the case of visual screening tests, acceptability in patients taking self-administered tests is high (Menozzi 2013). Furthermore, we were able to show that for the particular case of acuity testing, the standard procedure of acuity testing (ISO 8596:2009 “Ophthalmic optics—Visual acuity testing—Standard optotype and its presentation”) can be accomplished in a short amount of time (Menozzi 2013).

The implementation of standard vision screening procedures as a self-testing method necessitates a closer look on the method used to record patients’ responses. Input device requiring a visual feedback are disturbing the process of testing since the patient is required to alternate fixation between the visual target used in the test and the input device. A PC mouse may be used in tests requiring a simple “yes” or “no” answer, such as is the case in perimetry testing. As from our experience (Menozzi et al. 2012) the PC mouse can be operated blindfolded, even by untrained patients and either by using two fingers of the same hand or by using two hands. However, it is hard to use a PC mouse in tests requiring a complex response such as the standard visual acuity measurement using Landolt rings of eight different orientations (see Fig. 1, right). After practical and theoretical considerations the use of keyboards, keypads and voice input devices have been considered as not adequate to be used in large scale vision screenings. We therefore considered the joystick (see Fig. 1, left) as the next best choice to accommodate requirements in acuity vision measurement basing on the ISO 8596:2009 standard (“Ophthalmic optics—Visual acuity testing—Standard optotype and its presentation”).

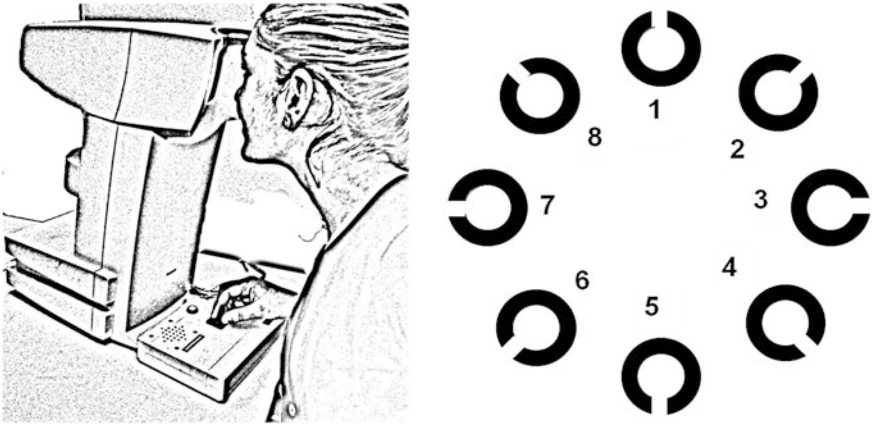


Fig. 1 The picture on the *left* shows a participant gazing into the vision screener and giving a response by means of the joystick included in the answering box which is placed besides the vision screener. For convenience of the photo, the box is placed in front of the screener. On the *right*, Landolt rings in eight different orientations are shown. Used test charts contained five lines, each consisting out of five Landolt rings having the same demand of acuity but varying in orientation

Blindfolded pointing and manipulations have been reported in the scientific literature (Wnuczko and Kennedy 2011; Gentaz et al. 2008). Findings show that blindfolded pointing may deviate from visually guided pointing and that participants perform less accurate in pointing in oblique directions than it is the case for orthogonal directions. However, the accuracy in blindfolded use of a joystick for pointing in eight pre-defined, equidistant orientations remains unclear. The aim of the here reported study was to gain more insight into the accuracy of blindfolded pointing using a joystick. For this purpose we analyzed visual acuity measurements recorded in 457 participants during a health promotion campaign.

In order to separate contributions of the motor system to response errors in blindfold operation of the joystick from response errors originating in the visual system, data recorded in an experiment (unpublished) were analyzed, in which 25 patients gave verbal response on the orientation of the Landolt ring.

2 Method

The accuracy in blindfolded operation of a joystick was investigated using anonymous records of 457 employees working in the railway sector who visited a health promotion campaign which was held in 2006 in Switzerland. Most of the participants (96 %) visiting the health promotion campaign were men and the age in about 45 % of the participants ranged between 41 and 50 y. Further details are given in a previous publication Menozzi (2013). Participants were offered to take an acuity test (Fog. 1) using a computerized self-testing device. The device consisted out of a commercial available vision screener (Rodatest 302) and a purpose built answering box. The answering box included, an analog joystick, a button for starting the test procedure and a loudspeaker. The lever of the joystick had a diameter of 0.8 cm and stick up about 3.5 cm from the top of the answering box. A bearing was inserted inside the housing of the joystick. The bearing served to limit movements of the joystick in the two orthogonal and the two diagonal directions in accordance to the eight orientations of the Landolt rings used in the acuity test.

The vision screener and answering box were connected to a notebook administering the tests in the vision screener and recording the answers of the participants. For taking a test, participants sat in front of the vision screener and pressed their forehead on the appropriate support of the vision screener (Fig. 1, left). After pressing the start button of the answering box instructions for taking the test were given to the participants by means of the loudspeaker. Test charts presented inside the vision screener were viewed though the optic of the vision screener.

Each participant underwent three acuity tests (left eye, right eye, binocular) for far (5 m) vision and one (binocular) acuity test for near (0.4 m) vision. In each acuity test a test chart including five lines of Landolt rings was presented. The acuity demand varied from line to line, starting from decimal acuity 0.5 (logMAR 0.3) in the top line and ending with decimal acuity of 1.25 (logMAR −0.1) in the bottom line. The orientation of the Landolt rings varied pseudo random in accordance to the ISO 8596:2009 standard. Participants were asked to read line by line all rings in the chart, starting from the top left ring and to enter the orientation of each ring by pushing the lever of the joystick in the appropriate direction. Before starting the acuity test, a trial session was performed in order to ascertain the correct use of the joystick. Landolt rings of a low acuity demand (decimal acuity 0.2) were used in the trial session. An acoustic feedback indicated the correct use of the joystick in the trial session.

For each participant a total of 125 responses were recorded. Responses and the correct orientation of each of the presented Landolt rings were stored in a file. The file was imported into an excel data sheet and processed by means of a macro. In a first step, the macro determined acuity achieved in each of the five tests by adopting rules in accordance to the ISO 8596:2009 standard. In a second step, the macro computed the frequency of errors as well as the distribution of sizes of the errors (mismatch in orientation) as function of the orientation of the Landolt ring. In the second step, only responses to Landolt rings having a demand of acuity lower than or equal achieved acuity were considered. This condition is further on referred to as the “pass condition”. The second step was repeated considering all responses to Landolt rings having a higher demand of acuity than the achieved one. This condition is further on referred to as the “fail condition”. In the “fail condition”, Landolt rings are smaller than in the “pass condition”.

In order to separate contributions of the motor system to response errors in blindfold operation of the joystick from response errors originating in the visual system, acuity data of a previous experiment (unpublished) were analyzed, in which 25 patients reported verbally the orientation of the Landolt rings. The experimenter recorded the orientation of presented Landolt rings as well as the reported orientation. Acuity measurements were carried monocularly and in accordance to the method described in the ISO 8596:2009 standard. The age of the patient in the previous experiment ranged between 14 y and 57 y and average visual acuity was −0.1 logMAR (decimal acuity 1.2) in eight and −0.2 logMAR (decimal acuity 1.5) in 17 eyes.

3 Results

For responses given to Landolt rings having an acuity demand below the achieved acuity level (the "pass" condition), data sets of 457 participants were processed. For responses given to Landolt rings having an acuity demand above the achieved acuity level (the "fail" condition), data of only 342 participants were processed due to failure of the macro processing the data.

The net diagrams in Fig. 2 report error frequency as function of the orientation of the Landolt ring. The left graph in Fig. 2 has been computed using responses given in the "pass condition". Data reported in the right graph has been computed using responses given to Landolt rings in the "fail condition".

The total number of errors was 6,310 and 1,291 in the "pass condition" and in the "fail condition" respectively. As shown by the graphs in Fig. 2, errors on orthogonal oriented Landolt rings (steps 1, 3, 6 and 7) appear visibly less frequent than errors on diagonal oriented rings. The ratio between the frequency of errors occurring on orthogonal orientations and errors occurring on diagonal orientations is 0.07 in the "pass condition" and 0.26 in the "fail condition". The size of the error is the mismatch between the orientation of the presented Landolt ring and the

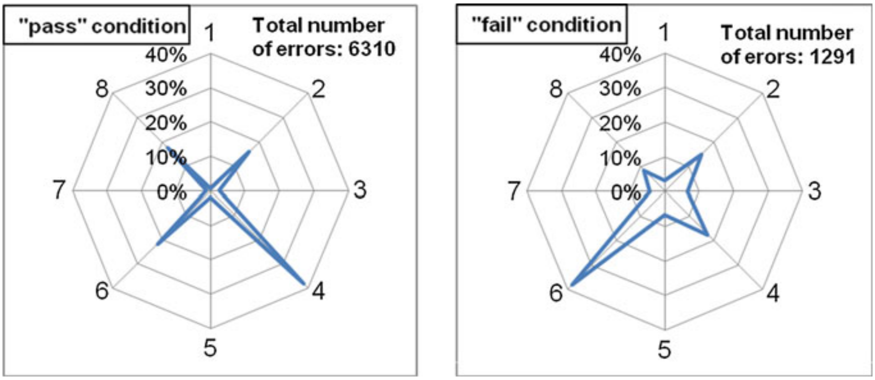


Fig. 2 Error frequency as function of orientation of the Landolt ring (see Fig. 1) for responses given to rings having a demand of acuity below or equal (left graph in Fig. 2) and above (right graph in Fig. 2) achieved acuity

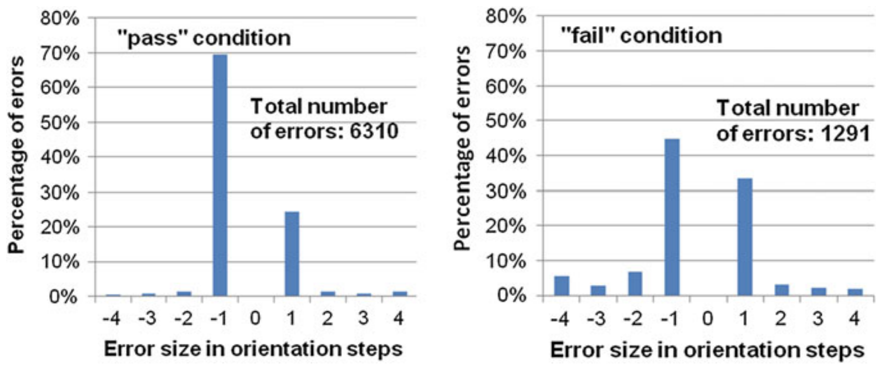


Fig. 3 Distribution of error size in orientation steps. One step corresponds to an error of 45°. Data in the *upper* graph refer to the "pass" condition, i. e. when the acuity demand was lower than achieved acuity. Data in the *bottom* graph report error sizes distribution for acuity demands higher than the achieved acuity

orientation which was pointed by the participant. Since the eight orientations are equidistant distributed, the size of the error varies in steps of 45°. In Fig. 3, the distribution of errors as function mismatch is reported for errors recorded in the "pass condition" (left in Fig. 3) and for errors reported in the "fail condition" (right in Fig. 3). Error size in Fig. 3 is reported in number of steps of orientation mismatch. As can be seen from Fig. 3, mismatch of one step appear much more frequent as larger size of mismatches. In the "pass condition" about 94 % of mismatches were either +1 or −1 step in size. In the "fail condition" mismatches of 1 step appear in 75 % of errors. Also mismatches with negative step size, which are in fact a counter clockwise (CCW) mismatch of the orientation, are more frequent than clockwise (CW) mismatches. The ratio between CCW and CW mismatches is 72/23 in the "pass condition" and 60/40 in the fail condition respectively.

Results of the experiment in which patients' answers were given verbally showed no substantial difference in error rates between errors appearing at orthogonal and errors appearing at diagonal oriented Landolt rings. A total of 398 answers were recorded, 234 for orthogonal and 164 for diagonal oriented Landolt rings. The percentage of errors was 21.8 % in orthogonal oriented rings and 18.9 % in diagonal oriented rings.

4 Discussion

In the experiment with the blindfold operation of the joystick, the errors were more equal distributed across orientation of the Landolt ring in the "fail condition" as was the case for the "pass condition". This is in part due to the reduced visibility of the Landolt rings in the "fail condition". However, in the "fail condition" diagonal errors still appear more pronounced in the diagonal orientation than is the case for the orthogonal orientation. Part of the effect could be due to the varying sensitivity of the visual system with orientation of a target as has been reported for sine wave gratings of different orientations (Watanabe et al. 1968). Possibly other than visual phenomenon may have a major contribution to the variation of errors as function or orientation. For instance, manipulation tasks in an orthogonal direction may be accomplished easier than manipulations in a diagonal direction.

In the "pass condition" 94 % of mismatches are of a size of 1 step, which is 45°. When the ring is less visible, as in the "fail condition", the percentage of mismatches of 1 step in size is reduced to 78 %. For a random response, we would expect the percentage of errors of a size of 1 step to be about 25 %. This finding suggests a limited accuracy in motor response in the blindfolded use of the joystick. Another effect indicating the impact of inaccurate motor response is the asymmetry of mismatches in counter clockwise and in clockwise direction.

Results of the experiment in which patients operated the joystick blindfold show a clear difference in error rates for orthogonal and for diagonal oriented Landolt rings. Such a difference was not found in results of the experiment in which patients reported verbally the orientation of the Landolt rings.

5 Conclusions

Our work aimed to investigate motor response accuracy in blindfolded operation of a joystick which was used as input device in a vision screener. For this purpose we analyzed response errors recorded in acuity tests of 457 participants who reported the orientation of Landolt rings by blindfold operation of a joystick. Possible contributions of the visual system to the inaccuracy in detecting orthogonal and diagonal oriented Landolt rings was investigated using 25 subjects verbally reporting the orientation of presented Landolt rings.

Given above reported findings we suggest to consider limited accuracy in motor response as an important issue in the blindfolded operation of a joystick. Accuracy of motor response for orthogonal directions (up, down, left, right) was found to be clearly better than for diagonal directions. Accuracy in verbal reporting of the orientation of the Landolt ring did not show a significant difference between orthogonal and diagonal orientations.

As for the case of the vision screener, a visual feedback of the joystick action could be displayed in combination with the targets used for the test of visual acuity. Alternatively, one could take into account limited accuracy of the motor responses by altering the evaluation of the response. A mismatch of one step in size could be considered as a correct answer. In order to keep the chance level for passing a given acuity the same as in the ISO 8596:2009 standard "Ophthalmic optics—Visual acuity testing—Standard optotype and its presentation", the stopping criterion must be altered from at least 3 correct readings in 5 presentations to at least 4 correct readings in 5 presentations.

Acknowledgments The authors wish to thank Esther Baumer-Bergande and Urs Hof for data collection and their great help in this project.

References

Gentaz E, Baud-Bovy G, Luyat M (2008) The haptic perception of spatial orientations. Exp Brain Res 187:331–348

Krueger H (1991) Der Betriebsarzt im Spannungsfeld zwischen Arbeitsplatzbegehung und spezieller arbeitsmedizinischer Vorsorgeuntersuchung aus der Sicht eines Arbeitsphysiologen. Zbl Arbeitsmed 41:361–368

Menozzi M (1995) Der Personal Computer im Einsatz beim Screening visueller Funktionen. Klin Monatsbl Augenheilkd 206(5):405–408

Menozzi M (2013) A field report on self-screening visual acuity using a computerized vision screener. Klin Monatsbl Augenheilkd (in press)

Menozzi M, Bauer-Bergande E, Seiffert B (2012) Working towards a test for screening visual skills in a complex visual environment. Ergonomics 55(11):1331–1339

Watanabe A, Mori T, Nagata S, Hiwatashi H (1968) Spatial sine-wave response in the human visual system. Vision Res 8:1245–1263

Wnuczko M, Kennedy JM (2011) Pivots for pointing: Visually-monitored pointing has higher arm elevation than pointing blindfold. J Exp Psychol Hum Percept Perform 37(5):1485–1491

3-Rainbow Domination Number in Graphs

Kung-Jui Pai and Wei-Jai Chiu

Abstract The k-rainbow domination is a location problem in operations research. Give an undirected graph G as the natural model of location problem. We have a set of k colors and assign an arbitrary subset of these colors to each vertex of G. If a vertex which is assigned an empty set, then the union of color set of its neighbors must be k colors. This assignment is called the k-rainbow dominating function, abbreviate as kRDF, of G. The weight of kRDF is the sum of numbers of assigned colors over all vertices of G. The minimum weight of kRDF is defined as the k-rainbow domination number of G. In this paper, we present an exact algorithm and a heuristic algorithm to obtain the 3-rainbow domination number and the weight of 3RDF in graphs, respectively. Then, we test the practical performances of these algorithms, including their run times and solution qualities.

Keywords Domination · k-rainbow domination · Location problems

1 Introduction

Domination problem and its variations have been studied since antiquity. They are natural models for the location problems in operations research. They have been extensively studied in the literature; see Haynes et al. (1998). A *dominating set* of a graph G is a subset D of V(G) such that every vertex not in D is adjacent to some vertex in D. We usually call the vertex in D as *dominating vertex*, and call the

K.-J. Pai (✉) · W.-J. Chiu
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei City, Taiwan
e-mail: poter@mail.mcut.edu.tw

W.-J. Chiu
e-mail: a123750203@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_86,

vertex not in D as *dominated vertex*. A graph is said to be dominated if any vertex is either a dominating vertex or a dominated vertex. Thus, a *dominated graph* is determined by the number of dominating vertices and the locations where they are placed. It is often desirable to build a fully dominating system with the minimum dominating vertices. The *domination number* $\gamma(G)$ of G is the minimum cardinality of a dominating set of G.

For example, a domination of graph G is shown in Fig. 1. We select vertices V_1, V_6 and V_9 in the dominating set. Vertices V_2, V_3, V_4 and V_5 are dominated by vertex V_1. Vertex V_7 are dominated by vertex V_6, and vertex V_8 are dominated by vertex V_9. Thus, the graph G is dominated and domination number $\gamma(G) = 3$.

The k-rainbow domination was introduced by Brešar et al. (2005), and it is a variant of classical domination. Let $G = (V(G), E(G))$ be a finite, simple and undirected graph, where V(G) and E(G) are the vertex and edge sets of G, respectively. Two vertices u and v are neighbors of each other if $(u, v) \in E(G)$. For a vertex $v \in V(G)$, the open neighborhood $N(v) = \{u \in V(G) \mid (u, v) \in E(G)\}$. Let $C = \{1, 2,\ldots, k\}$ be a set of k colors, and f be a function that assign to each vertex a set of colors chosen from C, that is, f: $V(G) \to P(\{1,\ldots, k\})$. If for each vertex $v \in V(G)$ such that $f(v) = \emptyset$ we have $\cup_{u \in N(v)} f(u) = C$ then f is called a *k-rainbow dominating function* (kRDF) of G. The *weight*, $\omega_k(f)$, of a function f is defined as $\omega_k(f) = \Sigma_{v \in V(G)} |f(v)|$. We call $\omega_k(f)$ as the *number of k-rainbow domination* that is the sum of numbers of assigned colors over all vertices of G. The *k-rainbow domination number*, $\gamma_{rk}(G)$, of G is the minimum weight of a k-rainbow dominating function.

For example, a 3-rainbow domination of graph G is shown in Fig. 2a. We assign a color set {1} to V_4, V_6, a color set {2} to V_3, V_9 and a color set {3} to V_5, V_7. Since the color set of every one of vertices V_1, V_2 and V_8 is empty, the union of color set of their neighbors must be 3 colors. Vertex V_1 has a neighbor V_4 with color set {1}, a neighbor V_3 with color set {2} and a neighbor V_5 with color set {3}, so Vertices V_1 is dominated. Similarly, Vertices V_2 and V_8 have neighbors with color sets {1}, {2} and {3}, respectively. Another 3-rainbow domination of graph G is shown in Fig. 2b. We assign a color set {1, 2, 3} to V_2, a color set {3} to V_4 and a color set {1, 2} to V_9. Vertices V_1, V_3, V_6 and V_7 have a neighbor V_2 with a color set {1, 2, 3}, so they are dominated. Vertices V_5 and V_8 are dominated, since common neighbors V_4 with a color set {3} and V_9 with a color set {1, 2}. Consequently, $\omega_3(f) = 6$ in both Fig. 2a and b. In fact, $\gamma_{r3}(G) = 6$ by brute-force search.

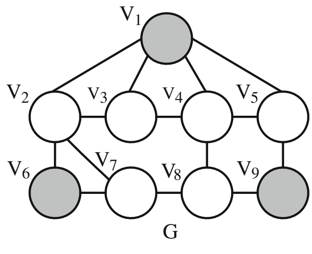


Fig. 1 A domination of graph G. Gray vertices represent dominating vertices and white vertices represent dominated vertices

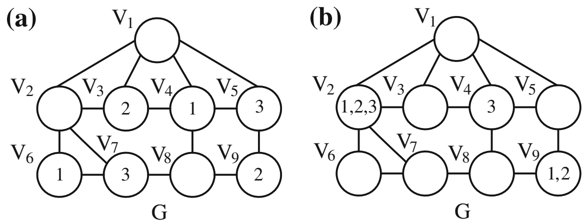


Fig. 2 3-rainbow dominations of G. The vertex with a color set {x, y, z} is labeled by "x, y, z" where y and z can be empty

In this paper, we present an exact algorithm to obtain $\gamma_{r3}(G)$ in graphs. When the number of vertices is fixed and the number of edges is decreasing, the run time of the exact algorithm is rapidly increasing. We design a heuristic algorithm to obtain the weight, $\omega_3(f)$, of 3RDF. Then, we test the practical performances of these algorithms, including their run times and solution qualities.

The remaining sections are organized as follows. In Sect. 2, we give a literature review. In Sect. 3, we present an exact algorithm and a heuristic algorithm for 3-rainbow domination of graph. The experiment results of two algorithms are shown in Sect. 4. Finally, some concluding remarks are given in Sect. 5.

2 Literature Review

The concept of k-rainbow domination of a graph G was introduced by Brešar et al. (2005). They stated that domination represents situations in which each vertex on that is not located by a guard needs to have a guard in a neighboring vertex. Then, they consider a more complex situation where there are different k types of guards. Each vertex that is not located with a guard has in its neighborhood all k types of guards. This relaxation leads to the concept of k-rainbow domination.

Brešar and Šumenjak (2007) showed that the decision version of 2-rainbow domination of graphs is NP-complete even when restricted to chordal graphs (or bipartite graphs). They also gave the exact values of the 2-rainbow domination numbers for paths, cycles and suns. Chang et al. (2010) extended the results of Brešar and Šumenjak (2007). They proved that k-rainbow domination problem is NP-complete even when restricted to chordal graphs or bipartite graphs. They also gave a linear-time algorithm for the k-rainbow domination problem on trees.

Thus, further investigations tended to study bounds on k-rainbow domination number for certain families of graphs, such as trees, generalized Petersen graphs and lexicographic product of graphs. This problem is widely studied in Ali et al. (2011), Brešar et al. (2005, 2008), Brešar and Šumenjak (2007), Chang et al. (2010), Fujita et al. (2012), Meierling et al. (2011), Šumenjak et al. (2012), Tong et al. (2009), Xu (2009), Wu and Rad (2010) and Wu and Xing (2010).

3 Algorithms for 3-Rainbow Domination

All graphs considered here are undirected and simple (i.e., finite, loopless, and without multiple edges). We shall use the following notation and terms in this paper. The degree of a vertex in a graph G is the number of its neighbors in G. A leaf is the vertex with degree 1. A support vertex is the only neighbor of leaf. A strong support vertex is the support vertex with at least 2 leaves. Let $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ be two graphs which have disjoint vertex sets V_1 and V_2 and disjoint edge sets E_1 and E_2, respectively. The Cartesian product of G_1 and G_2 is the graph $G_1 \in G_2$ whose set of vertices is the Cartesian product of the sets V_1 and V_2, so $V(G_1 \in G_2) = V_1 \times V_2$. Two vertices of $G_1 \in G_2$, say (v_1, v_2) and (u_1, u_2), are adjacent if and only if $v_1 = u_1$ and $v_2u_2 \in E(G_2)$, or alternatively, if $v_2 = u_2$ and $v_1u_1 \in E(G_1)$.

3.1 An Exact Algorithm

Brešar and Šumenjak (2007) give that the concept of 3-rainbow domination of a graph G coincides with the ordinary domination of the prism $G \in K3,_3$, where K_3 stands for a graph with 3 vertices and each pair of vertices is connected by an edge. By brute-force method, the exact algorithm E3RD test all combinations of γ ($G \in K_3$) vertices from $V(G \in K_3)$.

Algorithm E3RD (Exact 3-rainbow domination)

Input: a graph G.
Output: the $\gamma_{r3}(G)$-set S_2.
Step 1. Obtain the graph H from Cartesian product of G with K_3.
Step 2. Solve the dominating set S_1 on the graph H by brute-force method.
Step 3. The graph H can be treated as three copies of the graph G with additional edges.
Step 3.1. For vertex $v \in S_1$,
Step 3.2. If v is in the first copy, then add v with {1} in S_2.
Step 3.3. Else If v is in the second copy, then add v with {2} in S_2.
Step 3.3. Else add v with {3} in S_2.

+The time complexity of algorithm E3RD is $O(C_{\gamma(H)}^{|V(H)|})$.

3.2 A Heuristic Algorithm

In order to obtain the number of 3-rainbow domination quickly, we design a heuristic algorithm as follows.

Algorithm H3RD (Heuristic 3-rainbow domination)
Input: a graph.
Output: the set S_1 with a color set {1, 2, 3} and the set S_2 with a color set {1}.
Step 1.1. Let V_d be a strong support vertex in G. If $V_d \neq Ø$, go to Step 2.
Step 1.2. Let V_d be a support vertex in G. If $V_d \neq Ø$, go to Step 2.
Step 1.3. Let V_d be a vertex with maximum degree in G.
Step 2. Let set $S_1 = S_1 \cup V_d$.
Step 3. Remove V_d and its neighbors from graph G.
Step 4. Repeat from Step 1 until all degrees of vertices in G are less than 2.
Step 5. Let S_2 be the set with remaining vertices in G.
Step 6. Return S_1 with a color set {1, 2, 3} and the set S_2 with a color set {1}.

⁺The time complexity of algorithm H3RD is $O(|V(G)|^3)$.

4 Experimental Results

In order to observe the results of heuristic algorithm H3RD and exact algorithm E3RD, we have designed a number of experiments. First we design five cases which number of vertices is 16 and numbers of edges are 20, 24, 28, 32 and 36, respectively. For each case we randomly generate 30 connected graphs. The proposed Algorithms E3RD and H3RD were implemented in GNU C programming language. All experiments are performed on a personal computer with 3.4 GHz Intel Core i7-3770 CPU, 8 GB RAM, and running Linux (Fedora Core 17). Two subjects of experiments are to obtain the weight, $\omega_3(f)$, of 3RDF and run times of all graphs. In fact, $\gamma_{r3}(G) = \omega_3(f)$ by Algorithm E3RD.

Once the experiments had been carried out, we used statistics to make sense of the data. Table 1 shows $\omega_3(f)$ and run times of graphs with different number of edges by algorithms E3RD and H3RD. Then, Table 2 shows the difference between $\omega_3(f)$ of H3RD and $\gamma_{r3}(G)$ of E3RD in 30 graphs for each case.

We have the following results.

1. The relations between average $\omega_3(f)$ of 3RDF and the number of edges by two algorithms are shown in Fig. 3. In each algorithm, the average $\omega_3(f)$ of 3RDF is increasing when the number of edges is decreasing. The rum times of algorithm E3RD is increasing so fast when the number of edges is decreasing.
2. As shown in Table 1, the average difference between $\omega_3(f)$ of H3RD and $\gamma_{r3}(G)$ of E3RD is between 1.17 and 1.43 by varied number of edges.
3. As shown in Table 2. In more than 50 % samples, the differences between $\omega_3(f)$ of H3RD and $\gamma_{r3}(G)$ of E3RD are less than or equal to one.
4. In these experiments, the approximate ratio of average $_3(f)$ of H3RD to average $\gamma_{r3}(G)$ of E3RD is less than 1.13.

Table 1 ω_3(f) and run times of graphs with different number of edges by algorithms E3RD and H3RD

	Algorithm E2RD					Algorithm H2RD				
Edge no.	20	24	28	32	36	20	24	28	32	36
ω_3(G) (Max.)	12	11	10	9	9	14	13	13	12	11
ω_3(G) (Min.)	11	8	8	8	7	11	8	9	8	7
ω_3(G) (Ave.)	11.15	10.19	9.35	8.88	8.37	12.54	11.4	10.54	10.31	9.54
ω_3(G) (Std.)	0.36	0.8	0.56	0.33	0.56	1.03	1.25	0.99	0.84	0.81
Run time (Ave. seconds)	14,684	4721	1164	398	210	+	+	+	+	+
Run time (Std. seconds)	10,745	2959	599	125	133	+	+	+	+	+

$^+$ The computing time is less than 1 s

Table 2 The difference between ω_3(f) of H3RD and γ_{r3}(G) of E3RD in 30 graphs for each case

Edge no.	20	24	28	32	36
ω_3(f) of H3RD = γ_{r3}(G) of E3RD	6	11	8	3	6
ω_3(f) of H3RD = γ_{r3}(G) of E3RD + 1	12	9	11	12	16
ω_3(f) of H3RD = γ_{r3}(G) of E3RD + 2	5	4	8	14	6
ω_3(f) of H3RD = γ_{r3}(G) of E3RD + 3	7	6	3	1	2

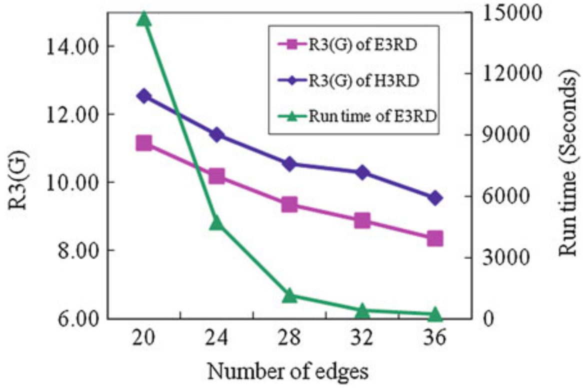


Fig. 3 The relations between average ω_3(f) of 3RDF and the number of edges by two algorithms

5 Conclusions

By the concept of Brešar and Šumenjak (2007), we present an exact algorithm to obtain γ_{rk}(G) in graphs. As shown in experimental results, the run time of exact algorithm is rapidly increasing when number of edges is decreasing. We design a heuristic algorithm to obtain 3-rainbow domination number ω_3(f). Then, we test the practical performances of these two algorithms, including their run times and solution qualities. As shown in the experimental results, our heuristic algorithm can find 1.15-approximation solutions in graphs with 16 vertices and less than 36 edges. The run time of our heuristic algorithm is less than one second which is much faster than the run time of exact algorithm.

Acknowledgments This work is partially supported by NSC101-221-E-131-039 from the National Science Council, Taiwan. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Ali M, Rahim MT, Zeb M, Ali G (2011) On 2-rainbow domination of some families of graphs. Int J Math Soft Comput 1:47–53

Brešar B, Šumenjak TK (2007) On the 2-rainbow domination in graphs. Discrete Appl Math 155:2394–2400

Brešar B, Henning MA, Rall DF (2005) Paired-domination of Cartesian products of graphs and rainbow domination. Electron Notes Discrete Math 22:233–237

Brešar B, Henning MA, Rall DF (2008) Rainbow domination in graphs. Taiwanese J Math 12:213–225

Chang GJ, Wu J, Zhu X (2010) Rainbow domination on trees. Discrete Appl Math 158:8–12

Fujita S, Furuya M, Magnant C (2012) k-Rainbow domatic numbers. Discrete Appl Math 160:1104–1113

Haynes TW, Hedetniemi ST, Slater PJ (1998) Fundamentals of domination in graphs. Marcel Dekker, NewYork

Meierling D, Sheikholeslami SM, Volkmann L (2011) Nordhaus-Gaddum bounds on the k-rainbow domatic number of a graph. Appl Math Letters 24:1758–1761

Šumenjak TK, Rall DF, Tepeh A (2012) Rainbow domination in the lexicographic product of graphs. Combinatorics arXiv:1210.0514

Tong CL, Lin XH, Yang YS, Lou MQ (2009) 2-rainbow domination of generalized Petersen graphs P(n, 2). Discrete Appl Math 157:1932–1937

Wu Y, Rad NJ (2010) Bounds on the 2-rainbow domination number of graphs. Graphs Combinatorics. doi:10.1007/s00373-012-1158-y

Wu Y, Xing H (2010) Note on 2-rainbow domination and Roman domination in graphs. Appl Math Letter 23:706–709

Xu G (2009) 2-rainbow domination of generalized Petersen graphs P(n, 3). Discrete Appl Math 157:2570–2573

A Semi-Fuzzy AHP Approach to Weigh the Customer Requirements in QFD for Customer-Oriented Product Design

Jiangming Zhou and Nan Tu

Abstract In this paper, a new analytic hierarchy process (AHP) is proposed to determine the importance weights of customer requirements (CRs) in quality function deployment (QFD) for customer-oriented product design. The new approach combines conventional and fuzzy AHP. It takes into account one's uncertainty in comparing different pairwise CRs to improve the imprecise rankings in conventional AHP. By employing semi-fuzzy matrices, it guarantees that the final pairwise comparison matrices based on fuzzy scales are positive reciprocal. The problem of imprecise pairwise comparisons in conventional AHP is ameliorated and more accurate results are provided. Finally, a case study of new sports earphones design is given as an example to illustrate this approach.

Keywords Analytic hierarchy process · Semi-fuzzy · Customer requirements · Importance weights · Quality function deployment · Customer-oriented product design

1 Introduction

The competition in new product development (NPD) has intensified and companies are forced to provide products that meet the fast-changing CRs. For the past decades, various NPD methodologies have been studied for customer-oriented product design and widely used in real cases.

J. Zhou (✉) · N. Tu
Research Center for Modern Logistics, Graduate School at Shenzhen, Tsinghua University, Shenzhen 518055, People's Republic of China
e-mail: jamin.zjm@gmail.com

N. Tu
e-mail: dr.nan.tu@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_87,

In order to increase customer satisfaction throughout customer-oriented product design, QFD has been commonly used to integrate CRs into product design (Akao 1990, 1997). The translation process is comprised of six steps (Hsiao 2002). Determining the relative importance of CRs is vital since the target value of DRs could be significantly affected. The conventional QFD employs point scoring scale in weighing CRs (Griffin and Hauser 1993) where human subjective judgments are usually ill-considered and imprecision in weighting CRs may exist.

The AHP, a common tool in solving multiple criteria decision making (MCDM) problems (William 2008), employs pairwise comparison to determine the relative importance to make a more promising decision. Combined with QFD, the methodology has been widely used in product design selection problems: for example, Wang et al. (1998) suggested that CRs and DRs can be regarded as criteria and alternatives in the AHP, Madu et al. (2002) employed AHP to obtain the relative importance weightings of CRs for further study in QFD.

In general, the AHP is comprised of three phases: hierarchy construction, priority analysis and consistency verification. The conventional AHP employs nine-point scale in crisp real numbers as pairwise comparison ratios. Furthermore, fuzzy sets are integrated with AHP to model the uncertainty in human assessment on qualitative attributes (Chan et al. 1999) using such methods as triangular membership functions (Van and Pefrycz 1983) and geometric mean (Buckley 1985). Kwong and Bai (2002, 2003) employed fuzzy comparison matrix to determine the importance weights of CRs in QFD. However, weaknesses exist in previous study:

First, when using the same index of certainty, the differences of one's uncertainty in comparing different CRs are ignored.

Second, when selecting values from the given interval using triangular fuzzy numbers for the whole comparison matrix, the pairwise comparison matrix may be not positive reciprocal.

In this paper, a semi-fuzzy AHP approach is described to provide a more accurate priority analyzing process. First, assessments on CRs are expressed using triangular fuzzy numbers with separate indexes of certainty. Then the pairwise comparison matrix is built with fuzzy numbers to provide interval estimations. When selecting a value from the given interval of an element in the fuzzy comparison matrix, only those with the corresponding crisp real numbers larger than 1 are used, which indicate significant preferences. Subsequently normalized importance weights of CRs at all levels can be calculated applying AHP and synthesization is implemented to get the overall weights of CRs. Finally, the proposed approach has been applied to a new sports earphones design as an illustrative example.

2 The Semi-Fuzzy AHP Approach

The overall procedure of the proposed approach is shown in Fig. 1.

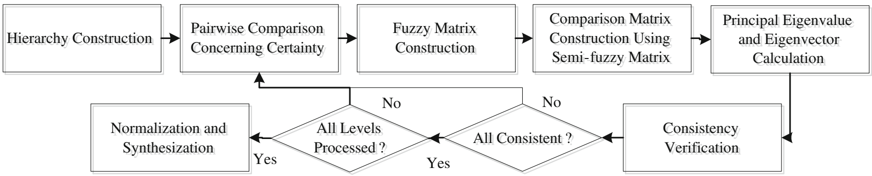


Fig. 1 Overall procedure of the semi-fuzzy AHP approach

2.1 Hierarchy Construction

The first step of applying AHP in weighing the importance of CRs is to structure CRs into different hierarchy levels. The aim is to decompose such a complex MCDM problem into simplified sub-problems for convenience. It has been shown that 7 is a practical bound on the number of elements at the same level, so far as consistency is concerned (Saaty 1980).

2.2 Priority Analysis Based on Semi-Fuzzy AHP

After hierarchy construction, comparisons are carried out on a pairwise basis to evaluate the relative importance. The conventional AHP employs nine-point scale to indicate the degree of preference. To take the uncertainty into account, the fuzzy AHP uses triangular fuzzy numbers, which are characterized as:

$$\forall \alpha \in [0,1], \tilde{x}^{\alpha} = \begin{cases} x, (x+2)^{\alpha}] = [x, x+2-2\alpha], & x = 1 \\ [(x-2)^{\alpha}, (x+2)^{\alpha}] = [x-2+2\alpha, x+2-2\alpha], & x = 3,5,7 \\ [(x-2)^{\alpha}, x] = [x-2+2\alpha, x], & x = 9 \end{cases} \tag{1}$$

The level of certainty is indicated by index α varying from 0 to 1, e.g., $\tilde{3}^{0.5}$ indicates that one is 50 % certain that the preference is moderately rather than equally or strongly. The larger the value, the higher degree of certainty. In this research, 0, 0.3, 0.5, 0.8, 1 are used to indicate such degrees as most uncertain, uncertain, neutral, certain and most certain respectively.

The pairwise comparison matrix is constructed based on the relative importance weights using fuzzy numbers. Taking into account the differences of one's uncertainty in comparing different pairwise CRs, the index of certainty α varies.

$$\tilde{a}_{ij}^{\alpha_{ij}} = \left[a_{ijl}^{\alpha_{ij}}, a_{iju}^{\alpha_{ij}}\right] = \begin{cases} \left[a_{ij}, a_{ij}+2-2\alpha_{ij}\right], & a_{ij} = 1 \\ \left[a_{ij}-2+2\alpha_{ij}, a_{ij}+2-2\alpha_{ij}\right], & a_{ij} = 3,5,7 \\ \left[a_{ij}-2+2\alpha_{ij}, a_{ij}\right], & a_{ij} = 9 \end{cases} \tag{2}$$

Using fuzzy numbers, interval estimation is given when weighing the relative importance of CRs. In order to prioritize the CRs for further study in NPD, agreements have to be reached when selecting a value from the given interval. The index of optimism μ is employed $(\mu \in [0,1])$ and defined as linear convex. In this research, fuzzy numbers from the fuzzy comparison matrix are used only when the central value (the corresponding crisp real numbers) are larger than 1, which indicates significant preferences. Thus, the selected value is characterized as:

$$\hat{a}_{ij}^{\alpha_{ij}} = \begin{cases} \mu a_{ijl}^{\alpha_{ij}} + (1-\mu) a_{iju}^{\alpha_{ij}}, \left(a_{ijl} + a_{iju}\right)/2 \geq 1 \\ 1/\hat{a}_{ji}^{\alpha_{ij}}, \left(a_{ijl} + a_{iju}\right)/2 \geq 1 \end{cases} \tag{3}$$

The final pairwise comparison matrix is characterized as:

$$\hat{\boldsymbol{A}} = \begin{pmatrix} 1 & \hat{a}_{12}^{\alpha_{12}} & \cdots & \hat{a}_{1n}^{\alpha_{1n}} \\ \hat{a}_{21}^{\alpha_{21}} & 1 & \cdots & \hat{a}_{2n}^{\alpha_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{a}_{n1}^{\alpha_{n1}} & \hat{a}_{n2}^{\alpha_{n2}} & \cdots & 1 \end{pmatrix} \tag{4}$$

The method of calculating the principle eigenvector is then used to produce the priority vector that indicates the relative importance weights of CRs. The priority vector derived from this method is demonstrated to reproduce itself on a ratio scale under the hierarchy composition principle (Saaty 2003).

To calculate the principal eigenvector, first solve the characteristic equation of matrix $\hat{\boldsymbol{A}}$ as $det\left(\hat{\boldsymbol{A}} - \lambda \boldsymbol{I}\right) = 0$, then substitute the largest eigenvalue into the equation $\hat{\boldsymbol{A}}\boldsymbol{X} = \lambda_m \boldsymbol{X}$ and calculate the vector. The priority vector needs to be normalized and synthesized to get the overall weights at each level.

2.3 Consistency Verification

Since in AHP comparisons are carried out through human judgment, inevitably inconsistency exists ($\tilde{a}_{ij}\tilde{a}_{jk}^{T} \neq \tilde{a}_{ik}$, e.g., i is preferred to j twice, j is preferred to k twice, but i is preferred to k only three times). It is acceptable whin an extent. Considered as an advantage of the AHP, the verification process is aimed to measure the degree of consistency.

First calculate the consistency index (CI) as $CI = \frac{\lambda_m - n}{n-1}$ where λ_m is the principal eigenvalue and n is the number of elements.

Then compare CI to the random index (RI). It is acceptable if $CI/RI < 0.1$. Otherwise unacceptable inconsistency exists and the comparison matrix should be reviewed and revised. The reference values of RI for different n are shown in Table 1 (Winston 1994).

Table 1 Random index of AHP

n	2	3	4	5	6	7
RI	0	0.58	0.90	1.12	1.24	1.32

3 A Case Study

An example of designing new sports earphones for joggers and hikers is given to demonstrate how the proposed semi-fuzzy AHP approach can be used to weigh the CRs.

3.1 Hierarchy Construction

A three-level hierarchy for the CRs, which were gathered from questionnaires and interviews, was constructed using affinity diagram as shown in Fig. 2. At the top of the hierarchy lies the ultimate design objective, which is sports earphones design. The lower level of the hierarchy are the CRs, which are divided into two levels with three categories so that the number of elements at each level does exceed the upper bound 7.

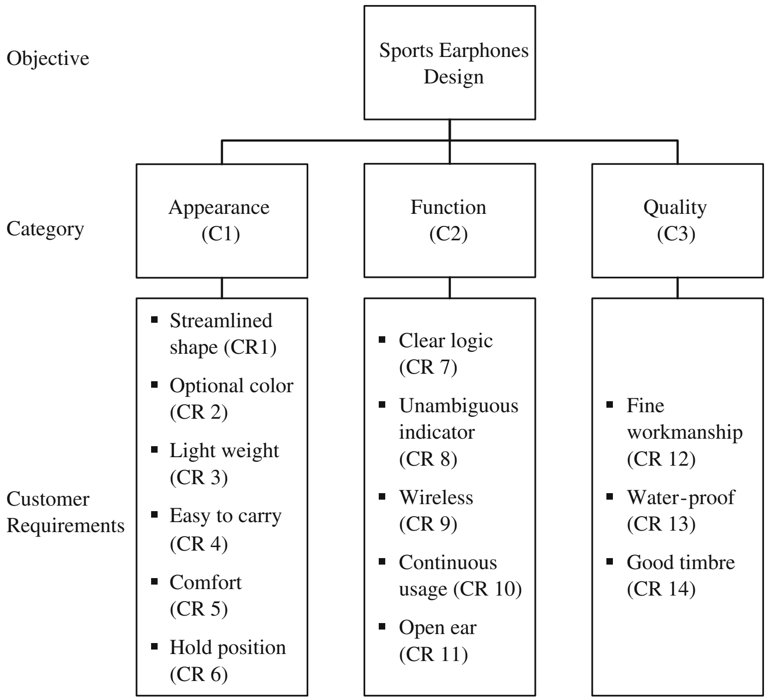


Fig. 2 A hierarchy for the CRs

3.2 Constructing the Comparison Matrix

After the hierarchy structure was constructed, questionnaires were used to gather pairwise comparison preferences of CRs with separate indexes of certainty, which were discussed by the panel of domain and industry experts.

Subsequently the comparison matrices were constructed. Indeed, iterations were carried out to revise the preferences since the consistency ratio might exceed the limit. The comparison matrix of CRs under the category of appearance is shown as an example.

The initial comparison matrix is constructed as:

$$C1:\tilde{\boldsymbol{A}}_1 = \begin{array}{c} \\ CR1 \\ CR2 \\ CR3 \\ CR4 \\ CR5 \\ CR6 \end{array} \begin{array}{c} \begin{array}{cccccc} CR1 & CR2 & CR3 & CR4 & CR5 & CR6 \end{array} \\ \begin{pmatrix} 1 & \tilde{3}^{0.5} & \tilde{1}^{0.5} & \tilde{3}^{0.5} & \tilde{1}^{0.3^{-1}} & \tilde{3}^{0.5^{-1}} \\ \tilde{3}^{0.5^{-1}} & 1 & \tilde{1}^{0.5^{-1}} & \tilde{3}^{0.5} & \tilde{5}^{0.5^{-1}} & \tilde{7}^{0.5^{-1}} \\ \tilde{1}^{0.5^{-1}} & \tilde{1}^{0.5} & 1 & \tilde{1}^{0.5} & \tilde{3}^{0.5^{-1}} & \tilde{1}^{0.8^{-1}} \\ \tilde{3}^{0.5^{-1}} & \tilde{3}^{0.5^{-1}} & \tilde{1}^{0.5^{-1}} & 1 & \tilde{5}^{0.5^{-1}} & \tilde{7}^{0.5^{-1}} \\ \tilde{1}^{0.3} & \tilde{5}^{0.5} & \tilde{3}^{0.5} & \tilde{5}^{0.5} & 1 & \tilde{1}^{0.3^{-1}} \\ \tilde{3}^{0.5} & \tilde{7}^{0.5} & \tilde{1}^{0.8} & \tilde{7}^{0.5} & \tilde{1}^{0.3} & 1 \end{pmatrix} \end{array}$$

By applying Eq. (2), the fuzzy comparison matrices using interval estimation are characterized as:

$$C1:\tilde{\boldsymbol{A}}_1 = \begin{pmatrix} 1 & [2,4] & [1,2] & [2,4] & [1/2.6,1] & [1/4,1/2] \\ [1/4,1/2] & 1 & [1/2,1] & [2,4] & [1/6,1/4] & [1/8,1/6] \\ [1/2,1] & [1,2] & 1 & [1,2] & [1/4,1/2] & [1/1.4,1] \\ [1/4,1/2] & [1/4,1/2] & [1/2,1] & 1 & [1/6,1/4] & [1/8,1/6] \\ [1,2.6] & [4,6] & [2,4] & [4,6] & 1 & [1/2.6,1] \\ [2,4] & [6,8] & [1,1.4] & [6,8] & [1,2.6] & 1 \end{pmatrix}$$

By applying Eq. (3) using the index of optimism as 0.95 which indicates a highly optimistic situation, the semi-fuzzy approach construct the final pairwise comparison matrices as:

$$C1:\hat{\boldsymbol{A}}_1 = \begin{pmatrix} 1.0000 & 3.9000 & 1.9500 & 3.9000 & 0.3968 & 0.2564 \\ 0.2564 & 1.0000 & 0.5128 & 3.9000 & 0.1695 & 0.1266 \\ 0.5128 & 1.9500 & 1.0000 & 1.9500 & 0.2564 & 0.7246 \\ 0.2564 & 0.2564 & 0.5128 & 1.0000 & 0.1695 & 0.1266 \\ 2.5200 & 5.9000 & 3.9000 & 5.9000 & 1.0000 & 0.3968 \\ 3.9000 & 7.9000 & 1.3800 & 7.9000 & 2.5200 & 1.0000 \end{pmatrix}$$

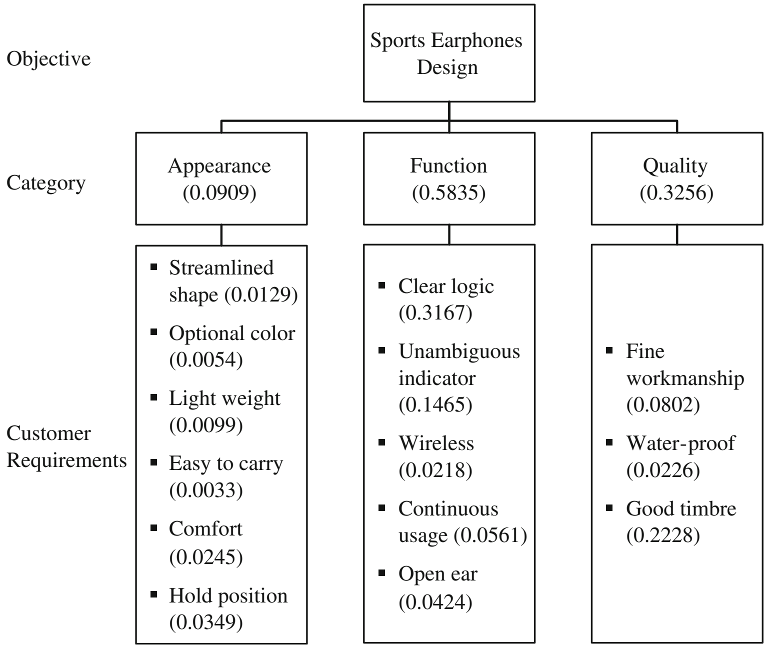


Fig. 3 Importance weights of the CRs

3.3 Prioritizing the CRs and Verification

MATLAB was used to calculate the principal eigenvalue and eigenvector of all the comparison matrices. Afterwards the ratios of CI to RI were calculated to verify the consistency of the matrices separately.

The eigenvectors were later normalized and synthesized to prioritize the overall weights of CRs which are shown in Fig. 3.

4 Conclusions

In this paper, a semi-fuzzy AHP approach is proposed to weigh the CRs for customer-oriented design using QFD, which brings the following benefits as:

First, separate indexes of certainty are used when constructing pairwise comparisons so that the differences of one's uncertainty in comparing different pairwise CRs are taken into account. Thus, more accurate priority rankings of the CRs can be provided.

Second, to construct the final pairwise comparison matrix, fuzzy number is used only when the preference is significant. This guarantees that the matrix is positive reciprocal, which meets the shortfalls using fuzzy AHP.

The proposed semi-fuzzy AHP approach is examined by a real case study of weighing the CRs for a sports earphones design product in Shenzhen, China. The results were later used in QFD to facilitate the decision making in product design.

Acknowledgement This work is partially supported by teams from Vtech Inc. (fake name to hide the identity of the company) in helping with data collection for the new sports earphone design project and providing valuable inputs into this research. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Akao Y (1990) Quality function deployment: integrating customer requirements into product design. Productivity Press, Cambridge

Akao Y (1997) QFD: past, present and future. Proceedings of the international symposium on QFD'97

Buckley JJ (1985) Fuzzy hierarchical analysis. Fuzzy Sets Syst 17:233–247

Chan LK, Kao HP, Ng A, Wu ML (1999) Rating the importance of customer needs in quality deployment by fuzzy and entropy methods. Int J Prod Res 37(11):2499–2518

Griffin K, Hauser JR (1993) The voice of the customer. Mark Sci 12(1):1–27

Hsiao SH (2002) Concurrent design method for developing a new product. Int J Ind Ergon 29:41–45

Kwong CK, Bai H (2002) A fuzzy AHP approach to the determination of importance weights of customer requirements in quality function deployment. J Intell Manuf 13:367–377

Kwong CK, Bai H (2003) Determining the importance weights for the customer requirements in QFD using a fuzzy AHP with an extent analysis approach. IIE Trans 35(7):619–626

Madu CN, Kuei C, Madu IE (2002) A hierarchic metric approach for integration of green issues in manufacturing: a paper recycling application. J Environ Manage 64(3):261–272

Saaty TL (1980) The analytic hierarchy process. McGraw-Hill, New York

Saaty TL (2003) Decision-making with the AHP: why is the principle eigenvector necessary. Eur J Oper Res 145:85–91

Van PJML, Pefrycz W (1983) A fuzzy extension of Saaty's priority theory. Fuzzy Sets Syst 11:229–241

Wang H, Xie M, Goh TN (1998) A comparative study of the prioritization matrix method and the analytic hierarchy process technique in quality function deployment. Total Qual Manag 9(6):412–430

William H (2008) Integrated analytic hierarchy process and its application: a literature review. E J Oper Res 186:211–228

Winston WL (1994) The analytic hierarchy process. Operations research: applications and algorithms. Wadsworth, Belmont, pp 798–806

An Optimization Approach to Integrated Aircraft and Passenger Recovery

F. T. S. Chan, S. H. Chung, J. C. L. Chow and C. S. Wong

Abstract In this paper, the allocation of aircrafts to each rescheduled flight with passengers concerns is considered. The problem consists of a recovered flight schedule within a recovery period, a pool of affected passengers with their initial itineraries, and a fleet of available aircrafts of various configurations. The objective is to route the suitable aircrafts to operate the suitable rescheduled flight legs, and at the same time, generating the corresponding itineraries for affected passengers. This paper proposes a new optimization formulation that integrates the recovery of aircrafts and passengers simultaneously to minimize the sum of passenger delay cost and airline operation cost. With the proposed algorithms, airlines will be able to assign suitable aircrafts to support flight recovery under disruptions within a short time-period, and at the same time reduce passenger delays.

Keywords Aircraft and passenger recovery · Airline scheduling · Disruption management · Fleet assignment · Genetic algorithm

F. T. S. Chan (✉) · S. H. Chung · J. C. L. Chow · C. S. Wong
Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
e-mail: f.chan@polyu.edu.hk

S. H. Chung
e-mail: nick.sh.chung@polyu.edu.hk

J. C. L. Chow
e-mail: jenny.chow@polyu.edu.hk

C. S. Wong
e-mail: mfsing@ymail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_88,

1 Introduction

As the aviation industry grows more complex and dynamic, effective generation of recovery plans once disruption occurs becomes inevitable for airlines to minimize any potential loses. Resources, including aircrafts and crew members etc., should also be well allocated to optimize the utilization rate during the recovery period, and to minimize the costs associated. In this paper, a model that focuses on integrated aircraft and passenger recovery is presented.

Most work on airline disruption management attempts to schedule aircraft, crew, and passenger recovery in a tractable manner (Filer et al. 2000). Since integrating the recovery of several resources simultaneously is a complicated task, the number of work attempts to integrate a subset of these components is relatively few and new (Kohl et al. 2007; Clausen et al. 2010). Research focusing on passenger recovery is also scarce.

Bratu and Barnhart (2006) described two integrated recovery models by determining whether the disrupted flight legs should be delayed or cancelled. The models were developed on a flight schedule based network with the aim of minimizing airline operation costs and estimated passenger disruption costs. Zhang and Hansen (2008) introduced an integration with other transportation modes to accommodate disrupted passengers in a hub-and-spoke network. An integer programming model was developed to minimize passenger costs caused by flight delays, cancellations, or substitutions with a nonlinear objective function.

A more recent approach by Jafari and Zegordi (2010) introduced an assignment model that recovers disrupted aircraft schedules and passenger itineraries concurrently with a framework of rolling horizon time. The objective of their model is to minimize costs on aircraft recoveries, delays and cancelations. Bisaillon et al. (2011) employed a neighborhood search heuristic in a large-scale to integrate reassignment of fleets, aircraft routings, and passengers to support resumption of regular operations. However, passengers are given low priority in their model. Petersen et al. (2012) presented an optimization approach to solve a fully integrated airline recovery problem. The problem is broken into four sub-problems to recover flight schedule, aircrafts, crews, and passengers within some time horizon. The objective seeks to minimize the total airline operation cost and passenger delay cost.

It is identified that passenger disruptions have rarely been considered or are given low priority in existing airline disruption management literature. In the limited researches that involve passenger considerations, the impact on passengers are usually not being modeled explicitly, in which their delay costs are only approximate. All these operation-centric approaches have led to a fact that passengers often suffer a much greater impact than that of airlines under disruptions. According to a recent report, the direct cost to passengers on flight delay on the U.S. economy in 2007 was US$16.7 billion, and that for airlines were US$8.3 billions only (NEXTOR 2010). In the view of this, an integrated recovery model that is more passenger-centric is therefore proposed, which aims to seek a tradeoff between airline operation and passenger disruption costs.

The remainder of the paper is organized as follow: Sect. 2 gives a description on the airline recovery problem considered in this paper. Focus is put on an aircraft rerouting problem. The proposed model for the integrated aircraft and passenger recovery is formulated in Sect. 3. The operation of the model is also presented. In Sect. 4, some discussions are made on the proposed model and a conclusion is drawn.

2 Problem Description

A *flight schedule* is a set of flights that operated by the airline in a given period of time. A *flight leg* is a non-stop flight from an origin airport to a destination airport. A *Fleet* is a group of aircrafts A that operated as a unit. It may contain aircrafts of more than one model that shares similar configurations. A *route* is the sequence of flight legs assigned to a given aircraft $a \in A$. *Turn-around time* is the time between arrival and departure of aircraft in a rotation.

In this paper, the integrated recovery problem comprises of an aircraft recovery problem and a passenger recovery problem. Given a set of rescheduled flight legs F, individual routings among a single fleet of aircrafts of two models, a_l and a_s, will be assigned to accommodate each rescheduled flight leg $f \in F$. The assignment will base on the number of affected passengers N_p and their itineraries over the recovery period. Passengers who cannot be transferred to the scheduled destination by the end of the recovery period will be transferred to other airlines. The cases of swapping or calling of spare aircraft are allowed. It is assumed the crew base is sufficient enough to cover all modified schedules.

2.1 The Aircraft Rerouting Problem

Once disruption occurs, the disrupted flights corresponded to a single fleet of aircraft bounded in the recovery period (t_0, T) are rescheduled by the airline operation centre. For clear illustration, an example of a repaired flight schedule of a network with 5 airports ($n_1, n_2, \ldots, n_5$) is given in Fig. 1. The network is served by a fleet of 2 aircrafts (a_{l1}, a_{s1}) with different seating capacities. Given the rescheduled flight legs ($f_1, f_2, \ldots, f_{13}$) that would be served by a_{l1} and a_{s1}, and a set of affected passengers $p \in P$ with their initial itineraries, the problem is to construct the best aircrafts routing to utilize the seating capacity to serve as many passengers as possible. Some possible sets of routings are shown in Table 1.

In typical cases, the amount of possible routes can be huge when the recovery period is long enough to cover significantly large number of flight legs. For the illustration above, there can be as many as 14 possible sets of routes for a simple case that consists only of 2 aircrafts with 13 flight legs. In reality, most recovery instances have between 30 and 150 aircrafts and the time horizons can be much longer (Rosenberger et al. 2003). With the cases of operating spare aircrafts also

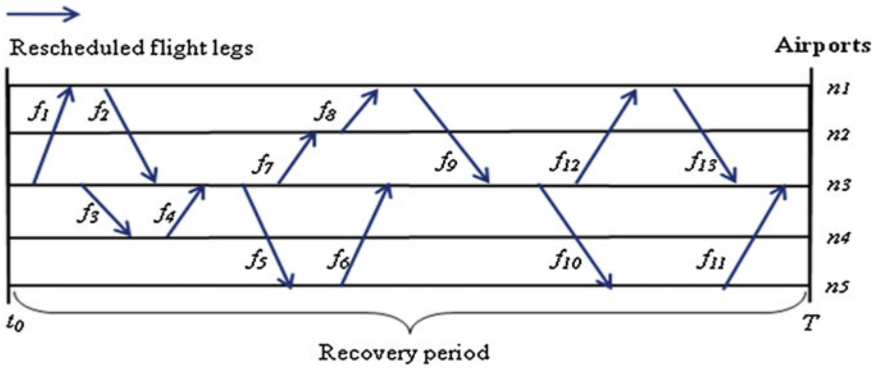


Fig. 1 A time-line network of rescheduled flight legs in a recovery period

Table 1 Some examples of possible routings of aircrafts a_{l1} and a_{s1}

Route 1		Route 2		Route 3	
Operate by aircraft a_{l1}	Operate by aircraft a_{s1}	Operate by aircraft a_{l1}	Operate aircraft a_{s1}	Operate by aircraft a_{l1}	Operate asircraft a_{s1}
f_1	f_3	f_1	f_3	f_3	f_1
f_2	f_4	f_2	f_4	f_4	f_2
f_7	f_5	f_5	f_7	f_5	f_7
f_8	f_6	f_6	f_8	f_6	f_8
f_9	f_{10}	f_{12}	f_9	f_{10}	f_9
f_{12}	f_{11}	f_{13}	f_{10}	f_{11}	f_{12}
f_{13}			f_{11}		f_{13}

being considered, the number of possible aircraft routes can thus be extremely huge. It would be difficult and time consuming to evaluate all possible routings and select the best among them.

In this paper, a comprehensive mathematical formulation that integrates aircraft and passenger rescheduling is presented. The cases of aircraft swapping, ferrying, and spare aircrafts operations, which are seldom being considered in most aircraft rerouting literature are also included.

3 Model Formulation

The objective of the model is to minimize the sum of passenger delay cost and airline operation cost. Passenger delay cost involves a delay cost of arrival time at destination to each passenger (in minute), and an inconvenient cost due to direction to other airlines, which causes a loss of goodwill to the airline. Airline operation cost includes an aircraft operation cost depends on the aircraft model (in minute flight time), a cost on swapping, ferrying, or flying spare aircraft, and a compensation cost on meal and drinks to passengers for departure delays over a given limit of time. The parameters common to the proposed model are:

C_{dp}	Cost of delay to passenger (per minute)
C_{cp}	Inconvenient cost to passengers who are directed to other airlines
C_{pf}	Cost of assigning a passenger to flight f
C_{sa}	Cost of swapping aircraft a
C_{aa}	Cost of operating spare aircraft a
C_{al}	Cost of operating aircraft model a_l (per minute)
C_{as}	Cost of operating aircraft model a_s (per minute)
C_{mp}	Compensation cost to airlines on meals and drinks to passengers with departure delay over a given time limit h_{mp}
H_{ta}	Minimum turn-around time for aircraft a
S_{al}	Seating capacity of aircraft model a_l
S_{as}	Searing capacity of aircraft model a_s
T_{ap}	Scheduled arrival time of passenger p
T_{dp}	Scheduled departure time of passenger p
N_f	Total number of rescheduled flight legs

The decision variables common to the model are:

k_{saf}	= 1 if aircraft a of flight f is swapped, and 0 otherwise
k_{fa}	= 1 if aircraft a is ferried, and 0 otherwise
k_{aaf}	= 1 if flight f is operated by a spare aircraft a, and 0 otherwise
k_{asf}	= 1 if flight f is operated by aircraft type a_s, and 0 otherwise
k_{alf}	= 1 if flight f is operated by aircraft type a_l, and 0 otherwise
t_{aaf}	= Actual arrival time of aircraft a for recovered flight f
t_{daf}	= Actual departure time of aircraft a for recovered flight f
b_{pf}	= 1 if passenger p is being served in flight f, and 0 otherwise
b_{cp}	= 1 if passenger p is being directed to other airlines, and 0 otherwise
b_{mp}	= 1 if $(b_{pf}\, t_{daf} - T_{dpi}) \geq h_{mp}$, and 0 otherwise
m_{alf}	= 1 if flight f is operated by aircraft model $a_{l,}$ and 0 otherwise
m_{asf}	= 1 if flight f is operated by aircraft model $a_{s,}$ and 0 otherwise
n_{pf}	= Number of passengers being assigned to flight f

The objective function is formulated as follows:

$$\min \sum_{f \in F} \sum_{p \in P} [(t_{aaf} - T_{ap})(b_{pf}) C_{dp}]$$
$$+ \sum_{a \in A} \sum_{f \in F} [(t_{daf} - t_{aaf}) m_{alf} k_{alf} C_{al}$$
$$+ (t_{daf} - t_{aaf}) m_{asf} k_{asf} C_{as} + k_{saf} C_{sa} + k_{aaf} C_{aa}$$
$$+ n_{pf} C_{pf}] + \sum_{p \in P} (b_{mp} C_{mp} + b_{cp} C_{dp})$$

Subject to:

$$m_{alf} + m_{asf} = 1 \, \forall f \in F \tag{1}$$

$$k_{asf} C_{as} + k_{alf} C_{al} \geq n_f \, \forall f \in F \tag{2}$$

$$t_{aaf_{i+1}} + t_{daf_i} \geq H_{ta} \, \forall a \in A, \; f \in F \tag{3}$$

$$b_{fp} + b_{cp} = N_p \, \forall p \in P \tag{4}$$

$$b_{pf} \cdot t_{daf} \geq T_{dp} \, \forall p \in P, \; f \in F \tag{5}$$

$$\begin{aligned} &k_{saf}, \; k_{fa}, \; k_{aaf}, \; k_{asf}, \; k_{alf}, \; b_{cp}, b_{mp}, \; m_{alf}, \; m_{asf} = \{0, 1\}, \text{ and} \\ &t_{aaf}, \; t_{daf} \text{ are REAL, and } n_{pf} \text{ is integer} \end{aligned} \tag{6}$$

Constraint (1) ensures all flight legs bounded in the recovery period are assigned to an aircraft of either model a_l or a_s. Constraint (2) is a seat capacity constraint for aircrafts. Constraint (3) guarantees a minimum turnaround time is assigned between flight legs operated by the same aircraft. Constraint (4) ensures all passengers are either being served or redirected to other airlines. Constraint (5) states that no passenger is allowed to depart before the initial scheduled departure time. Finally, constraints in (6) ensures that the decision variables k_{saf}, k_{fa}, k_{aaf}, k_{asf}, k_{alf}, b_{cp}, b_{mp}, m_{alf}, m_{asf} are binary variables, the aircraft departure times (t_{aaf}, t_{daf}) are real, and the number of assigned passengers to a specific flight (n_{pf}) is integer.

3.1 Model Operations

To support effective operation of the model, various forms of information is required. They include the initial fleet schedule before disruption; the initial passengers schedule, including the scheduled departure time, the origin airport, the destination airport, and the scheduled arrival time; the repaired flight schedule correspond to the fleet; the aircrafts combination in the fleet; and the location of each aircraft at the beginning of the recovery period.

Given these, the number of passengers that needed to arrive at a specific airport at a specific timeslot, the number of passengers that scheduled to depart from a specific airport at a specific timeslot, and the number of passengers in each initial scheduled flight can be determined The model would generate possible sets of aircraft routings to cover all rescheduled flight legs based on these and select the optimal set of routings. The proposed framework is modeled in Fig. 2.

The detailed operation process is as follows:

1. Identify the number of passengers whom requirements can be satisfied by traveling on flight f_1
2. Identify the available aircrafts that are able to operate flight f_1
3. Assign an aircraft to flight f_1
4. Check if the aircraft is a swapping or spare aircraft
5. Assign passengers to the flight
6. If the number of passengers exceeds the seating capacity of the assigned aircraft, move the remaining passengers to the next suitable flight
7. If there is no more suitable flight, direct them to other airlines
8. Repeat steps i to vii until all repaired flight legs are covered
9. Direct remaining passengers to another airline
10. Evaluate the generated routing set
11. Repeat steps i to x to get another possible routing set, until a stopping criteria is reached
12. Compare all generated routings and select the best one to implement.

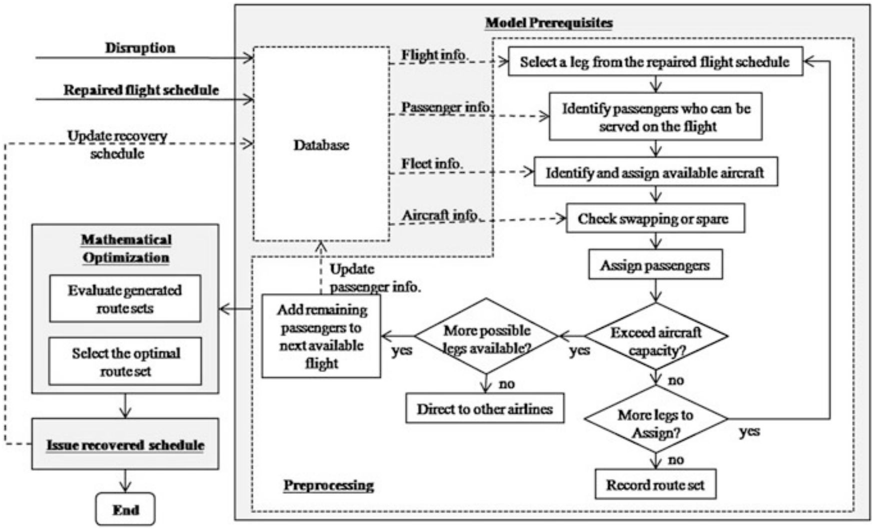


Fig. 2 Proposed model framework on integrated aircraft and passenger recovery

4 Discussions and Conclusions

In a given repaired flight schedule, the possible combination of aircraft routings can be huge. Also, given a high number of decision variables in the proposed model, identifying and evaluating all of them to find an optimized solution would be time consuming. It is recommended to use intelligent search heuristic, such as Genetic Algorithm (GA) or neighborhood search etc., to solve the identified problem to reduce the computation time. In this paper, a framework with the problem model is only provided to give a new research direction on passenger-oriented disruption management. Further investigations can be made to identify the most suitable algorithm in solving the model presented.

With the proposed model being solved, it is believed airlines can be equipped with higher reliability and customer service levels. This in turns increases customer retention rate and confidence of new customers in selecting the airline for air travels. The developed algorithm can further assist airlines in attracting high-value passengers who are sensitive to airline on-time reliability, increasing customer loyalty and satisfactory level, and reducing direct and indirect costs caused by passenger disruptions. These are especially important for airlines as the air travel market grows larger and more competitive.

In conclusion, a new optimization formulation that integrates the recovery of aircrafts and passengers simultaneously is proposed in this paper. The model routes the suitable aircrafts to operate the suitable rescheduled flight legs, and at the same time, generates the corresponding itineraries for affected passengers. The objective is to minimize the costs of passenger delay and airline operation, and to utilize the seating capacity of available aircrafts. After solving the model, airlines will be able to assign suitable aircrafts to support flight recovery under disruptions within a short time-period, reduce passenger delays, and at the same time achieve high customer satisfaction and remain competitive in the market.

Acknowledgments The work described in this paper was substantially supported by The Hong Kong Polytechnic University Research Committee for financial and technical support through an internal grant (Project No. G-UB03). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Bratu S, Barnhart C (2006) Flight operations recovery: new approaches considering passenger recovery. J Sched 9:279–298

Bisaillon S, Cordeau JF, Laporte G, Pasin F (2011) A large neighbourhood search heuristic for the aircraft and passenger recovery problem. Quat J Oper Res 9:139–157

Clausen J, Larsen A, Larsen J, Rezanova NJ (2010) Disruption management in the airline industry—Concepts, models and methods. Comput Oper Res 37:809–821

Filar JA, Manyem P, White K (2000) How airlines and airports recover from schedule perturbations: a survey. Ann Oper Res 108:315–333

Jafari N, Zegordi SH (2010) The airline perturbation problem: considering disrupted passengers. Transp Plann Technol 33:203–220

Kohl N, Larsen A, Larsen J, Ross A, Tiourine S (2007) Airline disruption management—Perspectives, experiences and outlook. J Air Transp Manage 13:149–162

National Center of Excellence for Aviation Operations Research (NEXTOR) (2010) Total delay impact study—A comprehensive assessment of the costs and impacts of flight delay in the United States. National Center of Excellence for Aviation Operations Research. Berkeley, CA

Petersen JD, Solveling G, Clark JP, Johnson EL, Shebalov S (2012) An optimization approach to airline integrated recovery. Trans Sci Artivles in Advance:1–19

Rosenberger JM, Johnson EL, Nemhauser GL (2003) Rerouting aircraft for airline recovery. Transp Sci 37:408–421

Zhang Y, Hansen M (2008) Real-time intermodal substitution: strategy for airline recovery from schedule perturbation and for mitigation of airport congestion. Transp Res Rec 2052:90–99

Minimizing Setup Time from Mold-Lifting Crane in Mold Maintenance Schedule

C. S. Wong, F. T. S. Chan, S. H. Chung and B. Niu

Abstract The integration of production scheduling and maintenance planning has received much attention in the past decade. However, most of the studies only focused on the availability constraint of machines. Other critical resources such as injection molds are usually assumed to operate without breakdown. In fact, the frequency of mold breakdown is even higher than the machine breakdown. It is therefore necessary to consider the availability constraint of injection molds during scheduling. Extending the preliminary study of the production-maintenance scheduling model in (Wong, International J Prod Res 50:5683–5697, 2011), this study aims to solve a new mold maintenance scheduling problem with the consideration of the setup time of using a mold-lifting crane. A Joint Scheduling (JS) approach is proposed to minimize the weighted sum of the makespan and the setup time. The approach is implemented in genetic algorithm to solve five hypothetical problem sets. The results show that the JS approach outperforms the traditional approach.

Keywords Mold maintenance · Production scheduling · Setup time · Genetic algorithm

---

C. S. Wong (✉) · F. T. S. Chan · S. H. Chung
Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hum, Hong Kong
e-mail: mfsing@ymail.com

F. T. S. Chan
e-mail: f.chan@polyu.edu.hk

S. H. Chung
e-mail: nick.sh.chung@polyu.edu.hk

B. Niu
College of Management, Shenzhen University, Shenzhen 518060, China
e-mail: drniuben@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_89,

1 Introduction

Production-maintenance scheduling problem has received much attention both in academia and in industry (Wang 2013; Ebrahimipour et al. 2013; Ben et al. 2011). Fitouhi and Nourelfath (2012) dealt with the production-maintenance scheduling problems considering noncyclical preventive maintenance. Mokhtari et al. (2012) developed a mixed integer nonlinear programming model of the production-maintenance scheduling problems with multiple preventive maintenance services. They solved the problems by a population-based variable neighborhood search (PVNS) algorithm with the objective of minimizing the makespan and the system unavailability. Naderi et al. (2011) integrated periodic preventive maintenance planning and flexible flowshop scheduling. They solved the problem by genetic algorithm and artificial immune system with the objective of makespan minimization. Pan et al. (2010) proposed a single-machine production-maintenance scheduling with the objective of minimizing the maximum weighted tardiness.

In most of the studies, however, the availability of other critical resources such as injection molds is usually ignored. In fact, in many manufacturing firms, injection molds represent a significant share of capital investment (Menges et al. 2001) and it is usually unique for a particular product. If a required mold is not available during production, many operations in the plant will be interrupted. Thus, there is no doubt that keeping all molds in a good condition during production can smoothen the overall manufacturing process. A preliminary study considering mold availability in production scheduling was carried out in Wong et al. (2011). The study proposed to integrate mold maintenance plan with production schedule. A Joint Scheduling (JS) approach was introduced to jointly (but not sequentially) allocate production and maintenance activities in the schedule. With the JS approach, a maintenance activity can be divided into several small-sized activities that may reduce the idle time of machines. It is shown that the JS approach not only improved the makespan, but also ensured all molds in a good working condition. However, with the JS approach, the setup time will increase since a number of small-sized maintenance activities are generated. Mold maintenance requires removal of molds with mold-lifting crane. It is likely that the mold-lifting crane can be the bottleneck of a production system if the molds on the machines are frequently changed. Thus, the frequency of mold changing becomes a critical factor in mold maintenance scheduling. In this connection, this study considers the constraints of a mold-lifting crane in the production-maintenance scheduling problem. In the new problem, we manage to minimize the makespan of jobs and the setup time of using the mold-lifting crane. The weighted sum of both objective values is taken as the combined objective function in the problem. Hypothetical problem sets are generated and solved by genetic algorithm. The JS approach can obtain satisfied results under the tradeoff between the makespan and the setup time from the mold-lifting crane.

2 Problem Description

2.1 Notations

The notations used are summarized as follow:

Index	Descriptions
j	Index of jobs, $j = 1, \ldots, J$
k	Index of machines, $k = 1, \ldots, K$
m	Index of injection molds, $m = 1,\ldots, M$
L_j	Processing time of job j
A	Maximum age of injection molds
T	Index of time slots, $t = 1, \ldots T$
S_i	Starting time of job j
C_j	Completion time of job j
$C_{\max}$	The makespan of all jobs

Decision Variables

X_{jkmt}	$= 1$, if job j occupies time slot t on machine k with mold m
	$= 0$, otherwise
Y_{jk}	$= 1$, if job j is allocated on machine k
	$= 0$, otherwise
Z_{jm}	$= 1$, if mold maintenance is performed on mold m after the completion of job j
	$= 0$, otherwise

2.2 Scheduling Problem Modeling

Objective function:

$$Objective: \ MIN\{C_{\max}\} \tag{1}$$

Equation (1) is the objective function of the problem that minimizing the makespan of all jobs.

Processing time constraint:

$$C_j - S_j = \sum_k Y_{jk} L_j \quad \forall jk \tag{2}$$

$$\sum_{kmt} X_{jkmt} = \sum_k Y_{jk} L_j \quad \forall jkmt \tag{3}$$

Equation (2) ensures that once a job starts operation, it will be operated without interruption. Equation (3) indicates that the allocated time slot for a job equals to the job processing time.

Job constraint:

$$\sum_{k} Y_{jk} = 1 \quad \forall jk \tag{4}$$

Equation (4) allows that each job is allocated on one machine only.

Machine capacity constraint:

$$\sum_{jm} X_{jkmt} \leq 1 \quad \forall jkmt \tag{5}$$

Equation (5) defines that one machine can perform one job only at each time unit.

Mold capacity constraint:

$$\sum_{jk} X_{jkmt} \leq 1 \quad \forall jkmt \tag{6}$$

Equation (6) defines that each injection mold can perform one job only at a time unit.

In the production scheduling model, there are J jobs, K injection machines and M injection molds. Each job is required to perform with a specific mold m. Each job spends processing time L_j on the available injection machine.

2.3 Maintenance Modeling

The injection molds in the problem follow an age-dependent maintenance scheme. Mold age is the cumulated operation time of a mold since the performance of the previous mold maintenance. Under the Maximum Age (MA) approach, the maintenance task of a mold will be performed when the mold age reaches the predefined maximum age A. After the maintenance, the mold age will become zero. The next maintenance will be performed when age A is reached again. Under the Joint Scheduling (JS) approach, mold maintenance will be performed according to not only the maximum age but also the maintenance schedule determined by the optimization algorithm.

2.4 Mold-Lifting Crane Modeling

The functions of a mold-lifting crane are to install and remove the injection mold. When a job is required to be operated with Mold m, Mold m must be installed on the machine by the mold-lifting crane before the job starts. If another mold is already installed on the machine, the mold must be removed before installing Mold *m*. Furthermore, if Mold *m* is required to perform maintenance, it must be removed from the machine before the maintenance task starts.

3 Genetic Algorithm

In this study, a genetic algorithm is applied for implementing the Joint Scheduling (JS) approach and solving the hypothetical problem sets. It is a well-known fact that genetic algorithms are widely for solving the scheduling problems.

Each gene consists of three digits, representing machine numbers, job numbers, maintenance decision making and domination. For example, there is a gene with the structure of 2–3–1–1. It means that Job 3 is allocated on Machine 2. The third digit is a binary variable. After performing Job 3, mold maintenance will be performed since the digit for maintenance decision making is 1. The last digit for domination is also a binary variable for recording good structure of a chromosome. If the digit is equal to 1, the gene will be recorded and brought to the next generation. This idea was first introduced by Chan et al. (2006).

At the beginning, a pool of chromosomes is generated randomly and evaluated according to a fitness function. The fitness function adopted is one minus the objective value (the weighted sum of the makespan and the setup time) and divided by the sum of the objective values of all chromosomes in the same generation. After that, a roulette wheel selection procedure will be performed to select the fitter chromosomes and form a new chromosome pool. An evolution procedure will then be performed to generate the next generation of the chromosomes. Crossover and mutation operations are included in the evolution procedure. In the crossover operation, the recorded genes in each pair of the chromosomes will be exchanged. In the mutation operation, some genes of the chromosomes will be changed with other parameters randomly. Once the new generation pool is created, the fitness value evaluation and selection procedure will be performed again. The whole evolution procedure will be terminated when the stopping condition is reached.

4 Computational Results

To testify the performance of the Joint Scheduling (JS) approach, five hypothetical problem sets are generated. In the problem sets, there are thirty jobs, three injection machines and five injection molds. The processing time of each job is around 4–25 h. The maximum age of each injection mold is 48 hand the maintenance duration is 10 h. Under the JS approach, mold maintenance can be performed before the maximum age. In that case, the maintenance duration will be

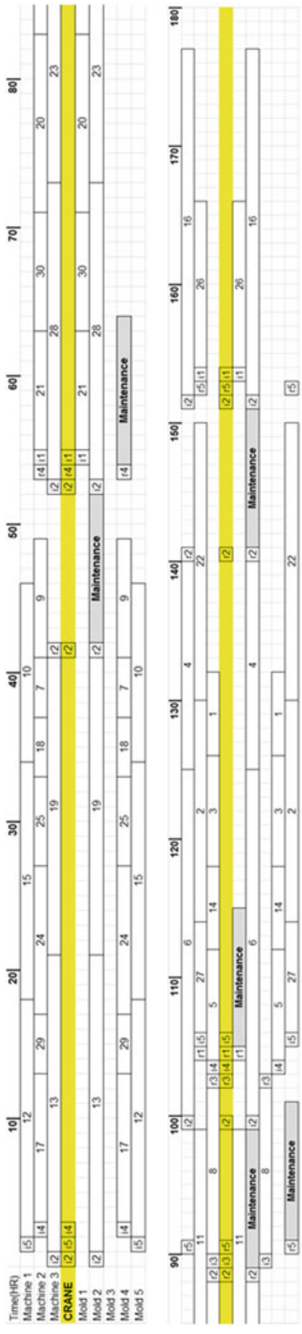


Fig. 1 The schedule from the MA approach optimizing the makespan and the setup time

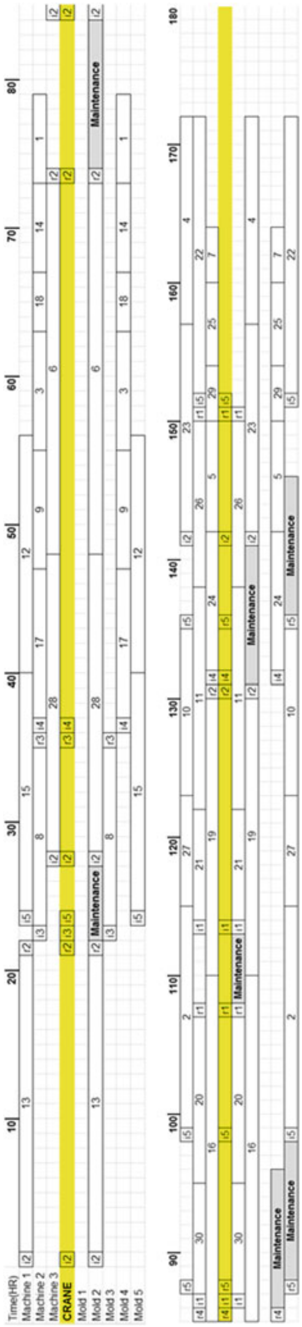


Fig. 2 The schedule from the JS approach optimizing the makespan and the setup time

Table 1 Comparison of the approaches

Problem		MA approach	JS approach	Improvement
Set 1	*Function value*	*74.5*	*73*	***2 %***
	Makespan	128	125	
	Setup time	21	21	
Set 2	*Function value*	*80*	*79.5*	***1 %***
	Makespan	135	134	
	Setup time	25	25	
Set 3	*Function value*	*98*	*96.5*	***2 %***
	Makespan	177	172	
	Setup time	19	21	
Set 4	*Function value*	*101*	*97*	***4 %***
	Makespan	181	175	
	Setup time	21	19	
Set 5	*Function value*	*107.5*	*106*	***1 %***
	Makespan	192	189	
	Setup time	23	23	

calculated linearly. The experiment is performed in Visual Basic for Applications (VBA) environment on a personal computer with Intel Core 2 Duo 2.13 GHz CPU.

Figures 1 and 2 are the optimized schedule of the MA and the JS approaches in Problem Set 3. In the figures, the letter “i” means mold installation; the letter “r” means mold removal. For example, “i3” indicates the installation of Mold 2 and “r4” indicates the removal of Mold 4. Table 1 shows the performance of the MA and the JS approaches. Comparing with the MA approach, the JS approach can obtain better function values with 1–4 % improvement. Since the JS approach allows more flexibility in mold maintenance scheduling, the genetic algorithm can decide a more favourable time for mold maintenance.

5 Conclusions

This paper aims to solve a new production-maintenance problem with the consideration of the setup time of a mold-lifting crane. The new problem is identified and demonstrated with the numerical examples. The results show that the proposed Joint Scheduling (JS) approach can achieve better function values than the traditional Maximum Age (MA) approach.

Acknowledgments The work described in this paper was substantially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. PolyU 510410); a research grant from the Hong Kong Polytechnic University (Project No. ZWOW (TCS 147)), and also a grant from The Hong Kong Scholars Program Mainland–Hong Kong Joint Postdoctoral Fellows Program (Project No.: G-YZ24).

References

Ben MA, Sassi M, Gossa M, Harrath Y (2011) Simultaneous scheduling of production and maintenance tasks in the job shop. Int J Prod Res 49(13):3891–3918

Chan FTS, Chung SH, Chan LY, Finke G, Tiwari MK (2006) Solving distributed FMS scheduling problems subject to maintenance: genetic algorithms approach. Robot Comput Integr Manuf 22(5–6):493–504

Ebrahimipour V, Najjarbashi A, Sheikhalishahi M (2013) Multi-objective modeling for preventive maintenance scheduling in a multiple production line. J Intell Manuf. doi:10.1007/s10845-013-0766-6

Fitouhi MC, Nourelfath M (2012) Integrating noncyclical preventive maintenance scheduling and production planning for a single machine. Int J Prod Econ 136(2):344–351

Menges G, Michaeli W, Mohren P (2001) How to make injection molds, 3rd edn. Hanser Publishers, Munich

Mokhtari H, Mozdgir A, Abadi INK (2012) A reliability/availability approach to joint production and maintenance scheduling with multiple preventive maintenance services. Int J Prod Res 50(20):5906–5925

Naderi B, Zandieh M, Aminnayeri M (2011) Incorporating periodic preventive maintenance into flexible flowshop scheduling problems. Appl Soft Comput 11(2):2094–2101

Pan ES, Liao WZ, Xi LF (2010) Single-machine-based production scheduling and integrated preventive maintenance planning. Int J Adv Manuf Technol 50(1–4):365–375

Wang S (2013) Bi-objective optimization for integrated scheduling of single machine with setup times and preventive maintenance planning. Int J Prod Res. doi:10.1080/00207543.2013.765070

Wong CS, Chan FTS, Chung SH (2011) A genetic algorithm approach for production scheduling with mold maintenance consideration. Int J Prod Res 50(20):5683–5697

Differential Evolution Algorithm for Generalized Multi-Depot Vehicle Routing Problem with Pickup and Delivery Requests

Siwaporn Kunnapapdeelert and Voratas Kachitvichyanukul

Abstract This paper presents a Differential Evolution (DE) algorithm for solving generalized multi-depot vehicle routing problem with pickup and delivery requests (GVRP-MDPDR). The GVRP-MDPDR does not require the restricted assumptions of CVRP, VRPSPD, etc. and it contains nearly all characteristics of real world vehicle routing problems. The solution is represented as a multidimensional vector where each dimension is filled with random number and a population of vectors is evolved via the mechanism of differential evolution. A decoding scheme (SD1) is applied to decode the vector into priority of requests and construct the routes of vehicles under the restricted constraints. Five groups of test problem instances, A, B, C, D, and E, with differences geographical data and number of requests are used to evaluate the performance of the algorithm. Each group of instance composes of three different location scenarios of requests: clustered (c), randomly distributed (r), and half-random-half-clustered (rc). The computational results demonstrated that DE algorithm is very competitive when compared to the results obtained by using Particle Swarm Optimization (PSO).

Keywords Metaheuristic · Differential evolution · Pickup and delivery · Vehicle routing problem

---

S. Kunnapapdeelert (✉) · V. Kachitvichyanukul
Industrial and Manufacturing Engineering, School of Engineering and Technology,
Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathumtani 12120, Thailand
e-mail: siwaporn.kunnapapdeelert@ait.ac.th

V. Kachitvichyanukul
e-mail: voratas@ait.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_90,

1 Introduction

The generalized multi-depot vehicle routing problem with pickup and delivery requests (GVRP-MDPDR) is the problem for designing the optimal vehicle route under pairing, precedence, vehicle capacity, and time windows constraints. It considered nearly all characteristics of practical vehicle routing problems. It is classified as NP-hard problem which consume high computational time to find the near optimal solutions for large size of problem when solves by exact algorithm. Consequently, various metaheuristics methods such as ant colony algorithm (ACO) (Carabetti et al. 2010; Nanry and Barnes 2000), tabu search (TA) (Cordeau et al. 2001; Wang 2008), genetic algorithm (GA) (Caramia and Onori 2008; Jung and Haghani 2000), and particle swarm optimization (PSO) (Ai and Kachitvichyanukul 2009a, b, c; Geetha et al. 2013; Sombuntham and Kachitvichyanukul 2010) have been developed to find solution in a reasonable time.

Differential evolution (DE) is firstly presented by Storn and Price (1997). The DE algorithm composes of four main process i.e. initialization of vector population, mutation, crossover, and selection. The algorithm has been successfully applied in various fields such as industrial engineering, electrical engineering, and communication. An algorithm based on differential evolution is proposed in this paper.

2 Generalize Multi-Depot Vehicle Routing Problem with Pickup and Delivery Requests

The GVRP-MDPDR can be considered as one of the most practical real world problems in VRP. Some characteristics of real-world practices for VRP can be described as follows.

- *Precedence constraint* is the condition that defines precedence relation of pickup and delivery. Once the request is assigned to a vehicle, location to pickup must be reached before the delivery location.
- *Vehicle constraint* is the limit that a load on a vehicle must not exceed capacity of vehicle.
- *Time window constraint* is the time period for the arrived vehicles to be served in each node. If any vehicle reaches the node too early, it must wait. In contrast, if the vehicle visit the node later than due time, the service will not be allowed for the vehicle.
- *Many requests at locations* refers to each location can have more than one pickup or delivery requests which may have to be delivered to different locations.

The frequently used objective of this problem is to minimize total routing cost which is corresponding to the traveling distance. Input parameters and variable used in the model are listed below follows by mathematical formulation for the problem based on Sombuntham (2010).

2.1 Input Parameters

P	set of pickup nodes, $\{1, \ldots, n\}$,
D	set of delivery nodes, $\{n + 1, \ldots, 2n\}$,
N	set of all pickup and delivery nodes, $N = P \cup D$,
H	penalty cost when the request i is not served, $i \in P$,
K	set of all vehicles, $\lvert K \rvert = m$,
C_k	vehicle capacity, k, $k \in K$,
f_k	fix cost of vehicle, k, $k \in K$, if it is used,
g_k	variable cost per a distance unit of vehicle, k, $k \in K$,
τ_k	start node of vehicle, k, $k \in K$,
τ'_k	end node of vehicle, k, $k \in K$,
V	set of all nodes, $V = N \cup \{\tau_1, \ldots, \tau_m\} \cup \{\tau'_1, \ldots, \tau'_m\}$,
A	set of (i, j) which represent an arc from node i to node j, where j, $i \in V$,
$d_{i,j}$	nonnegative distance from node i and node j, $i, j \in N$,
$t_{i,j}$	nonnegative traveling time from node i and node j, $i, j \in N$, travel times satisfy triangle inequality and $t_{i,j} \leq t_{i,l} + t_{l,j}$ for all j, i, $l \in V$,
s_i	fixed service time when visiting node i,
e_i	variable service time per item units of node i,
$[a_i, b_i]$	time windows for node i; a visit to node i can only happen between this time interval,
l_i	quality of goods to be loaded to the vehicle at node i when $i \in P$ and $l_i = -l_{i-n}$ for $i \in D$,
T_k	maximum route time of vehicle k, $k \in K$

In this work, request i is represented by node i and $i + n$, where $i \in P$ and $i + n \in P$. In addition, any node may have same x—y coordinate as the same location could have multiple request.

2.2 Decision variables

The key decision variables for the problem are

x_{ijk} $$x_{ijk} = \begin{cases} 1 & \textit{if edge between node i and j is used by vehicle k}, \\ 0 & \textit{otherwise} \end{cases}$$

S_{ik} nonnegative integer for indicating when vehicle k starts servicing at location i, $i \in V$, $k \in K$,

L_{ik} nonnegative integer that in an upper bound on amount of goods on vehicle k after servicing node i where i, $i \in V$, $k \in K$

z_i $$z_i = \begin{cases} 1 & \textit{if the request is placerd in te request bank} \\ 0 & \textit{otherwise} \end{cases}, i \in P$$

A. *Mathematical model*

$$\text{Minimize } \alpha \sum_{k \in K} g_k \sum_{(i,j) \in A} d_{ij} x_{ijk} + \beta \sum_{k \in K} \sum_{j \in P} f_k x_{\tau_k,j,k} + \gamma \sum_{i \in P} H_i z_i = 1 \tag{1}$$

$$\text{Subject to}: \sum_{k \in K} \sum_{j \in N_k} x_{ijk} + z_i = 1 \qquad \forall i \in P \tag{2}$$

$$\sum_{j \in V} x_{ijk} - \sum_{j \in V} x_{j,n+i,k} = 0 \qquad \forall k \in K, \forall i \in P \tag{3}$$

$$\sum_{j \in P \cup \{\tau'_k\}} x_{\tau_k,j,k} = 1 \qquad \forall k \in K \tag{4}$$

$$\sum_{i \in D \cup \{\tau_k\}} x_{i,\tau'_k,k} = 1 \qquad \forall k \in K \tag{5}$$

$$\sum_{i \in V} x_{ijk} - \sum_{i \in V} x_{j,i,k} = 0 \qquad \forall k \in K, \forall j \in N \tag{6}$$

$$x_{ijk} = 1 \Rightarrow S_{ik} + s_i + t_{ij} \le S_{jk} \qquad \forall k \in K, \forall (i,j) \in A \tag{7}$$

$$a_i \le S_{ik} \le b_i \qquad \forall k \in K, \forall i \in V \tag{8}$$

$$S_{ik} \le S_{n+i,k} \qquad \forall k \in K, \forall i \in P \tag{9}$$

$$x_{ijk} = 1 \Rightarrow L_{ik} + l_i \le L_{jk} \qquad \forall k \in K, \forall (i,j) \in A \tag{10}$$

$$L_{ik} \le C_k \qquad \forall k \in K, \forall i \in V \tag{11}$$

$$L_{\tau_k k} = L_{\tau'_k k} = 0 \qquad \forall k \in K \tag{12}$$

$$x_{ijk} \in \{0,1\} \qquad \forall k \in K, \forall (i,j) \in A \tag{13}$$

$$z_i \in \{0,1\} \qquad \forall i \in P \tag{14}$$

$$S_{ik} \ge 0 \qquad \forall k \in K, \forall i \in V \tag{15}$$

$$L_{ik} \ge 0 \qquad \forall k \in K, \forall i \in V \tag{16}$$

$$S_{\tau'_k k} \le T_k \quad \forall k \in K \tag{17}$$

The objective function is to minimize total distance traveled under various constraints. The first and the second constraints in Eqs. (2) and (3) ensure that both pickup and delivery orders are done with the same vehicle. Equations (4) and (5) make sure that vehicle departs from its start terminal and arrives at its end terminal. Equation (6) guarantees that the consecutive paths between τ_k and τ'_k are constructed for each vehicle $k \in K$. Equations (7) and (8) confirmed that S_{ik} is set accurately along the paths within the given time windows. These constraints also assure that sub tours will not be created. Equation (9) is used to enforce the condition that each pickup must take place before the corresponding delivery. Equations (10)–(12) guarantee that the load variable is precisely set along the path and vehicle capacity constraints are used. Lastly, Eq. (17) limits a maximum route time of each vehicle allowed.

3 Differential Evolution

Differential evolution (DE) algorithm is first proposed by Storn and Price (1997). It has been successfully applied in various scientific and engineering fields (Das and Suganthan 2011). It is a population-based random search that utilizes a population of size N of D-dimensional vectors. Each candidate or target vector in a population is perturbed to form a new vector called a trial vector by mutation and crossover operations as explained below.

For a target vector, $X_{i,g}$, the mutation process is used to create a mutant vector, $V_{i,g}$. In DE, a mutant vector, $V_{i,g}$, at generation g is generated by combining three randomly selected vector from the current population which are mutually exclusive and different from its corresponding mutant vector. The mutant vector can be generated based on $V_{i,g} = X_{r1,g} + F * (X_{r2,g} - X_{r3,g})$ where X_{r1}, X_{r2}, and X_{r3} are the three randomly selected vectors. The scale vector, F, is used for scaling the differential variation $(X_{r2,g} - X_{r3,g})$ and it is a parameter in DE.

The mutant vector, $V_{i,g}$ is then crossover with the target vector, $X_{i,g}$ to create the trial vector, $Z_{i,g}$ to enhance the diversity of the perturbed parameter vectors. In DE algorithm, the two commonly used crossover schemes are the binomial crossover (bin) and the exponential crossover (exp). The crossover probability, C_r, must be specify for controlling the portion of parameter values copied from the mutant vector in each dimension. The smaller C_r value leads to the trial vector, $Z_{i,g}$, that is more similar to the target vector, $X_{i,g}$. In contrast, the higher C_r value leads to the trial vector, $Z_{i,g}$, that is more similar to the mutant vector, $V_{i,g}$.

The selection process is made by selecting the superior vector between the trial vector, $Z_{i,g}$ and the target vector, $X_{i,g}$. If the fitness of the trial vector, $f(Z_{i,g})$ is better than or equal to that of the target vector, $f(X_{i,g})$, the trial vector, $(Z_{i,g})$ will replace the target vector and become part of the next generation $(X_{i,g+1})$. Otherwise, the target vector, $X_{i,g}$ still remains in the population for the next generation.

3.1 Differential Evolution for Solving GVRP-MDPDR

To apply DE algorithm to solve GVRP-MDPDR, the relationship between vector and vehicle route must be defined. The solution representation used in this research is (SD1) from Ai and Kachitvichyanukul (2009a, b, c). Vector in this solution representation is composed of $n + 2\ m$ elements which are divided into two main parts. The first n dimensions of each vector represent priority of the locations. The last 2 m dimensions hold x, y coordinate of the orientation points of the m vehicles. Each vector is decoded into the vehicle route in each iteration. The decoding procedure is divided into three main steps. First, a location priority list is created. The vehicle priority matrix is created next. The last step is to construct the vehicle route. This step can be done by assigning requests based on the outcomes from the first two steps, location priority and vehicle priority.

After the vehicle route is generated based on both customer priority list and vehicle priority matrix, the lowest cost insertion heuristics is applied to find the best insertion position of each customer. However, some unfulfilled requests might still be unassigned in some cases. Neighborhood moves concept from Nanry and Barnes (2000) are then applied for inserting the unfulfilled requests into the vehicle routes. Finally, the attempt for reducing number of vehicle from Sombuntham and Kachitvichyanukul (2010) is also applied to improve the solutions.

4 Experimental Results

Five groups of benchmark instances, A, B, C, D, and E, from Sombuntham and Kunnapapdeelert (2012) are used to test the DE algorithm for solving GVRP-MDPDR. Three different locations scenarios of the request are available in all instances i.e. clustered location (c), random (r), and half-random-half-cluster (rc). Each dataset consists of Cartesian coordinate for representing locations, fix and variable service time, ready and due time. Vehicle information includes vehicle capacity, time limit, fix and variable costs, start and end stations of vehicle. Information of the request such as, quantity, pickup and delivery locations are provided. Additionally, Euclidean distances among locations are also given.

The algorithm is solved for 10 times for each problem instance. Parameters setting of DE algorithm for solving this problem are set as follows. Population size N is set at 200 and number of iteration is 500. Crossover rate, C_r, is linearly increasing from 0 to 1. The scaling factor, F, is randomly change in the range [0, 2] in every iteration. The experimental results of the DE approach for solving GVRP-MDPDR when compared to those of PSO are depicted in Table 1.

The obtained results in Table 1 show that the proposed algorithm outperforms the PSO in terms of solution quality when apply to solve GVRP-MDPDR in most cases. However, it cannot reach the best known solution from PSO in some cases.

Table 1 Computational results for solving GVRP-MDPDR via DE and PSO algorithm

Instance	PSO	DE	% deviation
Aac1	864.22	887.59	2.70
Aac2	782.54	903.36	15.44
Aar1	2004.06	2135.32	6.55
Aar2	2373.18	2524.57	6.38
Aarc1	1436.74	1441.76	0.35
Aarc2	1679.34	1741.87	3.72
Bac1	1805.82	1674.92	−7.25
Bac2	1897.47	1833.40	−3.38
Bar1	4196.45	3965.09	−5.51
Bar2	7848.43	7330.13	−6.60
Barc1	2838.10	2646.12	−6.76
Barc2	2838.10	2680.15	−5.57
Cac1	3379.24	3346.96	−0.96
Cac2	4297.98	4296.36	−0.04
Car1	6153.78	5907.51	−4.00
Car2	7643.92	7218.50	−5.57
Carc1	4406.78	4400.51	−0.14
Carc2	4320.85	4229.50	−2.11
Dc1	2715.44	2933.20	8.02
Dc2	2670.12	2777.18	4.01
Dr1	3424.96	2931.97	−14.39
Dr2	3484.56	3057.33	−12.26
Drc1	4388.53	3642.21	−17.01
Drc2	4865.68	4143.95	−14.83
Ec1	3100.78	4220.76	36.12
Ec2	3165.58	4165.22	31.58
Er1	3404.02	3400.22	−0.11
Er2	3260.52	2961.68	−9.17
Erc1	4157.00	4072.59	−2.03
Erc2	6882.52	6184.88	−10.14

This indicates that the search process might require improvement or that the solution representation used in this work cannot reach certain area of the search space.

5 Conclusions

The DE algorithm and solution representation for solving generalized multi-depot vehicle routing problem with pickup and delivery requests (GVRP-MDPDR) are presented in this paper. The results depict that the proposed DE algorithm can provide good quality of solution to GVRP-MDPDR problem. In comparison, the results from the DE algorithm are better than those obtained by PSO for most of the problem instances. The proposed algorithm performs worse than PSO only for dataset A and clustered distributed location instances of some dataset.

References

Ai TJ, Kachitvichyanukul V (2009a) Particle swarm optimization for the vehicle routing problem with time windows. Int J Oper Res 9:519–537

Ai TJ, Kachitvichyanukul V (2009b) Particle swarm optimization and two solution representations for solving the capacitated vehicle routing problem. Comput Ind Eng 56:380–387

Ai TJ, Kachitvichyanukul V (2009c) Particle swarm optimization for the vehicle routing problem with simultaneous pickup and delivery. Comput Oper Res 36:1693–1702

Carabetti EG, de Souza SR, Fraga MCP, Gama PHA (2010) An application of the ant colony system metaheuristic to the vehicle routing problem with pickup and delivery and time windows. Paper presented at 2010 Eleventh Brazilian Symposium on Neural Networks, Centro Fed. de Educ. Technol. De Gerais, Belo Horizonte, Brazil, pp 23–28 Oct 2010

Caramia M, Onori R (2008) Experimenting crossover operators to solve the vehicle routing problem with time windows by genetic algorithm. Int J Oper Res 3:497–514

Cordeau JF, Laporte G, Mercier A (2001) A unified tabu search heuristic for vehicle problem with time windows. J Oper Res Soc 52:928–936

Das S, Suganthan PN (2011) Differential evolution: a survey of the state-of-the-art. IEEE Trans Evol Comput 15:4–31

Geetha S, Poonthalir G, Vanathi PT (2013) Nested particle swarm optimisation for multi-depot vehicle routing problem. Int J Oper Res 16:329–348

Jung S, Haghani A (2000) A genetic algorithm for pickup and delivery problem with time windows. In: Transportation Research Record 1733, Transportation Research Broad 1–7

Nanry WP, Barnes JW (2000) Solving the pickup and delivery problem with time windows using reactive tabu search. Transp Res Part B 34:107–121

Sombuntham P (2010) PSO algorithms for generalized multi-depot vehicle routing problems with pickup and delivery requests. Thesis, Asian Institute of Technology

Sombuntham P, Kachitvichyanukul V (2010) A particle swarm optimization for multi-depot vehicle routing problem with pickup and delivery requests. Paper presented at proceedings of the international multiconference of engineers and computer scientists, Hong Kong (China), pp 17–19

Sombuntham P, Kunnapapdeelert S (2012) Benchmark problem instances for generalized multi-depot vehicle routing problems with pickup and delivery requests. Paper presented at proceedings of the Asia Pacific industrial engineering and management systems conference, Patong Beach, Phuket, Thailand, pp 2–5

Storn R, Price K (1997) Differential evolution—a simple and efficient heuristic for global optimization over continuous spaces. J Global Optim 11:341–359

Wang Y (2008) Study on the model and tabu search algorithm for delivery and pickup vehicle routing problem with times windows. Paper presented at 2008 IEEE international conference on service operations and logistics, and informatics, Beijing, China, pp 12–15

A Robust Policy for the Integrated Single-Vendor Single-Buyer Inventory System in a Supply Chain

Jia-Shian Hu, Pei-Fang Tsai and Ming-Feng Yang

Abstract To find the best production quantity for the vendor and the order quantity for the buyer, the integrated single-vendor single-buyer inventory model is proposed with the aim to minimize the total costs of the entire supply chain. In the Traditional supply chain, the most of integrated inventory is to develop a model that assumes that the input data is deterministic and equal to some nominal values. However, few researches have considered data uncertainty such as in demands, lead times, or even setup/ordering costs. Instead of solving for the optimal solution under the assumption of deterministic demands, here we provide a prescriptive methodology for constructing uncertainty sets within a robust optimization framework for integrated inventory problems with uncertain data. We accomplish this by taking as primitive the decision maker's attitude toward risk. A numerical study and sensitive analysis are conducted to examine the integrated inventory model.

Keywords Robust optimization · Integrated inventory · Supply chain

1 Introduction

Collaboration between buyer and vendor is getting more critical in a supply chain environment. In increasingly competitive and globalized world markets, companies are constantly under pressure to find ways to cut inventory and production

J.-S. Hu · P.-F. Tsai (✉)
Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei, Taiwan, Republic of China
e-mail: ptsai@ntut.edu.tw

M.-F. Yang
Department of Transportation Science, National Taiwan Ocean University, Keelung, Taiwan, Republic of China
e-mail: yang60429@pchome.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_91,

costs since the annual inventory cost accounts for 10 % of the annual profit on average. To manage the inventory more effectively implies to reduce cost and increase competitive for the company.

In the late 19th century, companies were under the challenges of cost reduction while satisfying customers requires in the timely manner. It led to the success in implementation of just-in-time (JIT) production system, originated from Japan. The objective of JIT manufacturing is to eliminate all wastes by having almost no inventories between operations. Pan and Liao (1989) incorporated JIT concept to the traditional EOQ model. They demonstrated the effect of frequent shipments for a small lot size and total cost. However, small lot-size delivery costs such as shipping, receiving, and inspection costs were ignored on their model. Ramasesh (1990) separated the total ordering cost into the cost of placing a contact order and the cost associated with multiple shipments in small lots.

Instead of focusing on individual inventory control policy, an integrated inventory approach has been proposed to determine optimal order quantity and shipment policy for buyers and vendors simultaneously. In traditional inventory management systems, vendor or buyer adopted an optimal economic order quantity (EOQ) with the consideration of self-interest only. However, this optimal solution approach might not be the best inventory policy for the entire supply chain. Banerjee and Kim(1995) assumed that the optimal inventory policies were determined jointly under the setting of JIT purchasing and JIT manufacturing. Ha and Kim (1997) considered the integration between single-vendor and single-buyer in a JIT environment. Their results showed that this integrated approach might further reduce total costs for both the vendor and the buyer.

Goyal(1977) was first advocated the concept of integrated inventory model for a single supplier–single customer problem. The optimal ordering and production frequencies were decided with the assumption that the ratio between supplier's production cycle time and the customer's order time interval was fixed. This model was further extended by Banerjee (1986), assuming that a vendor had a finite production rate with a lot-for-lot policy. Goyal (1988) relaxed the lot-for-lot policy to achieve lower joint total relevant costs. Goyal and Gupta (1989) showed that the loss of one partner from the buyer-vendor coordination can be compensated by the benefit of other partners. It was suggested that the net benefit should be shared by both parties in some equitable fashion.

Lu (1995) developed a heuristic approach for the one-vendor multi-buyer case, and proved assumption of completing a batch before a shipment is started and explored a model that allowed shipments to take place during production cycle and the delivery quantity to the buyer is known for one-vendor one-buyer problems. Pan and Yang (2002) presented an integrated supplier-purchaser model concentrated on the profit from lead time reduction. Siajadi et al. (2006) presented a single-vendor multiple-buyer integrated inventory model to minimize joint total relevant cost for both vendor and buyer with a multiple shipment policy by determining optimal ordering/production cycle time, and a significant savings in joint total relevant cost is achieved when the total demand rate is close to the production rate.

Uncertainty in the process of globalization is more complex than before. Thus, developing the inventory model of the uncertainty model is inevitable. Most literature on inventory models assumed certainty in demand rates. However, they are usually difficult for the managers to decide the parameters accurately as crisp values in reality. Only limited research discussed the variations in parameters. Here we propose a robust optimization framework for an integrated inventory problem with uncertain demands.

2 A Robust Model

Here a robust optimization framework for an integrated inventory problem was proposed with uncertain demands. The optimization problem with inexact data was investigated by Soyster (1973). A decomposition procedure was then proposed by solving a problem which maximizes the minimum of a finite set of functions over a common domain. The concept of robust optimization was proposed by Bertsimas and Sim (2004), in which the parameters could take values different than the nominal ones. They found that the optimal solution using the nominal data might no longer be optimal or even feasible as several constraints may be violated after the problem was realized.

According to the tradition inventory model, the demand is given and ordering quantity is a decision variable. The total cost is minimized by economic ordering quantity in the model. Now we consider that the demand is happened with uncertainty in the inventory model. In this paper, we assume that the demand is uncertainty, but know that the number of demands will happened in the future. Thus, the different demands produce the total cost functions respectively in the future scenarios. However, by analyzing the demands in the future, we find the worst-case scenario policy in which the solution is the best one should the worst situation is realized. This robust method is as following:

Step 1. To find the minimum total cost, the economic ordering quantity by the possible demand must be calculated. The several ordering quantities are provided the total cost function and find the minimum total cost in the each demand of future scenarios.

Step 2. The ordering quantities which come from possible demand of future scenarios respectively calculate the total cost by the several total cost functions. Therefore, we know what happen the ordering quantity which is the ordering quantity in the specific demand of scenarios apply in the different total cost function, and the order quality may be not the economic ordering quantity in applying total cost function.

Step 3. Following the Step 2, we know the many total costs which are calculated by the economic ordering quantity which is in the specific demand of scenarios. Through the maximin strategy with the total costs find the conservative policy.

2.1 Notations and Assumptions

The notations used in this integrated inventory model are as follows:

D	Average demand rate per year for buyer
P	Production rate per year
A	Ordering cost per order for buyer
S	Setup cost per lot
Q	Total order/production quantity per cycle time
C_v	Unit production cost paid by the vendor
C_b	Unit purchase cost paid by the purchaser
r	Annual inventory holding cost per dollar invested in stocks

The notations used in this integrated inventory model are as follows:

1. The demand rate is constant and deterministic after realization.
2. The order quantity need not be an integral number of units, and there are no minimum or maximum restrictions on its size.
3. The unit variable cost does not depend on the replenishment quantity; In particular, there are no dis counts in either the unit purchase cost or the unit transportation cost.
4. The cost factors do not change appreciably with time; in particular, inflation is at a low level.
5. The item is treated entirely independently of other items; that is, benefits from joint review or replenishment do not exist or are simply ignored.
6. The replenishment lead time is of zero duration.
7. No shortages are allowed.
8. The entire order quantity is delivered at the same time.
9. The planning horizon is very long. In other words, we assume that all parameters will continue at the same value for a long time.

2.2 Formulations

Based on the above notations and assumptions, the buyer's total relevant cost is the sum of ordering costs and holding costs, which can be calculated as in Eq. (1).

$$TC_p = A\frac{D}{Q} + \frac{Q}{2}C_v r \tag{1}$$

In order to find the minimum cost for this problem, we should take the first partial derivatives of TC_p with Q and the derivatives to zero. The optimal order quantity (or economical ordering quantity) can be evaluated as:

$$EOQ = \sqrt{\frac{2AD}{c_p r}} \tag{2}$$

We then consider the vendor's model before introducing the integrated inventory model. The vendor's total relevant cost the sum of set-up costs and holding costs, which can be calculated as in Eq. (3).

$$TC_v = S\frac{D}{Q} + \frac{Q}{2}C_v r\left(1 - \frac{D}{P}\right) \tag{3}$$

As the cost functions for the vendor and the buyers shown above, the joint total cost for the integrated inventory problem is the sum of TC_v and TC_p, as shown in Eq. (4).

$$TC = \frac{D}{Q}(A + S) + \frac{Q}{2}\left[C_v r\left(1 - \frac{D}{P}\right) + C_P r\right] \tag{4}$$

One convenient way to find the minimum is to use the necessary condition that the tangent or slope of the curve is zero at the minimum. Then, we have the optimal order quantity as in Eq. (5).

$$Q = \sqrt{\frac{2D(A + S)}{C_v r\left(1 - \frac{D}{P} + C_P r\right)}} \tag{5}$$

3 Numerical Examples

3.1 EOQ Model

To illustrate the results of the proposed method, consider an EOQ inventory system with data: We consider the possible future demand about D = 500, 1,000 or 1,500 unit/year, A = \$100/order, Cb = \$20/unit, r = 0.2. The optimal ordering quantity (EOQ*) and optimal total cost (TC*) for all possible demands are as shown in Table 1.

We used these three EOQs as the ordering quantity under different demands and calculate the resulting total cost, as shown in Table 2. By the maxi-min principle, we can find the most conservative solution in Table 1, top right point. The solution of EOQ model help people to resist the uncertainty future, letting the user not fall to the worse place. Thus, we chose the ordering quantity 193.65, and the policy is conservative to face future.

To analyze the deviation of total cost to the optimal one, we calculate the absolute difference as in Eq. (6). It means that the costs more close the minimum value when the absolute difference being more small.

Table 1 Summary of computation results for EOQ model

D	EOQ*	TC*
500	111.80	223.61
1,000	158.11	316.23
1,500	193.65	387.30

Table 2 Robust method for EOQ model

TC function for demand	Ordering quantity			Max	Min
	111.80	158.11	193.65		
500	223.61	237.17	258.20	258.20	258.20
1,000	335.41	316.23	322.75	335.41	
1,500	447.21	395.28	387.30	447.21	

$$\frac{TC_{(EOQ)} - TC_{(Q)}}{TC_{(EOQ)}} \tag{6}$$

The absolute difference of total costs is showing in Table 3. If we use the robust ordering quantity 431.13 then the average absolute difference 0.058 may not be the best but absolutely not be the worst.

3.2 Integrated Inventory Model

To illustrate the results of the proposed method, consider an integrated inventory system with data: We consider the possible future demand about D = 500, 1,000 or 1,500 unit/year, A = \$100/order, Cp = \$20/unit, r = 0.2, Cv = \$15/unit, P = 32,000 unit/year, S = 400/set-up. The total cost (TC*) including the buyer and vendor cost is calculated from the optimal quality (Q*) in the all possible demands are listed in Table 4.

Table 5, the robust number is showing by the robust method. Thus, the ordering quantity 431.13 is our conservative policy. Then, we calculate the absolute

Table 3 Total Cost of Absolute Difference with TC* in respective total cost function of possible demand for EOQ

TC function for demand	Ordering quantity		
	247.23	350.82	431.13
500	0.000	0.061	0.155
1,000	0.061	0.000	0.021
1,500	0.155	0.021	0.000
Average	0.072	0.027	0.058

Table 4 Summary of computation results for integrated inventory

D	Q*	TC*
500	247.23	1,719.03
1,000	350.82	2,422.87
1,500	431.13	2,957.31

Table 5 Robust method for integrated inventory model

TC function for demand	Ordering quantity			Max	Min
	247.23	350.82	431.13		
500	1,719.03	1,825.38	1,991.75	1,991.75	1,991.75
1,000	2,572.75	2,422.87	2,474.53	2,572.75	
1,500	3,426.48	3,020.37	2,957.31	3,426.48	

Table 6 Total cost of absolute difference with TC* in respective total cost function of possible demand for integrated inventory model

TC function for demand	Ordering quantity		
	247.23	350.82	431.13
500	0.000	0.062	0.159
1,000	0.062	0.000	0.021
1,500	0.159	0.021	0.000
Average	0.074	0.028	0.060

difference similar to Eq. (6) and the results are listed in Table 6. The ordering quantity 431.13 is our conservative decision.

4 Conclusions

Instead of solving for the optimal solution under the assumption of deterministic demands, here we provide a prescriptive methodology for constructing uncertainty sets within a robust optimization framework for integrated inventory problems with uncertain data. From both numerical examples in Sect. 3, it was found that the robust ordering quantity has the lowest average risk among possible demands. Furthermore, decision makers could even weight in additional information on the possibilities among demands to obtain the final solution.

References

Banerjee A (1986) A joint economic-lot-size model for purchaser and vendor. Decis Sci 17(3):292–311

Banerjee A, Kim S-L (1995) An integrated JIT inventory model. Int J Oper Prod Manage 15(9):237–244

Bertsimas D, Sim M (2004) The price of robustness. Oper Res 52(1):35–53

Ha D, Kim S-L (1997) Implementation of JIT purchasing: an integrated approach. Prod Plann Control 8(2):152–157

Goyal SK (1977) An integrated inventory model for a single supplier-single customer problem. Int J Prod Res 15(1):107–111

Goyal SK (1988) A joint economic-lot-size model for purchaser and vendor: a comment. Decis Sci 19(1):236–241

Goyal SK, Gupta YP (1989) Integrated inventory models: the buyer-vendor coordination. Eur J Oper Res 41(3):261–269

Lu L (1995) A one-vendor multi-buyer integrated inventory model. Eur J Oper Res 81(2):312–323

Pan AC, Liao C-J (1989) An inventory model under just-in-time purchasing agreement. Prod Inventory Manage J 30(1):49

Pan JC-H, Yang J-S (2002) A study of an integrated inventory with controllable lead time. Int J Prod Res 40(5):1263–1273

Ramasesh RV (1990) Recasting the traditional inventory model to implement just-in-time purchasing. Prod Inventory Manage J 31(1):71

Siajadi H, Ibrahim RN, Lochert PB (2006) A single-vendor multiple-buyer inventory model with a multiple-shipment policy. Int J Adv Manuf Technol 27(9–10):1030–1037

Soyster AL (1973) Technical note—convex programming with set-inclusive constraints and applications to inexact linear programming. Oper Res 21(5):1154–1157

Cost-Based Design of a Heat Sink Using SVR, Taguchi Quality Loss, and ACO

Chih-Ming Hsu

Abstract This study proposed a cost-based procedure for resolving multi-response parameter design problems using support vector regression (SVR), Taguchi quality loss and ant colony optimization (ACO). A case study aiming to optimize the design of a heat sink applied in a high-power MR16 LED lamp was used to demonstrate the proposed procedure. The experimental results indicated that the proposed procedure can provide highly robust settings of design parameters which can maximize the thermal performance, as well as can minimize the actual material cost of a heat sink. Furthermore, decision makers no longer need to determine the relative weight of each response subjectively. Therefore, the proposed approach in this study can be considered as feasible and effective, and can be popularized to be a useful tool for resolving general multi-response parameter design problems in the real world.

Keywords Heat sink · Support vector regression · Taguchi quality loss · Ant colony optimization · Multi-response parameter design

1 Introduction

The Taguchi method is a well-known traditional approach for tackling multi-response parameter design problems; however, it has not proved to be fully functional for optimizing multiple responses, especially in the case of correlated responses (Sibalija et al. 2011). Therefore, many recent studies have centered on using/integrating techniques from various fields to find the continuous settings of control factors for a multi-response parameter design problem, e.g. Kim and Lin (2000), Kovach and Cho (2008), Sibalija et al. (2011), Bera and Mukherjee (2012),

C.-M. Hsu (✉)
Department of Business Administration, Minghsin University of Science and Technology, 1 Hsin-Hsing Road, Hsin-Fong, Hsinchu 304, Taiwan, Republic of China
e-mail: cmhsu@must.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_92,

Devi et al. (2012), He et al. (2012), Mukherjee et al. (2012) and Salmasnia et al. (2012).

In the above studies, the estimation of functional relationship between control factors and responses usually relies on the accuracy of second-order polynomials, which are not always suitable (Goethals and Cho 2012). Next, decision makers must specify the relative weight (importance) of each response and/or set the coefficient that manipulate the shape of a desirability function subjectively while transforming multiple responses into a single objective. Furthermore, the manufacturing or material cost of a product is not considered while determining the optimal settings of design/process parameters. To overcome these shortcomings, this study attempts to apply the support vector regression (SVR), Taguchi quality loss and ant colony optimization (ACO) to develop a procedure for resolving a multi-response parameter design problem.

2 Research Methodologies

2.1 Support Vector Regression

Support vector regression (SVR) (Vapnik et al. 1997; Drucker et al. 1997) is the application of support vector machine (SVM) to the case of function approximation or regression. Given a training data $\{X_k, d_k\}_{k=1}^{Q}$ where the input variable $X_k \in \mathbb{R}^n$ is an n-dimensional vector and the output variable $d_k \in \mathbb{R}$ is a real value, SVR approximates a function of the form

$$f(X, W) = \sum_{i}^{m} w_i \varphi_i(X) + w_0 = W^T \Phi(X) + w_0 \tag{1}$$

where w_i is the weight; W is the weight vector; $\varphi_i(X)$ is the feature; $\Phi(X)$ is the feature vector; w_0 is the bias. In order to evaluate the prediction error, Vapnik (1998) introduced the ε-insensitive loss function, defined by

$$L_\varepsilon(d, f(X, W)) = \begin{cases} 0 & \text{if} |d - f(X,W)| \leq \varepsilon \\ |d - f(X,W)| - \varepsilon & \text{otherwise} \end{cases}. \tag{2}$$

Therefore, the penalty (loss) can be expressed by

$$d_i - W^T \Phi(X) - w_0 - \varepsilon \leq \xi_i, \quad i = 1, \ldots, Q \tag{3}$$

$$W^T \Phi(X) + w_0 - d_i - \varepsilon \leq \xi_i', \quad i = 1, \ldots, Q \tag{4}$$

$$\xi_i \geq 0, \quad i = 1, \ldots, Q \tag{5}$$

$$\xi_i' \geq 0, \quad i = 1, \ldots, Q \tag{6}$$

where ξ_i and ξ_i' are non-negative slack variables. The empirical risk minimization problem then can be defined as Vapnik (1995), (1998)

$$\frac{1}{2}||W||^2 + C\left(\sum_{i=1}^{Q}\xi_i + \sum_{i=1}^{Q}\xi_i'\right) \tag{7}$$

subject to the constraints in (3)–(6), where C is a user specified parameter for the trade-off between complexity and losses. To solve the optimization in (7), the Lagrangian in primal variables are constructed and its partial derivatives with respect to the primal variables have to vanish at the saddle point for optimality. Therefore, the simplified dual form then can be obtained, and the optimal weight vectors can be obtained, with the Lagrangian optimization done, as follows

$$\hat{W} = \sum_{i=1}^{Q}(\hat{\lambda}_i - \hat{\lambda}_i')\Phi(X_i) = \sum_{k=1}^{n_s}(\hat{\lambda}_k - \hat{\lambda}_k')\Phi(X_k) \tag{8}$$

where n_s is the number of support vectors. Finally, the optimal bias can be obtained as follows

$$\hat{w}_0 = \frac{1}{n_{us}}\sum_{i=1}^{n_{us}}\left(d_i - \sum_{k=1}^{n_s}\beta_k K(X_k, X_i) - \varepsilon\ \mathrm{sign}(\beta_i)\right) \tag{9}$$

where n_{us} is the number of unbounded support vectors with Lagrangian multipliers satisfying $0 < \lambda_i < C$, and $\beta_i = \hat{\lambda}_i - \hat{\lambda}_i'$.

2.2 Ant Colony Optimization

The ant colony optimization (ACO) approach, which extends to the continuous domain as proposed by Socha (2004), is closest to the spirit of ACO for discrete problems (Blum 2005). Suppose a population with a cardinality of k is used to solve a continuous optimization problem with n dimensions, Socha (2004) used the Gaussian function to estimate the distribution of each member (ant) in the solution population. For the ith dimension, the jth Gaussian function, with the mean μ_j^i and standard deviation σ_j^i, is represented by

$$g_j^i(x) = \frac{1}{\sigma_j^i\sqrt{2\pi}}e^{-\frac{(x-\mu_j^i)^2}{2\sigma_j^{i2}}}, \quad \forall i = 1,\ldots,n,\ \forall j = 1,\ldots,k,\ \forall x \in \mathrm{R} \tag{10}$$

All solutions in the population are ranked based on their fitness with rank 1 for the best solution, and the associated weight of the jth member of the population in the mixture is calculated by Blum (2005):

$$w_j = \frac{1}{qk\sqrt{2\pi}} e^{-\frac{(r-1)^2}{2q^2k^2}}, \quad \forall j = 1, \ldots, k \tag{11}$$

where r is the rank of the jth member and q (> 0) is a parameter of the algorithm. Each ant j must choose one of the Gaussian functions $(g_1^1, g_2^1, \ldots, g_j^1, \ldots, g_k^1)$ for the first dimension, i.e. the first construction step, with the probability (Blum 2005)

$$p_j = \frac{w_j}{\sum_{l=1}^{k} w_l}, \quad \forall j = 1, \ldots, k. \tag{12}$$

For the j^*th Gaussian function in the ith dimension, the mean and standard deviation are set by Blum (2005)

$$\mu_{j^*}^i = x_{j^*}^i, \quad \forall i = 1, \ldots, n, \tag{13}$$

$$\sigma_{j^*}^i = \frac{1}{k}\rho \sum_{j=1}^{k} \sqrt{(x_j^i - x_{j^*}^i)^2}, \quad \forall i = 1, \ldots, n, \tag{14}$$

respectively, where x_j^i is the value of the ith decision variable in solution (ant) j and $\rho \in (0, 1)$ is the parameter which regulates the speed of convergence. For the detailed execution steps of the ant colony optimization for continuous domains, readers can refer to Socha (2004) and Blum (2005).

3 Proposed Cost-Based Parameter Design Procedure

In this study, a cost-based parameter design procedure for resolving multi-response parameter design problems using SVR, Taguchi quality loss and ACO was proposed to overcome the shortcomings in the literatures. The proposed procedure is described as follows:

Step 1: Determine the key quality characteristics of a product and specification limits.
Step 2: Identify and arrange control factors.
Step 3: Identify and arrange noise factors.
Step 4: Conduct each experimental trial and collect data.
Step 5: Build SVR estimation models.
Step 6: Optimize settings of control factors through ACO.
Step 7: Conduct the confirmation experiment.
Step 8: Review the results, re-identify the control factors and repeat Steps 2–7 if the confirmation result is unsatisfactory.

Notably, the overall quality regarding a product under a certain combination of control factors' settings is evaluated through a single minimized objective function calculated by

$$TQL = MC + \sum_{j=1}^{r} AQL_j \tag{15}$$

where MC is the actual manufacturing or material cost of a product and r is the total number of quality characteristics. In addition, the AQL_j is the average quality loss calculated by

$$AQL_j = \sum_{k=1}^{s} \frac{QL_j^{(k)}}{s} \tag{16}$$

where s is the total number of combinations of noise factors' evaluation levels and $QL_j^{(k)}$ is the quality loss under a certain combination of control factors' settings along with the kth combination of noise factors' evaluation levels.

4 Case Study on Designing a Heat Sink

Figure 1 is a typical heat sink used in a high-power MR16 LED (light emitting diode) lamp. In order to maximize the thermal performance of a heat sink, the geometric appearance requires an elaborate design as well as the material should be selected carefully. Furthermore, the geometric design affects the volume of a heat sink thus determining its related material cost.

Fig. 1 A typical heat sink for a high-power MR16 LED lamp

Based on the quality improvement objectives, the designers and quality managers of LED lamps determine three key quality characteristics of a heat sink as maximum temperature (y_1), thermal resistance (y_2) and material cost (y_3). The typical upper specification limits for the maximum temperature (y_1) and thermal resistance (y_2) are 85 °C and 3.5 °C/W, respectively, at an ambient air temperature of 25 °C.

Brainstorming with design engineers identified two critical material properties and four main geometric parameters which might significantly affect the three concerned key quality characteristics of a heat sink as control factors including coefficient of thermal radiation (x_1), coefficient of thermal conductivity (x_2), rotation angle (x_3), height of a fin (x_4), width of a fin (x_5), number of fins (x_6). The parameters x_3, x_4 and x_5 are illustrated in Fig. 2. Three types of materials with different coefficients of thermal conductivity and two types of coefficients of thermal conductivity, as summarized in Table 1, were applied in this study. In addition, three experimental levels were set for parameters x_3 to x_6, as summarized in Table 1, in order to estimate their non-linear effects upon the critical quality characteristics. Therefore, a Taguchi $L_{18}(2^1 \times 3^7)$ orthogonal array was selected as the inner array. In addition, a Taguchi $L_9(3^4)$ orthogonal array was used to arrange the noise factors z_1 and z_2 for considering the limitations of machining while making a heat sink as shown in Table 1.

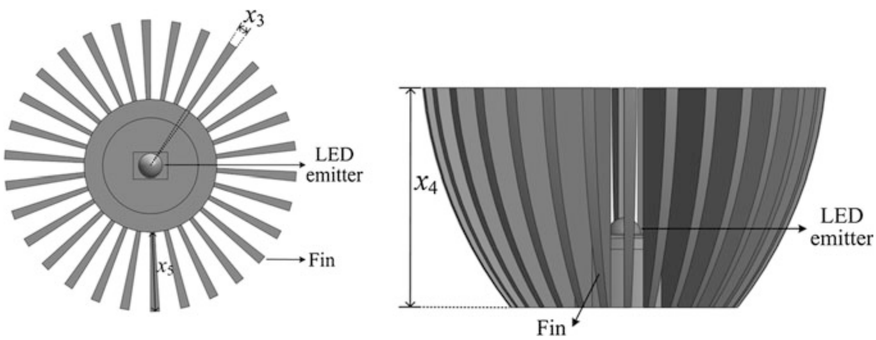


Fig. 2 Illustration of geometric design parameters of a heat sin

Table 1 Experimental settings of control and noise factors

Control factors	x_1	x_2 (W/m·K)	Density (g/cm^3)	Unit cost (NTD/kg)	x_3 (degree)	x_4 (mm)	x_5 (mm)	x_6
Level 1	0.5	170	2.7	120	1.5	18	10.0	20
Level 2	0.9	200	2.8	135	2.5	24	12.5	25
Level 3	–	380	8.9	288	3.5	30	15.0	30
Noise factors	–	–			–	z_1 (mm)	z_2 (mm)	–
Level 1	–	–			–	−0.05	−0.05	–
Level 2	–	–			–	0.00	0.00	–
Level 3	–	–			–	+0.05	+0.05	–

Table 2 Partial experimental trials and collected data

No.	Control factors						Noise factors		Quality characteristics			Average temperature (°C)	Volume (mm^3)
	x_1	x_2 (W/m·K)	x_3 (degree)	x_4 (mm)	x_5 (mm)	x_6	z_1 (mm)	z_2 (mm)	Maximum temperature (y_1, °C)	Thermal resistance (y_2, °C/W)	Material cost (y_3,NTD)		
1	0.5	170	1.5	18	10.0	20	−0.05	−0.05	69.27	3.5774	0.6686	55.74	2,064
2	0.5	170	1.5	18	10.0	20	−0.05	0.00	69.14	3.5804	0.6713	55.60	2,072
3	0.5	170	1.5	18	10.0	20	−0.05	+0.05	69.01	3.5884	0.6740	55.45	2,080
160	0.9	380	3.5	24	10.0	25	+0.05	−0.05	55.05	3.1633	14.3480	43.10	5,598
161	0.9	380	3.5	24	10.0	25	+0.05	0.00	55.11	3.1585	14.2726	43.17	5,568
162	0.9	380	3.5	24	10.0	25	+0.05	+0.05	55.04	3.1513	14.3571	43.12	5,601

Table 3 Execution results of SVR

Dependent variable	Training MSE ($\times 10^{-5}$)	Test MSE ($\times 10^{-5}$)	Training R^2	Test R^2
Maximum temperature	4.95	5.01	0.9997	0.9999
Average temperature	6.29	4.03	0.9997	0.9995
Volume	7.45	3.66	0.9995	0.9998

The SolidWorks 2010 (http://www.solidworks.com) and ANSYS 13 (http://www.ansys.com) were used to conduct the experiment. Table 2 presents a part of the collected experimental results. The SVR using the LIBSVM (http://www.csie.ntu.edu.tw/~cjlin/libsvm/) was employed to build the estimated mathematical models for describing the dependence of the maximum temperature, average temperature and volume on the design parameters based on the collected data in Table 2. The results are summarized in Table 3.

In order to find the optimal settings of six design parameters for a heat sink, this study applied the ACO algorithm to explore the experimental ranges of design parameters where the SVR models were used to describe the mathematical dependence of the maximum temperature, average temperature and volume on the design parameters, respectively. Notably, the objective function that we want to minimize in ACO was designed by (15). The ACO search procedure was implemented for 10 runs. With the aim of minimizing the objective function's value, the combination of design parameters' settings ($x_1 = 0.9$, $x_2 = 170$, $x_3 = 2.08$, $x_4 = 28.41$, $x_5 = 10$ and $x_5 = 23$) was determined as the optimal solution.

A confirmation experiment was conducted to verify the feasibility and effectiveness of the optimal combination of design parameters' settings. According to the simulation results in Table 4, the maximum temperature (y_1) and thermal resistance (y_2) in all confirmation trials can confirm to their specification limits of 85 °C and 3.5 °C/W, respectively. This implies that the proposed procedure indeed provides an optimal design of a heat sink which can optimize the thermal performance and can minimize the actual material cost of a heat sink.

5 Conclusion

To overcome the shortcomings in the literatures, including insufficient accuracy of second-order polynomials as well as subjective determination of relative weights and shape coefficients, this study applied the support vector regression (SVR), Taguchi quality loss, and ant colony optimization (ACO) to develop a cost-based procedure for resolving a multi-response parameter design problem. The feasibility and effectiveness of the proposed approach were verified through a case study on optimizing the design of a heat sink used in a high-power MR16 LED lamp. The experimental results indicated that the proposed solution procedure can provide highly robust design parameters' settings of a heat sink that can optimize the

Table 4 Summary of confirmation experiment results

No.	x_1	x_2 (W/m·K)	x_3 (degree)	x_4 (mm)	x_5 (mm)	x_6	Maximum temperature (y_1, °C)	Thermal resistance (y_2, °C/Watt)	Material cost (y_3, NTD)	Average temperature (°C)	Volume (mm^3)
1	0.9	170	2.08	28.41	10.00	23	56.41	3.4667	1.3285	42.89	4,100
2	0.9	170	2.08	28.36	9.95	23	56.48	3.4667	1.3217	43.09	4,079
3	0.9	170	2.08	28.36	10.00	23	56.44	3.4667	1.3260	43.01	4,093
4	0.9	170	2.08	28.36	10.05	23	56.40	3.4667	1.3304	42.94	4,106
5	0.9	170	2.08	28.41	9.95	23	56.45	3.4667	1.3241	42.99	4,087
6	0.9	170	2.08	28.41	10.00	23	56.41	3.4667	1.3285	42.98	4,100
7	0.9	170	2.08	28.41	10.05	23	56.37	3.4667	1.3328	42.97	4,114
8	0.9	170	2.08	28.46	9.95	23	56.43	3.4667	1.3265	42.91	4,094
9	0.9	170	2.08	28.46	10.00	23	56.39	3.4667	1.3309	42.98	4,108
10	0.9	170	2.08	28.46	10.05	23	56.35	3.4667	1.3353	42.91	4,121

critical quality characteristics of a heat sink, as well as can minimize the actual material cost.

Acknowledgments The author would like to thank the National Science Council, Taiwan, ROC, for its support of this research under Contract No. NSC 101-2221-E-159-009, and also to thank Raymond Huang for his valuable assistance during this study.

References

Bera S, Mukherjee I (2012) An adaptive penalty function-based maximin desirability index for close tolerance multiple-response optimization problems. Int J Adv Manuf Tech 61(1–4):379–390

Blum C (2005) Ant colony optimization: introduction and recent trends. Phys Life Rev 2(4):353–373

Devi SP, Manivannan S, Rao KS (2012) Comparison of nongradient methods with hybrid Taguchi-based epsilon constraint method for multiobjective optimization of cylindrical fin heat sink. Int J Adv Manuf Tech 63(9–12):1081–1094

Drucker H, Burges CJC, Kaufman L, Smola A, Vapnik V (1997) Support vector regression machines. In: Mozer MC, Jordan MI, Petsche T (eds) Advances in Neural Information Processing Systems, vol 9. MIT Press, Cambridge, MA, pp 155–161

Goethals PL, Cho BR (2012) Extending the desirability function to account for variability measures in univariate and multivariate response experiments. Comput Ind Eng 62(2):457–468

He Z, Zhu PF, Park SH (2012) A robust desirability function method for multi-response surface optimization considering model uncertainty. Eur J Oper Res 221(1):241–247

Kim KJ, Lin DKJ (2000) Simultaneous optimization of mechanical properties of steel by maximizing exponential desirability functions. J Roy Stat Soc C-App 49:311–325

Kovach J, Cho BR (2008) Development of a multidisciplinary-multiresponse robust design optimization model. Eng Optimiz 40(9):805–819

Mukherjee R, Chakraborty S, Samanta S (2012) Selection of wire electrical discharge machining process parameters using non-traditional optimization algorithms. Appl Soft Comput 12(8): 2506–2516

Salmasnia A, Kazemzadeh RB, Tabrizi MM (2012) A novel approach for optimization of correlated multiple responses based on desirability function and fuzzy logics. Neurocomputing 91:56–66

Sibalija TV, Majstorovic VD, Miljkovic ZD (2011) An intelligent approach to robust multi-response process design. Int J Prod Res 49(17):5079–5097

Socha K (2004) ACO for continuous and mixed-variable optimization. Paper presented at the 4th international workshop, Brussels, Belgium, 5–8 Sept 2004

Vapnik V (1995) The nature of statistical learning theory. Springer, New York

Vapnik V (1998) Statistical learning theory. Wiley, New York

Vapnik V, Golowich S, Smola A (1997) Support vector method for function approximation, regression estimation, and signal processing. In: Mozer MC, Jordan MI, Petsche T (eds) Advances in neural information processing systems, vol 9., MIT PressCambridge, MA, pp 281–287

Particle Swarm Optimization Based Nurses' Shift Scheduling

Shiou-Ching Gao and Chun-Wei Lin

Abstract The nurse scheduling is a multifaceted problem with the extensive number of constraints requires. In the past, many researchers tried to find the high-quality nursing schedule by analyzing their different aspects and targets, including the lowest cost and the highest efficiency. However, the study lacks of the consideration for nurses' happiness. The nurses with bad mood will feel distracted in their working time, and even quit their jobs in the end. This thesis not only contains the scheduling constraints by the Administrative Regulations and the Hospital Regulations to construct the mathematical models, but also includes the consideration of nurses' happiness. The main algorithm of this research is the Particle Swarm Optimization (PSO). We used PSO to look for the most suitable schedule for nursing staffs to maximize their working happiness.

Keywords Nurses · Shift scheduling · Happiness · PSO

1 Introduction

Hospital is an all year-round, the 24 h operation of the service units, in addition to the outpatient nurses to care for the sick as the main core work, that necessarily take a substantial period of time to get along with patients, their performance is more important, so the nurses the scheduling core operations of the hospital medical management, improve staff morale and productivity has considerable

S.-C. Gao (✉) · C.-W. Lin
Industrial Engineering and Management, National Yunlin University of Science and Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, Republic of China
e-mail: m10021011@yuntech.edu.tw

C.-W. Lin
e-mail: lincwr@yuntech.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_93,

influence (Wen 2008). How to properly manage the nursing manpower arrangement is a major issue. For an adequate supply of services during working hours manpower, the current shift system as the main arrangement, they should make every certain time interval repeating in a new shift table. The a suitable schedules for whether or not the new nurses, on the quality of medical care and other medical services have considerable influence (Lee 2005). Especially nursing staff is not just a job, but a burden of relating to other people's lives and safety of nurses not only is the physical exertion, but also the psychological pressure (Liu 2011).When the accumulation of physical and mental unhappiness and pressure, but can not be properly relieve to cause nurses can not concentrate on work, or even leave. Therefore, the scheduling of the nurses in addition to emphasis on fairness and feasibility, as far as possible to meet the nurses' degree of happiness, construct nurses the highest degree of happiness schedules.

Nurse Scheduling in general hospitals in Taiwan in 24 h shifts a day divided into three classes eight hours, respectively, for the day shift, evening shift and night shift, some differences in different classes of the nature of work, manpowerdemand is not the same (Huang et al. 2009). Must be arranged in accordance with the demand for each shift, to avoid the nurses work excessive burden is too heavy, will have a negative impact on physiological conditions and job preferences (Berrada et al. 1996). Therefore the Nurse Scheduling need to be considered seven factors as fair, reasonable, flexible, humane considerations, etc. (Chang and Lee 1992). And through the unit scheduling, each unit head nurses considering the nurses' personal wishes to schedule. It can improve not only the lack of understanding of the centralized scheduling for nurses demand conditions, and help reduce the self-scheduling to provide high autonomy, easy to increase the difficulty of communication and coordination between the nursing staff, it is both time-consuming and expensive effort.

2 Happiness

The word "happiness" of the Chinese people, including the meaning of happy, pleasant, joy, and it symbolizes a person's heart was filled with joyand happy. In the Analects of Confucius, the word "happiness" expresses personal inner pleasant feelings and spiritual enrichment. It's a self-inner feelings (Bai 2008). Homer and Herodotus believes that happiness is the human body and mind feel exhilarated. And Allard et al. believes that happiness is an emotional joy and happiness, when forward personal emotions than negative emotions will feel happy (Shin and Johnson 1978).

Happiness is a psychological feeling of self-inner, according to the level of consciousness can be divided into three levels: 1. Competitive happiness: The lowest level of happiness, compared competing with others to get happy, the competitive process is not necessarily happy, even in the final happiness is limited; if the lost, the result is not only unhappy, but pain. It is the worst kind. 2. Conditional happiness:The most common and most easily achieve happiness. People tend to be happy with some of the specific conditions tied together, people will be happy when the conditions are met. 3. Unconditional happiness: True happiness does not come from their own people and things, is derived from the self-bliss, not subject to change due to the interference and influence of external things (Ye 2009). Everyone in the pursuit of happiness, in other words the person's life is the target of numerous stacked or chained together (Ye 2009). Each person's definition of happiness is different; in this study for the definition of happiness is a subjective feeling of pleasant personal feelings on their own lives. Freud once said: make up the not enough make people happiness and pleasure (Ma 2005). When a person to get what he wants, needs, or goals to achieve satisfactory level, he has sufficient reason that he is happiness (Simpson 1975). On the contrary, when the demand cannot be met will feel pain (Ma 2005).

Argyle also pointed out that the degree of happiness can be understood as the extent of personal life satisfaction or positive emotional intensity of feelings (Argyle et al. 1997). Diener also believes that the degree of happiness is a personal assessment of the cognitive experience of own lives (Bai 2008). So when the needs and wants of a person's life as much as possible to meet, there will be a happy life (Shin and Johnson 1978). If a person can do what he wants to do, to get what he needs, he will be glad. Therefore, it is a pursuit of happiness behavior, happiness can be obtained through certain events (Dilman 1982).

Happiness is a feeling. People like a bottle filled with Sense and Sensibility, when put in more rational, emotional lacking something more sensual, so that we have the courage to pursue their full measure of happiness. The ratio to adjust the standard is that our own "three benefits": Benefit our feeling, benefit our existence, and benefit our lives (Ye 2009). When beneficial conditions exist, we can feel happy and get happiness. We can through the conditions which would be benefit people are able to do what he wants to do to get what he needs, so that he can be happiness.

3 Model Construction

Nurse Scheduling addition to consider the degree of happiness, must also consider the existing restrictions. Nurse Scheduling limits can be classified as administrative law and hospitals, and regulations of the Association, as well as meet particular target or nurses wishes (Berrada et al. 1996). This study refer to the collation Nurse Scheduling restrictions and limitations, and review the limitations of the study. Summarized as follows:.

1. In accordance with Article 30 of the Labor Standards Law, the labor daily work can not be more than eight hours, and the bi-weekly work hours should not be more than eighty-four hours.
2. In accordance with Article 34 of the Labor Standards Law, If a rotation system, the work shift should be rotate at least once a week. After the shift has been replaced, should be given appropriate time to rest.

3. In accordance with Article 36 of the Labor Standards Law, Workers should have at least a day as official holiday in every seven days.
4. The minimum limit demand, the number of nurse required to meet the demand of the daily each shift.
5. Continuous scheduling restrictions, each nurse only can arrange one shift, to avoid the night shift followed by the evening shift.
6. Each nurses cannot work continuously for more than six days.
7. The combination of each nurse for three days continuously cannot shift off day, works, off day.
8. Each nurse duty at the night shift cannot take every other day the day shift or evening shift.
9. Each nurse duty at the evening shift cannot take every other day the day shift.
10. Each nurse cannot off day continuously for more than five days.

The purpose of this study is that the maximum degree of happiness pursuit of nurses schedules. Mathematical functions in addition to the inclusion in the above constraints, and joined the nurses measure of the degree of happiness, in the limited solution space to find the optimal solution allows nurses to obtain the maximum degree of happiness.

3.1 Parameters

i	Index for nurses; $\forall i = 1, 2, \ldots, I$
j	index for days within the scheduling horizon; $\forall j = 1, 2, \ldots, J$
k	Shift type; $\forall k = 0, 1, 2, 3$ (off day, day, evening, and night shifts, respectively)
d_{jk}	Demand for nurses of shift type k on day j
h_{ij}	Happiness for nurse i on day$j$

3.2 Variables

x_{ijk} nurse i on day j for available shift type l to be assigned

$$x_{ijl} = \begin{cases} 1, \text{if nurse } i \text{ on day } j \text{ for available shift type } k \text{ to be} \\ \text{assigned; } \forall k = 0, 1, 2, 3 \\ 0, \text{otherwise} \end{cases}$$

A_{ij} $A_{ij} = k$, when $x_{ijk} = 1 \, \forall i = 1, 2, \ldots, I$; $\forall j = 1, 2, \ldots, J$; $\forall k = 0, 1, 2, 3$

B_{ij} The shift type which nurse i have on the table with happiness on day j ; $B_{ij} \in 0, 1, 2, 3$ (off day, day, evening, and night shifts, respectively)

L_{ij} $L_{ij} = A_{ij} - B_{ij}$

U_{ij}
$$U_{ij} = \begin{cases} 1, L_{ij} = 0 \\ 0, L_{ij} \neq 0 \end{cases}$$

3.3 Mathematical Model

The objective of this study is to obtain the greatest happiness of the nurses. The objective function is the sum of all shifts consistent happiness for nurse *i* on day *j*. That is:

$$Maximize\,H$$

$$H = \sum_{i=1}^{I}\sum_{j=1}^{J}\left(U_{ij} \times h_{ij}\right) \tag{1}$$

s.t

$$\sum_{k=0}^{3} x_{ijk} = 1 \qquad \forall i = 1,2,\ldots,I; \forall j = 1,2,\ldots,J \tag{2}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{3} x_{ijk} \geq \sum_{k=1}^{3} D_{jk} \qquad \forall j = 1,2,\ldots,J \tag{3}$$

$$D_{jk} = \sum_{i=1}^{I} x_{ijk} \qquad \forall j = 1,2,\ldots,J;\ \forall k = 1,2,3 \tag{4}$$

$$\sum_{j}^{j+6}\sum_{k=1}^{3} x_{ijk} \leq 6 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,8,15,22 \tag{5}$$

$$\sum_{j}^{j+13}\sum_{k=1}^{3} x_{ijk} \leq 10 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,8,15 \tag{6}$$

$$\sum_{j}^{j+5} x_{ij0} \leq 5 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-5 \tag{7}$$

$$\sum_{j}^{j+6}\sum_{k=1}^{3} x_{ijk} \leq 6 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-6 \tag{8}$$

$$x_{ij0} + \sum_{t=1}^{3} x_{i(j+1)k} + x_{i(j+2)0} \leq 2 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-2 \tag{9}$$

$$x_{ij3} + x_{i(j+1)1} \leq 1 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-1 \tag{10}$$

$$x_{ij3} + x_{i(j+1)2} \leq \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-1 \tag{11}$$

$$x_{ij2} + x_{i(j+1)1} \leq 1 \qquad \forall i = 1,2,\ldots,I;\ \forall j = 1,2,\ldots,J-1 \tag{12}$$

$$x_{ijk}, A_{ij}, B_{ij}, U_{ij} \geq 0;\;\; L_{ij} \in Z;\;\; x_{ijk}, U_{ij}, \in \{0,1\};\;\; A_{ij}, B_{ij} \in 0,1,2,3 \tag{13}$$

(1) The objective function. (2)–(13) The constraints. (2) The nurses i only arrange a shifts type k on day j. (3) The minimum limit demand, the sum of the nurses arrange shifts type k on day j should greater than or equal to the demand. (4) The demand on duty, the sum of the nurses arrange not off day shifts type k on day $j$should greater than or equal to the demand. (5) Minimum weekly days off limit, workers should have at least a day as official holiday in every seven days (6) Minimum bi-weekly days off limit, every two weeks working days must be less than or equal to ten days. (7) Number of consecutive off days shall not exceed five. (8) Consecutive days limit, number of consecutive days shall not exceed six. (9) The combination of each nurse for three days continuously cannot shift off day, works, off day. (10) , (11) each nurse duty at the night shift cannot take every other day the day shift or evening shift. (12) Each nurse duty at the evening shift cannot take every other day the day shift. (13) Description of all variables limit.

4 Instance Validation

In this study mathematical functions use the particle swarm algorithm (PSO) to solve the optimal solution. PSO was published by Kennedy and Eberhart in 1995. By observing nature birds foraging search behavior, they developed the optimized search algorithms. It was applied in various fields for more than ten years. Its biggest advantage is that it only requires a few parameters to adjust, can be used to solve most of the optimization problem. In this algorithm, every possible solution is called particle. Each particle to move in the search space dimension D, and note the move once the optimal solution here, to convey the message of the particles. Including the location of the particles x now, acceleration v and the particles adaptation values,For each generation, each particle updates the acceleration and a new location by using the following equation:

$$v_i(t+1) = w \cdot v_i(t) + c_1 \cdot rand() \cdot [p_i - x_i(t)] + c_2 \cdot rand() \cdot [p_g - x_i(t)] \tag{14}$$

Rand() is a random number between 0 and 1, i means the i particle, t means the number of iterations, w means the inertia weight, p_i means the particle once moved best local solution, p_g means the particle once moved best global solution, $c_1$and $c_2$are the learning factors. Calculate the acceleration of a particle, and then update the new location of the particles according to the following formula, and find the optimal solution:

$$x_{\mathrm{i}}(t+1) = x_i(t) + v_i(t+1) \tag{15}$$

PSO step-by-step instructions are as follows:

Step 1: Set parameters.

Table 1 Happiness table (part)

No.	1	2	3	4	5	6	7	8	9	10	11
1				0 100	0 100						
2										0 90	0 100
3											

Table 2 Shift table (part)

NO	1	2	3	4	5	6	7	8	9	10	11
1	0	1	1	0	0	1	1	1	3	3	0
2	3	0	2	2	1	1	1	3	3	0	0
3	0	2	2	0	1	1	1	0	0	2	2

shifts :0: off day, 1: day, 2: evening, 3: night

Step 2: Establish initial solution and randomly generated initialization particle swarm position and speed.
Step 3: Based on the objective function to calculate the fitness values.
Step 4: Compare particles fitness values, if relatively good, updat the location.
Step 5: According to Eqs. (14), (15), adjustment and update the position and velocity of the particles.
Step 6: Back to the Step3 and calculate the new particle fitness value. Stop searching when the iterations reaches the maximum number of searches.

The goal of this study is to obtain the scheduling with the maximum degree of happiness. Happiness comes from people's own feelings, Through to meet the demand, you can get pleasure. So through the investigation of nurses demand for the next month, learning how the scheduling arrangement enables nurses to obtain the maximum degree of happiness. For example, the date 4, 5, and 10, 11 for the holidays, No. 2 nurse hope can arrange shift 0 on date 10 and 11. If come true, it can get 90 and 100 degree of happiness.

Using Table 1 and parameters set into the mathematical functions, and use PSO to find the optimal solution as the following table, nurses can get at least 390 degree of happiness: (Table 2).

5 Conclusion

This study constructs a mathematical model to maximize the nurse happiness, and solve it through the PSO. Use computer program to help nurses arrange schedules, solving the maximum degree of happiness schedules. That not only can reduce the time-consuming manual scheduling, but also try to meet the needs of each nurse, to obtain the maximum degree of happiness schedules.

Acknowledgments The authors are grateful to nurses and friends for careful guidance and help to overcome all the difficulties and trials. Finally thanks the reviewers members of this seminar with the relevant staff.

References

Argyle M, Shi J-B, Lu L (1997). The psychology of happiness. CHULIU, Taipei

Bai S-H (2008) Positive life events on happiness, happiness, self-esteem. Dissertation, Fo Guang University

Berrada I, Ferland JA, Michelon P (1996) A multi-objective approach to nurse scheduling with both hard and soft constraints. Socio-Economic Plann Sci 30(3):183–193

Chang C-Y, Lee S-S (1992) Nurse scheduling system of experimental design. Hosp Comp 8:65–70

Dilman I (1982) Happiness. J Med Ethics 8(4):199–202. doi:10.2307/27716097

Huang Y-C, Jian S-H, Kang J-R (2009) Nurses rostering under the consideration of staff preferences. J Health Sci 11(1):57–69

Lee J-D (2005) Constraint programming models for 7 × 24 manpower scheduling problem: a case of nurse scheduling application. Dissertation, National Chiao Tung University

Liu Z-Y (2011) The research of the relationship between employee assistance programs and employee's turnover intention- taking employee's job satisfaction as a mediator. Dissertation, National Central University

Ma Z-F (2005) Turn the key to happiness: Oscar Wilde, "The happy prince analysis". Elementary Educ J 52(1):50–57

Shin DC, Johnson DM (1978) Avowed happiness as an overall assessment of the quality of life. Soc Indic Res 5(1):475–492

Simpson RW (1975) Happiness. American Philos Q 12(2):169–176. doi:10.2307/20009571

Wen J-B (2008) A study of nurse scheduling factors in a regional hospital. Dissertation, Southern Taiwan University of Science and Technology

Ye Z (2009). Peking university professor given 28 Happy rule, 1st edn. Taiwan: by the Court Press (Knowledge and Innovation Agency), Taiwan

Applying KANO Model to Exploit Service Quality for the Real Estate Brokering Industry

Pao-Tiao Chuang and Yi-Ping Chen

Abstract This research applies Kano model to exploit service quality for the REB industry in Taiwan. The study, firstly, collected data about the importance degree of each REB quality requirements through a questionnaire survey. Meanwhile, the Kano questions and evaluation criteria were designed in the functional and dysfunctional questions of the questionnaire to collect data for further classifications of the two-dimensional quality model of REB industry. Then, a factor analysis was used to group the quality requirements into quality dimensions. Finally, a satisfaction-dissatisfaction matrix analysis was performed to confirm what quality attribute that each quality dimension of REB belongs to in the Kano's two dimensional model. Results show that quality dimensions of security and dependability are confirmed as the "must-be" attributes of Kano model. Reliability is the "one-dimensional" attribute. Profession and information belong to the "attractive" attributes. Whereas, tangibility, communication, and empathy are identified as the "indifference" attributes of Kano model. Managerial suggestions are also provided.

Keywords Service quality · KANO model · Satisfaction coefficient · Dissatisfaction coefficient · Satisfaction-dissatisfaction matrix

P.-T. Chuang (✉)
Department of Asia–Pacific Industrial and Business Management, National University of Kaohsiung, Kaohsiung, Taiwan
e-mail: ptchuang@nuk.edu.tw

Y.-P. Chen
Catcher Technology Co., Ltd, Tainan, Taiwan
e-mail: zeus925854@yahoo.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_94,

1 Introduction

According to the Directorate General of Budget, Accounting and Statistics (DGBAS) of Executive Yuan, Taiwan, the percentage of households that self-owned the house or apartment in Taiwan is 84.58 % in year of 2011. In most European nations and the United States, relatively, the percentage is around 60 %. From this statistics, we can realize that most Taiwanese would prefer living in self-owned house or apartment. Therefore, finding a suitable and comfortable self-owned house or apartment becomes an important issue to most Taiwanese family. Nevertheless, it always spends lots of time and energy to find an ideal house, and needs to consider many factors such as location, traffic condition, as well as living functions of the vicinity. Thus, most people would consign this job to the real estate brokers, who are more professional in searching an appropriate house for the clients and saving their time and energy.

Real estate brokering (REB) industry can provide service to satisfy customer's requirements on searching a house or apartment. Like other service industries, REB may either bring good service to satisfy customers or disregard customer's needs that results in unsatisfied customers. That is, when a customer who needs a brokering service for either buying or renting a house/apartment, he or she would have some quality requirements (expectations) from the service. Throughout the entire process, the customer would perceive how well (perceptions) the service is provided and evaluate the REB service quality. Literatures have shown that the higher the service quality is, the higher the satisfaction and the loyalty of customers will be; and this would bring more profitability to the service company (Heskett et al. 1994, Heskett and Sasser Jr 2010).

Service quality is defined as the measure of how well the service level delivered matches the customer expectations (Grönroos 1982, Parasuraman et al. 1985, 1988). Delivering a quality service means conforming to customers' expectations on a consistent basis. Perceived service quality can be evaluated as the degree and direction of discrepancy between consumers' perceptions and their expectations about the particular service provided by the service company. Following this definition, the service quality can then be evaluated, compared to its counterpart of manufacturing product quality, from the perspective of customer. After this debut, a lot of literatures regarding service quality has been evaluated and analyzed, both practical and academic applications, for either a specific service industry or a particular service company, (e.g., Berry et al. 1994, 1997, Harrison-Walker 2002, Taylor 2004, Peiró et al. 2005, Pakdil and Aydin 2007, Lin 2010). Regarding the REB service quality, Zeng (1990), Mao (1995), and Wang (2007) adopted the SERVQUAL instrument, which proposed by Parasuraman et al. (1988), to empirically studied the service quality of the real estate brokering industry in Taipei city, Taichung city, and Taipei county of Taiwan, respectively.

Most of the existing research about REB service quality adopted a one-dimensional viewpoint to evaluate each of the quality requirements. It means the higher the perceived service quality, the higher the customer's satisfaction, and vice versa. In fact, nevertheless, not all the quality requirements have linear contributions to the overall customer satisfaction. Some of them may have curvilinear relationship between the perception of quality requirement and the extent of customer satisfaction. In this aspect, Kano et al. (1984) proposed a two-dimensional quality model, the so-called Kano model, which distinguished five categories of quality attributes (must-be, one-dimensional, attractive, indifference, and Reverse) that influence customer satisfaction on different ways when met (Matzler and Hinterhuber 1998).

This research applies Kano model to exploit service quality for the REB industry in Taiwan. The study, firstly, collected data about the importance degree of each REB quality requirements through a questionnaire survey. Meanwhile, the Kano questions and evaluation criteria were designed in the functional and dysfunctional questions of the questionnaire to collect data for further classifications of the two-dimensional quality model of REB industry. Then, a factor analysis was used to group the quality requirements into quality dimensions, which identify latent dimensions that direct analyses may not and reduce number of variables that consist of quality requirements. Finally, a satisfaction-dissatisfaction matrix analysis was performed to confirm what quality attribute that each quality dimension of REB belongs to in the Kano's two dimensional model. Based on this analysis, corporate resource allocation strategy for improving service quality is suggested for the REB companies.

2 Kano Two-Dimensional Model

Unlike conventional one-dimensional viewpoint on quality attributes, the two dimensional model addresses the non-linear relationship between quality attribute performance and overall customer satisfaction. Kano et al. (1984) were the first to propose that quality attributes can be classified into five categories based on the level of impact of individual attributes on overall customer satisfaction. The five categories are must-be (basic), one-dimensional (performance), attractive (excitement), indifference, and reverse quality. The definition of those five quality attributes is also shown below.

(1) Must-be (Basic) quality: The "must-be" attributes are basic criteria of a product/service. If these attributes are not fulfilled, the customer will be extremely dissatisfied. On the other hand, as the customer takes these attributes for granted, their fulfillment will not increase his satisfaction.
(2) One-dimensional (Performance) quality: For "one-dimensional" attribute, customer satisfaction is proportional to the level of fulfillment. The higher the level of fulfillment is, the higher the customer's satisfaction is; and vice versa.
(3) Attractive (Excitement) quality: The relation curve for the "attractive" attribute is upward with a steeper slope in the presence of the attribute, implying

that a lack of this attribute has little impact on customer satisfaction but the presence of the attribute provides great satisfaction.

(4) Indifference quality: With regards to the “indifference” attribute, customer satisfaction will not be affected no matter whether this quality attribute is provided or not. That is, providing indifference quality attributes do not bring advantages to customer satisfaction.

(5) Reverse quality: The influencing direction of “reverse” attribute on customer satisfaction is opposite to that of “one-dimensional”. Customers will be dissatisfied if this quality attribute is provided; otherwise, they will be satisfied.

3 Factor Analysis for Quality Dimensions of REB Service

To construct the Kano questionnaire, this research firstly listed 34 items of service quality requirements of REB by explorative investigation and synthesizing those literatures of Zeng (1990), Mao (1995) and Wang (2007). These quality requirements are shown in Table 1. The importance degree for each quality requirements were investigated by a questionnaire survey, in which the data regarding to customer responses for those Kano questions were also collected. The Likert-five-scale was used for the importance degree. A total of 300 questionnaires were distributed to those respondents who had bought or rent houses by way of the REB companies. Among those 153 questionnaires were collected and 127 were determined as valid.

Based on the importance degree, the factor analysis was used to group the quality requirements into 8 dimensions, by deleting 5 items of quality requirements that have factor loadings less than 0.5. This leaves a total of 29 quality requirements that spread in 8 dimensions.

Table 1 Kano’s functional and dysfunctional questions in the questionnaire

Kano question	Respondent’s answer
Functional form of the question (e.g., If the service is conforming to the facts, how do you feel?)	I like it that way It must be that way I am neutral I can live with it that way I dislike it that way
Dysfunctional form of the question (e.g., If the service is not conforming to the facts, how do you feel?)	I like it that way It must be that way I am neutral I can live with it that way I dislike it that way

4 Kano Questionnaire Design and Evaluation Criteria

In the questionnaire survey, the Kano questions were designed to collect data for further classification of quality attributes in the two-dimensional quality model. The paper adopted the types of question that were designed and proposed by Kano et al. (1984). The Kano questions are shown as Table 1. In the questionnaire, questions regarding to the extent of customer satisfaction when individual quality requirements are presented and the extent of customer dissatisfaction when individual quality requirements are absent were answered by the respondents. For each quality requirement a pair of questions is formulated to which the customer can answer in one of five different ways when he or she faces the functional or dysfunctional situations, respectively. That is, the first question concerns the reaction of the customer if the REB service has that quality requirement; and the second question concerns the reaction of the customer if the REB service does not have that quality requirement.

For each individual questionnaire, the category for each of the quality requirements is determined by the Kano evaluation table, shown as Table 2. If the customer answers, for example, "I like it that way" for the functional question and answer "I am neutral" for the dysfunctional question, the corresponding quality requirement is determined as "Attractive" quality attribute in the Kano classification.

5 Satisfaction-Dissatisfaction Matrix Analysis

To confirm which quality attribute of Kano classification that each quality dimension belongs to, the paper proposed a matrix analysis that displays the relative location of each pair of standardized dissatisfaction coefficient with the dysfunctional quality dimension (Zx) and standardized satisfaction coefficient with the functional quality dimension (Zy).

The dissatisfaction coefficient (X), when a particular quality dimension is dysfunctional, is computed as Eq. (1). The Satisfaction coefficient (Y), when a particular quality dimension, is functional is computed as Eq. (2). The

Table 2 Kano evaluation table

		Dysfunctional form of the question				
		Like	Must-be	Neutral	Live with	Dislike
Functional form of the question	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Table 3 Computation results for dissatisfaction and satisfaction coefficients

Factor (Quality Dimension)	Quality requirement	A	O	M	I	R	Q	Dissat. Coeff.	Sat. Coeff.	Zx (Dissat. With Dysfunc.)	Zy (Satis. With Func.)
Security	Q1	11	43	52	21	0	0	0.459	0.791	1.958	−0.206
	Q2	9	51	54	13	0	0				
	Q3	10	42	58	13	3	1				
	Q4	19	41	49	15	2	1				
	Q5	13	49	57	7	1	0				
Reliability	Q7	15	37	39	33	3	0	0.482	0.595	0.550	0.143
	Q8	29	31	33	32	2	0				
	Q9	13	44	42	24	3	1				
	Q10	35	36	34	21	1	0				
Information	Q12	29	49	21	27	1	0	0.533	0.503	−0.110	0.945
	Q13	22	41	24	37	1	2				
	Q14	42	24	25	33	3	0				
	Q15	18	32	60	17	0	0				
	Q16	43	34	30	18	1	1				
	Q17	49	18	21	39	0	0				
Communication	Q18	30	38	39	19	1	0	0.434	0.466	−0.378	−0.601
	Q19	27	26	23	44	7	0				
	Q20	26	27	25	47	2	0				
	Q21	13	28	25	58	3	0				
Profession	Q22	19	48	33	26	1	0	0.591	0.484	−0.246	1.860
	Q23	53	29	12	32	1	0				
Empathy	Q27	28	30	28	41	0	0	0.466	0.391	−0.915	−0.093
	Q28.	28	32	9	57	0	1				
Tangibility	Q29.	32	11	6	78	0	0	0.392	0.340	−1.279	−1.266
	Q30	29	13	26	59	0	0				
	Q31	31	21	16	58	0	1				
	Q32	13	48	31	34	1	0				
Depend-ability	Q33	12	42	46	26	1	0	0.422	0.577	0.422	−0.784
	Q34	23	29	28	45	1	1				

standardized dissatisfaction coefficient with the dysfunctional quality dimension (Zx) is computed as Eq. (3) and the standardized satisfaction coefficient with the functional quality dimension (Zy) is computed as Eq. (4). Results of these coefficients are shown in Table 3.

$$X_i = \sum_{i=1}^{k_i} \left(\frac{A+O}{A+O+M+I} \right) \tag{1}$$

$$Y_i = \sum_{i=1}^{k_i} \left(\frac{O+M}{A+O+M+I} \right) \tag{2}$$

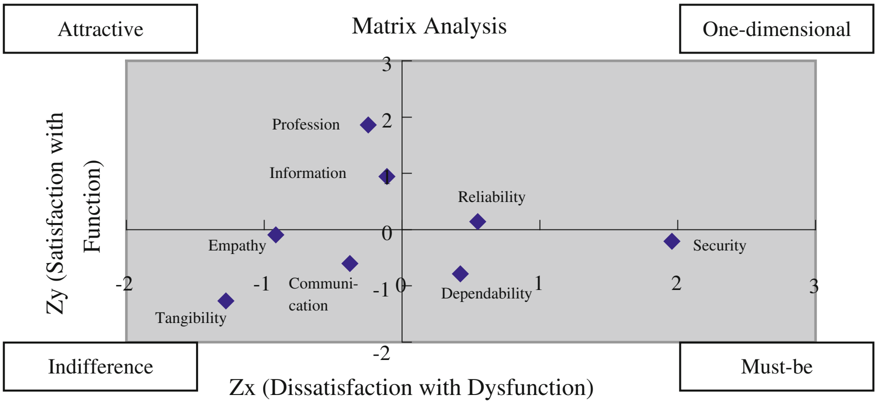


Fig. 1 Satisfaction-dissatisfaction matrix analysis

$$Z_{X_i} = \frac{X_i - \overline{X}}{s_X} = \frac{X_i - \frac{\sum_{i=1}^{8} X_i}{8}}{\sqrt{\frac{\sum (X_i - \overline{X})^2}{7}}} \tag{3}$$

$$Z_{Y_i} = \frac{Y_i - \overline{Y}}{s_Y} = \frac{Y_i - \frac{\sum_{i=1}^{8} Y_i}{8}}{\sqrt{\frac{\sum (Y_i - \overline{Y})^2}{7}}} \tag{4}$$

where, A is the frequency of respondents whose answer is classified as "attractive" quality attribute; O is the frequency for "one-dimensional"; M for "must-be; I for "Indifference"; R for "reverse"; and Q for questionable result. k_i represent the number of quality requirements that are grouped into the ith quality dimension by factor analysis.

Results of the satisfaction-dissatisfaction Matrix is shown in Fig. 1. From the figure, quality dimensions of security and dependability are confirmed as the "must-be" attributes of Kano model. Thus, REB companies should ensure those quality dimensions work functionally well to prevent from refusal of customers. Reliability is the "one-dimensional" attribute. That is, the REBs need to continue increase the function of reliability to increase the customer's satisfaction and decrease the dissatisfaction. Profession and information belong to the "attractive" attributes. It tells the REBs that providing good functions of profession and information could be sources of increasing customer loyalty. Whereas, tangibility, communication, and empathy are identified as the "indifference" attributes of Kano model. Therefore, some of resources that were previously put in those quality dimensions can be adjusted to strengthen other attributes of quality dimensions.

6 Conclusion

Existing research about REB service quality always adopted a one-dimensional viewpoint to evaluate each of the quality requirements. In fact, nevertheless, not all the quality requirements have linear contributions to the overall customer satisfaction. Some of them may have curvilinear relationship between the perception of quality requirement and the extent of customer satisfaction. This research applies Kano model to exploit service quality for the REB industry in Taiwan. In the research, a factor analysis was used to group the quality requirements into eight quality dimensions. The Kano questions and evaluation criteria were designed in the functional and dysfunctional questions of the questionnaire to collect data for further classifications of the two-dimensional quality model of REB industry. A satisfaction-dissatisfaction matrix analysis was performed to confirm what quality attribute that each quality dimension of REB belongs to in the Kano's two dimensional model. Results show that quality dimensions of security and dependability are confirmed as the "must-be" attributes of Kano model. Reliability is the "one-dimensional" attribute. Profession and information belong to the "attractive" attributes. Whereas, tangibility, communication, and empathy are identified as the "indifference" attributes of Kano model. Based on this analysis, corporate resource allocation strategy for improving service quality is suggested for the REB companies.

Acknowledgments This work is partially supported by the National Science Council of Taiwan under the grant (NSC 101-2221-E-390-012). The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Berry LL, Parasuraman A, Zeithaml VA (1994) Improving service quality in America: lessons learned. Acad Manage Executive 8:32–45

Berry LL, Parasuraman A (1997) Listening to the customer: the concept of a service-quality information system. Sloan Manage Rev 38:65–66

Grönroos C (1982) Strategic management and marketing in the service sector. Swedish Sch Econ Bus Adm, Helsingfors, Sweden

Harrison-Walker LJ (2002) Examination of the factorial structure of service quality: a multi-firm analysis. Serv Ind J 22:59–72

Heskett JL, Jones TO, Loveman GW, Sasser WE Jr, Schlesinger LA (1994) Putting the service-profit chain to work. Harv Bus Re 72:164–174

Heskett JL, Sasser WE Jr (2010) The service profit chain. In: Maglio PP et al (eds) Handbook of service science. Springer Science+Business Media, LLC, pp 19–29

Kano N, Seraku N, Takahashi F, Tsuji S (1984) Attractive quality and must-be quality. Hinshitsu: J. Japanese Soc for Quality Control, 39–48

Lin HT (2010) Fuzzy application in service quality analysis: an empirical study. Exp Sys Appl 37:517–526

Mao CK (1995) A study of service quality of real estate agent in Taichung city. Unpublished Master Thesis. Dept. of Land Management, Feng Chia University

Matzler K, Hinterhuber HH (1998) How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. Technovation 18:25–38

Pakdil F, Aydin Ö (2007) Expectations and perceptions in airline services: an analysis uing weighted SERVQUAL scores. J Air Transp M 13:229–237

Parasuraman A, Zeithaml VA, Berry LL (1985) A conceptual model of service quality and its implications for future research. J Marketing 49:41–50

Parasuraman A, Zeithaml VA, Berry LL (1988) SERVQUAL: a multiple item scale for measuring consumer perceptions of service quality. J Retail 64:12–40

Peiró JM, Martínes-Tur V, Ramos J (2005) Employees' overestimation of functional and relational service quality: a gap analysis. Serv Ind J 25:773–788

Taylor A (2004) A journey to the truth: achieving top box customer satisfaction at enterprise. Executive Speeches 19:12–18

Wang HY (2007) The real estate brokerage service quality research of Taipei county. Unpublished Master Thesis. Graduate School of Business and Management, Vanung University

Zeng YM (1990) A study of service quality research: a study case of rehouse industry in Taipei. Unpublished Master Thesis. Institute of Management Science, Tamkang University

Automated Plastic Cap Defect Inspection Using Machine Vision

Fang-Chin Tien, Jhih-Syuan Dai, Shih-Ting Wang and Fang-Cheng Tien

Abstract Plastic caps are the most commonly seen bottle caps used in beverage and food containers. They are widely used to seal freshness of beverage or liquids in bottles. Threads are usually grooved inside the caps for easy twist-off caps and sealing rings prevent the liquids from bacterial infection. Companies print logos or pictures on the top surface of plastic cap, such that the quality of printing also indirectly affects the customers purchase. Inspection of plastic caps, including the surface printing, thread, and sealing ring, is a great issue during the caps production currently. The objective of this study is to use machine vision to inspect the defect of the sealing area and the printing surface of a plastic cap. An automated inspection system, which includes two CCD camera, lighting source, sensors, and a cap transporter, is constructed, and a digital image processing software is designed to learn good caps and screen out the defective ones. The experimental results show that the proposed inspection system can self-learn the features of a good surface printing, and effectively detect the defective caps under very few parameters setting, while the major defects in the sealing ring and thread area such as malformation, contamination, overfill, incomplete, scratches, can be successfully identified under the rate of 1,200 piece per minute.

Keywords Machine vision inspection · Plastic cap · Cap print inspection · Cap sealing ring inspection

F.-C. Tien (✉) · J.-S. Dai · S.-T. Wang
Department of Industrial Engineering, Taipei Tech, 1, Chung-Hsia East Road Sec. 3, Taipei, Taiwan, Republic of China
e-mail: fctien@ntut.edu.tw

F.-C. Tien
Department of Applied Statistics, Chung Hua University, 707, Sec.2, WuFu Rd, Hsinchu, Taiwan, Republic of China30012,

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_95,

1 Introduction

Plastic cap is the most commonly used item to seal the PET bottles for most of the drinks. In plastic caps, threads are usually grooved inside the caps for easily twist-off, while sealing rings are designed to prevent the liquids from bacterial infection. Besides, producers print logos or pictures on the top surface of plastic caps, such that the quality of printing also indirectly affects the customers purchase. In this study, the size of cap with printed logos and sealing ring is ranged between 28 and 30 mm. The automated detection technology (Chin and Harlow 1982; Newman and Jain 1995) is an integrated technology, including optical technology, mechanical design, image processing, computer-aided processing and control. A machine vision system is composed with hardware and software, which using a variety of algorithms and computing capabilities to develop different applications. The hardware is composed of light sources, lens, CCD, video capture card, computer and I/O devices. The software usually includes the technology of pattern recognition (Belongie et al. 2002), feature extraction (Torralba et al. 2007), spatial data capture, etc.

The objective of this study is to use machine vision to inspect the defect of the sealing area and the printing surface of a plastic cap. An automated inspection system, which includes two CCD camera, lighting source, sensors, and a cap transporter, is constructed, and a digital image processing software is designed to learn good caps and screen out the defective ones.

2 Proposed Method

The configuration of proposed system is shown in Fig. 1. This study sets up a set of lighting device and two CCD cameras on a conveyor, which transport caps to a proper position; the CCD cameras are triggered by sensors to acquire the cap top and bottom images; and to use appropriate image processing method (Qing hua et al. 2010) to determine the cap defects. Then, the inspected cap is transported to screener to screen out the defective caps. In particular, this study develops a learning process which acquires cap patterns to find inspection parameters automatically for surface inspection, while the sealing ring inspection uses connected-component labeling (Haralick and Shapiro 1992) to get image parameters. The details of inspection process are described in the following sections.

3 Inspection of Sealing Ring

This study adopts high speed black-and-white cameras to acquire images with 900×900 pixels on the fly for sealing ring inspection. As shown in Fig. 2a, the cap and its background are highly different, so can be easily differentiated through

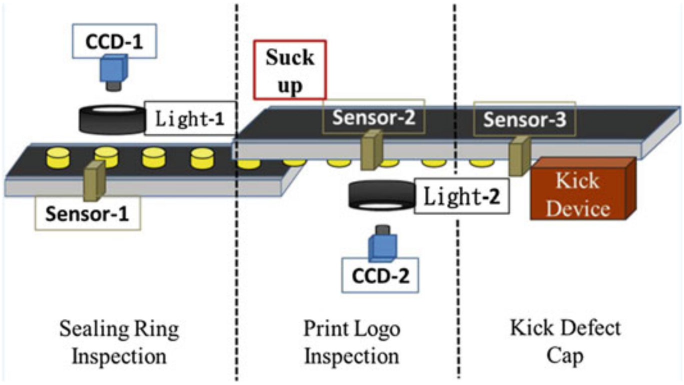


Fig. 1 Configuration of proposed inspection system

a simple threshold. After that, the center of the cap and its radius is calculated by blob analysis such that the image of cap is segmented into five circular regions, so called cap edge, cap base, bottle top, cap sealing ring, and cap center, which are denoted by R0, R1, R2, R3, R4 respectively as shown in Fig. 2.

After segmentation, the gray vale of each region can be calculated. The maximum and minimum gray values are set as upper and lower limits for double thresholding processing. A set of normal caps are collected to learn the average of

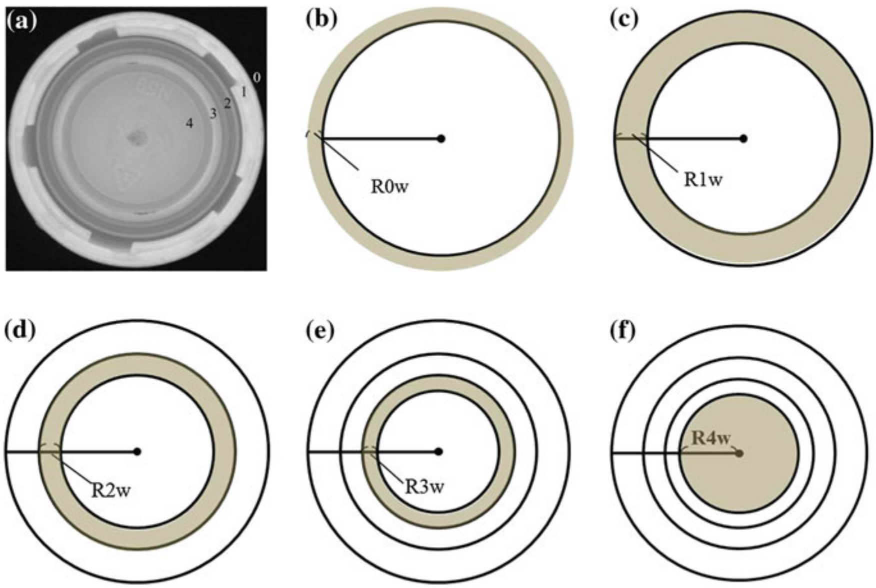


Fig. 2 Segmentation of cap image. **a** A cap image divided into five sections. **b** Cap edge. **c** Cap base. **d** Bottle top. **e** Cap sealing ring. **f** Cap center. *Riw* represents the radius of ith region

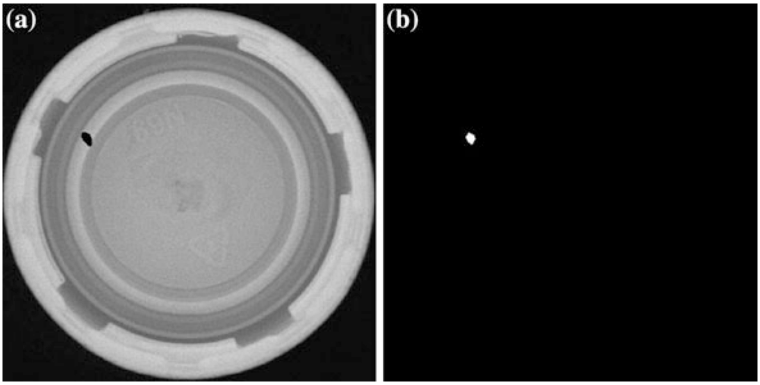


Fig. 3 Defect detection process. **a** A cap with defect in region 3. **b** After defect detection

Table 1 Gray value limits of each region

Region	Min gray value	Max gray value
R0	0	37
R1	103	228
R2	102	155
R3	118	195
R4	114	184

upper and lower limits, and then use these two limits to identify any abnormal gray value in these region. An example is shown in Fig. 3 and Table 1. The upper and lower limits of trained caps are first calculated, and then a cap with a defect in region 3 can be easily detected by its lower limit of gray value.

4 Inspection of Printing Logo

Most of caps have distinctive features such as changeable print logos and color patterns. This study uses a color CCD camera to acquire images for print logos on top surface with the same image size, and then a two-step inspection process, learning and inspecting, are developed.

4.1 Learning Process

Each cap owns different printing logos and color patterns. In this study, we first convert the color image into three color channels (RGB) of image, and calculate the image variance of each image. Instead of processing three images, we select

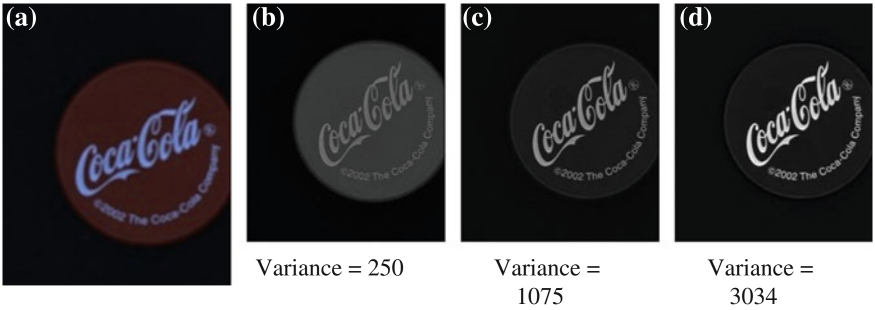


Fig. 4 Color image convert to three grayscale image and variance of cap image. **a** Color image. **b** *Red grayscale* image with variance 250. **c** *Green grayscale* image with variance 1,075. **d** *Blue grayscale* image with variance 3,034

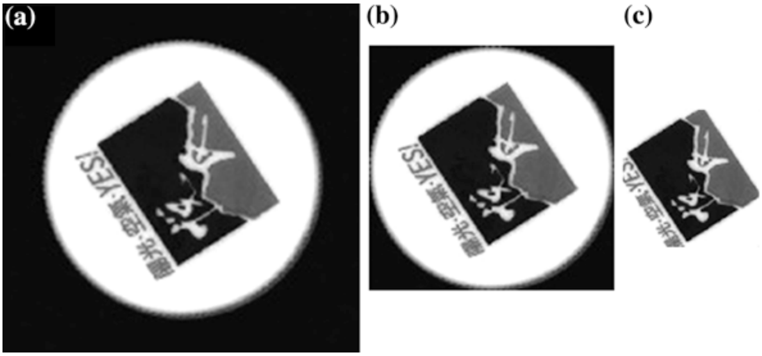


Fig. 5 Selection of ROI. **a** Normal cap image. **b** ROI selection. **c** Remove background by image pre-processing

the image with the maximum variance as the target image to conduct the following inspection procedure. As show in Fig. 4, the original image is converted into R, G, and B three channels of monochrome images. Based on the calculated variance, the Blue channel image is selected as the target image. After that, an ROI, which defines the normal cap pattern, is selected and its background is removed through an image pre-processing as shown in Fig. 5a–c.

4.2 Inspecting Stage

The inspection process of print logo cap is described as below:

(1) Image Matching with learned pattern:By conducting a pyramid matching process, we derive the information of the target cap including: the similarity of

Fig. 6 Image comparing. **a** Normal cap image. **b** Defective cap image. **c** Difference image

inspected cap (matching score), the pattern angle (matching angle), and the center position of cap. Matching score value shows matching level which can filter some large defect. Matching angle is a direction gap between object cap and learned normal cap. Matching center position is the location of the target cap.

(2) Image rotating: It is important preprocessing of image compare. The target cap is rotated so that its direction is same as the learned cap.

Fig. 7 Ten different testing caps

(3) Image comparing: By subtracting the gray value in the corresponding coordinates of good cap (Fig. 6a) and the target cap (Fig. 6b), we obtain the difference image (Fig. 6c), which shows the cap with some contamination and an incomplete printing.
(4) Image thresholding and morphology: There are many noises in difference-image due to system noise and printing deviation of every cap. Image thresholding is used to segment the defective region, and then the morphology, including: opening and closing, are used to filter out the noise and retain the defects.

In this study, we validate our method with ten caps with different print logos and color patterns. After testing with our proposed method, the proposed method successfully detects the defects in the case study company (Fig. 7).

5 Conclusion

The proposed inspection method is applicable to a variety of caps with sealing rings and printing logos. A normal cap is first learned in this system and parameters for inspecting are learned to reduce the complexity of inspection. The proposed method segments bottom cap image into five key regions and derive the parameters of each region automatically. Then, based on the derived parameters of regions, the defect of the cap can be detected. For the top of cap, the standard printing pattern is learned first, and then the defect and abnormal printing (missing, extra or blur printing) can be detected by matching and comparing the inspecting cap with the standard printing pattern. Ten different printing logos and color patterns cap are used to validate the print inspection process. The experimental results show that the proposed inspection system can self-learn the features of a good surface printing, and effectively detect the defective caps under very few parameters setting, while the major defects in the sealing ring and thread area such as malformation, contamination, overfill, incomplete, scratches, can be successfully identified under the rate of 1,200 piece per minute.

References

Belongie S, Malik J, Puzicha J (2002) Shape matching and object recognition using shape contexts IEEE trans. Pattern Anal Mach Intell 24:557–573

Chin RT, Harlow CA (1982) Automated visual inspection: a survey. IEEE Trans Pattern Anal Mach Intell 4:557–573

Haralick RM, Shapiro LG (1992) Computer and robot vision volume I. Addison-Wesley Publishing Company Inc, United States of America

Newman TS, Jain AK (1995) A survey of automated visual inspection. Comput Vis Image Underst 61:231–262

Qing hua W, Xunzhi L, Zhen Z, Tao H (2010) Defects inspecting system for tapered roller bearings based on machine vision. Paper presented at International Conference on Electrical and Control Engineering 25–27 June 2010

Torralba A, Murphy KP, Freeman WT (2007) Sharing visual features for multicalss and multiview object detection. IEEE Trans Pattern Anal Mach Intell 29:854–868

Coordination of Long-Term, Short-Term Supply Contract and Capacity Investment Strategy

Chiao Fu and Cheng-Hung Wu

Abstract This research studies contract design and capacity investment problem in a two-echelon supply chain consisting of a supplier and a downstream retailer who has in-house capacity. After building in-house capacity, the retailer would use his own capacity first. Under such situation, the risk of the variance of capacity utilization would be transferred to suppliers. The objective of this research is to protect the suppliers' profit by exploring the coordination of supply contract (combining long-term and short-term contract) and capacity investment strategies. At the beginning of each period, the demand uncertainty would be realized, and then the supplier would offer both long-term and short-term contracts. In long-term contract, the retailer makes a reservation for the next two successive periods; in short-term contract, the retailer orders products to fulfill the reserved deficiency. Additionally, both parties would make capacity investment decision in every period. The supplier has higher market power, making the capacity investment decision first and deciding the contracts. To solve the problem, we build a mathematical model, using game theory to decide the short-term decisions and exercising the dynamic programming to obtain the optimal policy in long-term.

Keywords Supply chain management · Supply chain contract · Capacity investment

C. Fu (✉) · C.-H. Wu
Institute of Industrial Engineering, National Taiwan University, Taipei, Taiwan, Republic of China
e-mail: r00546018@ntu.edu.tw

C.-H. Wu
e-mail: wuchn@ntu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_96,

1 Introduction

In this research, we study contract design and capacity investment problem under demand uncertainty, multi-period, and the situation that a retailer begins to build in-house capacity. We consider the two-echelon supply chain including an upstream supplier (who provides finished product to the downstream firm) and a downstream retailer (who buys product from the supplier or produces by himself, and sells the product to the market).

The downstream retailer's capacity would cause enormous impact on the performances of upstream firms. If business environment stays prosperous, both upstream and downstream firms' capacity could be utilized well; while if a recession occurs, the retailers would use in-house capacity, and the suppliers' capacity would be idle. Thus suppliers might have to face not only the dropped order but also the risk of the variance of capacity utilization which is transferred by those retailers.

Taking a point of suppliers' view, we want to help the upstream firms to protect their profit. To do this, we propose the long-term contract and short-term contract in order to reallocate the risk in such supply chain. Additionally, both of them could make capacity investment at each period. Each party's goal is to maximize their own expected profit. After defining the problem, we would build a mathematical model to determine the optimal contracts structure and capacity investment policies for each decision maker. Then, we would examine the interaction of capacity investment among such supply chain contracts, and discuss the comprehensive decision making scheme of combined contracts.

2 Research Problem

We consider a two-echelon supply chain, in which a supplier sells products to a retailer who has in-house capacity. Both of the two parties' production plans are constrained by their own capacity level, and they could do capacity investment decisions at each period. In our model, we propose a long-term contract and a short-term contract. In long-term contract, the retailer makes a reservation for the next two successive periods; in short-term contract, the retailer orders products to fulfill the reserved deficiency. The retailer faces demand uncertainty. The ε is used to described the demand scenarios, which are adapted to stand for possible business environment (high, medium and low).

$$d_A = a - bp_A + \varepsilon \tag{1}$$

To simplify the problem we want to solve, we make assumptions as following:

- It is a complete information market.
- The business environment transition follows Markov process.

- The result of capacity investment has no uncertainty, and the invested capacity would be available at the next period.
- Both parties produce products only for the current period, they can't sell inventory.

3 Model Description

We break down the 2 parties' decisions into two parts: the short-term decisions and the long-term decisions. In our model, the short-term decisions would cause effects only on the current profit; while the long-term decisions are those could influence the future state. As we mentioned previously that the supplier is a leader and the retailer is a follower, and so the decision process could be modeled as a Stackelberg game. We would use dynamic programing method to find the solution. The objective of each decision maker is to obtain capacity expansion policy that maximizes their respective expected profits.

3.1 Short-term Decisions

For the supplier, the short-term decision is the short-term contract price; while for the retailer, the short-term decisions include the short-term contract order quantity, the product quantity, and the market price.

According to the contract price announced by the supplier and the retailer's produce cost per product, the retailer would decide the priority of using his in-house capacity or making a short-term order to fulfill his reserved deficiency.

Thus, when the reserved quantity (the total ordered quantity of long-term contract in the last two periods) is deficient, the short-term contract price would be separated to two intervals: (1) the contract price per product is higher than the retailer's produce cost per product. (2) the contract price per product is lower than the retailer's produce cost per product. First, the supplier would choose contract price in these respective intervals, and then choose the price which could make the maximum current profit for him.

3.2 Long-term Decisions

To solve the long-term decisions, we use the result of the short-term decisions, and conduct dynamic programming model to determine the optimal policy of long-term contract and capacity investment. For supplier, his long-term decisions are the long-term contract price, and the capacity expansion amount; while for retailer, it includes the long-term contract order, and the capacity expansion amount.

In this supply chain, each party's goal is to maximize their own expected value. By implementing backward induction and value iteration, the optimal policy for each firm can be obtained. Since the supplier is a leader, the retailer would make response to leader's action.

4 Numerical Study and Discussion

The following parameters were used in our numerical study and discussion. In Table 1 we illustrate the parameter settings.

4.1 Numerical Result

A. Optimal Capacity Expansion

Due to the high cost of capacity investment, both of the two firms would expand their capacity at early period as Fig. 1 shows (the business environment is medium, the supplier's capacity level is 5, the retailer's capacity is 0 and there is no reserved quantity). Thus, they could have sufficient time to earn profit to cover the cost.

B. Long-term Contract

The result of long-term contract would be affected by different time period. We find that at earlier period, the contract price is lower than the price at later period, taking Fig. 2 for example (the business environment is medium, the supplier's capacity level is 10, the retailer's capacity is 3 and there is no reserved quantity.

Table 1 Parameter settings

Time horizon		Constraints of capacity quantity	
T	15	Supplier's UB	10
Market states		Retailer's UB	5
Market size	32	Cost of capacity investment	
Price sensitivity of product	1	Supplier	60
Fluctuation rate	2	Retailer	100
Market transition		Cost of production per product	
$\begin{array}{c} \\ H \\ M \\ L \end{array} \begin{array}{c} \begin{array}{ccc} H & M & L \end{array} \\ \begin{bmatrix} 0.6 & 0.3 & 0.1 \\ 0.1 & 0.8 & 0.1 \\ 0.1 & 0.3 & 0.6 \end{bmatrix} \end{array}$		Supplier	6
		Retailer	10
		Initial setting	
		Business environment	Medium
		Supplier's capacity level	5
		Retailer's capacity	0

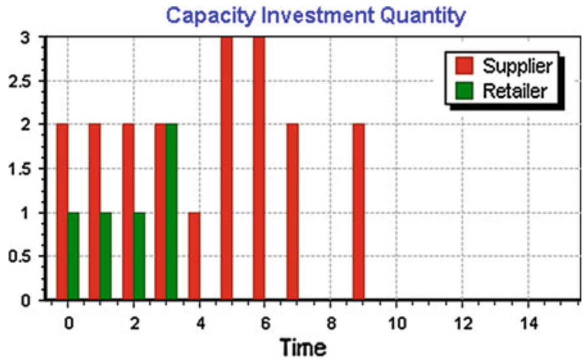


Fig. 1 The capacity investment quantity

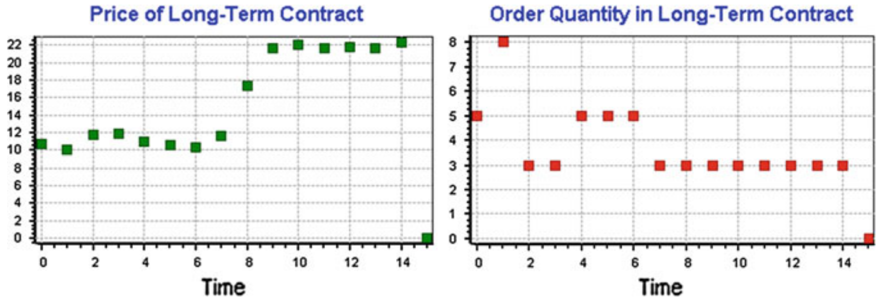


Fig. 2 The optimal long-term decision

The reason is that at early period, the high long-term price would make the retailer be unwilling to reserve but invest in-house capacity. Once the retailer expands capacity, the supplier's expected profit would drop dramatically as Fig. 3 presents (the order quantity and the expansion amount of the retailer are at right-axis; the 2 parties expected profits are at left-axis).

5 Conclusions

In this research, we combine long-term and short-term contracts to provide a risk-sharing mechanism that encourages the supplier to expand capacity and to raise the flexibility of capacity utilization. Given these contracts, we investigate the interaction between the two parties' capacity investment behaviors.

We have shown that the retailer's bargaining power is stronger at early period or with high in-house capacity level. Once the retailer has in-house capacity, supplier's profit would dramatically drop. Therefore, we advise the supplier to

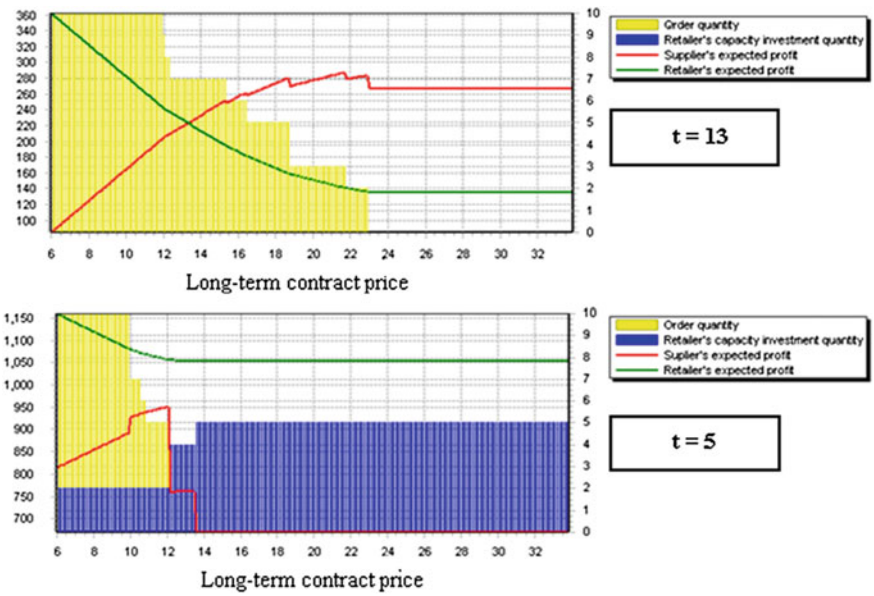


Fig. 3 The long-term price decision process when $t = 13$ and $t = 5$

announce low long-term contract price at early period in order to avoid the retailer to build in-house capacity.

We also explained how each party's capacity level influence their expected profit. Surprisingly, an increase in supplier's capacity level can cause a reduction in supplier's expect profit. We conclude that when the supplier's capacity level is over threshold, he has to reduce contract price to maximum short-term profit, which would eat into long-term profit.

Our results come with several limitations. There are many possible extensions to this research. For example, our model has only one retailer. In real world, the retailer could have more than one supplier and have other competitors. In future study, we could add more downstream retailers to study the consequence of competition between retailers.

References

Cachon GP (2003) Supply chain coordination with contracts. Handbooks Oper Res Manag Sci 11:229–340

Erkoc M, Wu SD (2005) Managing high-tech capacity expansion via reservation contracts. Prod Oper Manag 14(2):232

Serel DA, Dada M, Moskowitz H (2001) Sourcing decisions with capacity reservation contracts. Eur J Oper Res 131(3):635–648

Sethi SP, Yan H, Zhang H (2004) Quantity flexibility contracts: optimal decisions with information updates. Decision Sci 35(4):691–712

Spengler JJ (1950) Vertical integration and antitrust policy. J Polit Econ 58(4):347–352

Spinler S, Huchzermeier A (2006) The valuation of options on capacity with cost and demand uncertainty. Eur J Oper Res 171(3):915–934

Tomlin B (2003) Capacity investments in supply chains: Sharing the gain rather than sharing the pain. Manuf Serv Oper Manage 5(4):317–333

Tsay AA (1999) The quantity flexibility contract and supplier-customer incentives. Manage Sci 45(10):1339–1358

Wang TM (2012) Coordination of supply contract design and long term capacity strategy. Dissertation, National Taiwan University

Wu SD, Murat Erkoc M, Karabuk S (2005) Managing capacity in the high-tech industry: a review of the literature. Eng Econ 50:125–158

An Analysis of Energy Prices and Economic Indicators Under the Uncertainties: Evidence from South East Asian Markets

Shunsuke Sato, Deddy P. Koesrindartoto and Shunsuke Mori

Abstract It is well known that the worldwide financial crisis has caused various international issues. For instance, it is pointed out that the Euro-crisis has spread the financial instability to the other markets e.g. equity, oil, gold, etc. In addition, the energy and the commodity market are known as major factors which influence the decision making of investors in currency market or stock market in both long and short term. Thus it is an important thing for the decision making for investors to find out the relationships among various markets. There are two scenarios in this paper. In the first one, we analyze the future forecasts by applying Vector Error Collection Model (VECM) to economic indicators which have influential power all over the world, and then, we get the relationship among these markets via Granger Causality test. On the other hand, it is also important to predict which factors would be market driven in the future. Then in the second one, since South East Asian market is known as the potential markets for driving the market in the future, we add the variables which belong to South East Asian markets to the

S. Sato (✉)
Shunsuke Sato, Master of Engineering in Industrial Administration, Graduate School of Science and Technology, Tokyo University of Science, Yamazaki 2641, Noda, Chiba Prefecture, Japan
e-mail: syunnsuke0130@gmail.com

S. Sato
Master of Science in Management, Graduate School of Business and Management, Bandung Institute of Technology, Jl. Ganesha 10, Bandung, West Java, Indonesia

D. P. Koesrindartoto
Assistant Professor at School of Business and Management, Bandung Institute of Technology, Jl. Ganesha 10, Bandung, West Java, Indonesia
e-mail: deddypri@sbm-itb.ac.id

S. Mori
Department of Industrial Administration, Faculty of Science and Technology, Tokyo University id Science, Yamazaki 2641, Noda, Chiba Prefecture, Japan
e-mail: mori@ia.noda.tus.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_97,

variables in the first scenario. This outcome will give some opportunity to get the interest to the investors.

Keywords Time series analysis · Vector error collection model (VECM) · Oil price · Index · Currency · South East Asia

1 Introduction

The factor of energy price volatility has been a controversial issue for the policy makers and researchers who have various positions depending on the country conditions as seen in the international conferences. As one of the claims, there is a world energy model where the price is determined by the relationship between supply and demand. For instance, Matsui et al. explored the future trends of the global warming problem mainly due to carbon dioxide by using a world energy supply and demand model (Matsui et al. 1995). In addition, International Energy Agency (IEA) reported about the effects of pushing down real GDP due to higher oil prices by using the large-scale computer simulation model which seems based on “World Energy Model” (IEA 2004).

However, the movement of energy prices in recent years might not simply be a behavior caused by the supply and demand equilibrium in energy prices. In 2008, Saudi Arabia’s Oil Minister Ali al-Nuaimi said that “Clearly Something other than supply and demand fundamentals is at work here, and a simplistic focus on supply expansion is therefore unlikely to tame the current price behavior”.

There are a large number of papers suggesting that energy prices are moved by the temporal market principles. These are generally analyzed by using time-series analysis such like Generalized Autoregressive Conditional Heteroscedasticity model (GARCH) and Vector Error Collection Model (VECM). Mohamed et al. found dynamic linkages between the European stock market and crude oil price by GARCH. Our Results show strong significant linkages between oil price changes and stock markets for most European sectors (Hedi Arouri and Khuong Nguyen 2010). As well, Kofi et al. showed that crude oil prices affect the stock market by VECM. While currency prices significantly explain Israeli stock returns, crude oil futures prices relate significantly to the Egyptian and Saudi Arabian stock exchanges (Amoateng and Kargar 2004). Therefore, energy market may also be affected from another market such like stock market, currency market and etc. This is referred as market integration in the world market.

1.1 *Southeast Asian Market*

As an example of the market is being integrated, there is a Association of Southeast Asian Nations (ASEAN). The growth of the Southeast Asian market in recent years, there are remarkable. In particular, Indonesia, has been reached 6.5 % GDP growth in 2012, is attracting attention as a country to lead the Southeast Asian market. Goldman Sachs estimated that GDP of Indonesia will be greater than Japan in 2050 (Wilson and Stupnytska 2007). As well, Indonesia is counted as core countries, is called as P4, in the TPP which is one of the significant international frameworks. Developed countries such as Japan and the United States are also included as TPP negotiations participating countries, and in the future deep cooperation is expected. However, papers exploring dynamic linkages like this are small.

1.2 Statistical Analyzing Method

As a model for analyzing the dynamic linkage between markets, Vector Error Collection Model (VECM) is widely known. VECM is one of the regression models extending Vector Auto Regressive Model (VAR) by using the method of cointegration. It is possible to find the dynamic coordination using Granger Causality Test. However, it must be noted that the statistical time-series analysis is not necessarily a panacea for every events. Lucas criticized, known as Lucas critique, that the macro-econometric model does not have micro natures (Lucas 1976). Thus, I would like to note in advance that current statistical analysis cannot solve this bias that arises from empirical results.

1.3 Research Objectives

By the flow of market integration, it becomes more complex for policy makers and investors to identify the significant factors. In this study, the authors show a method for the decision making by examining the following 2 scenarios:

Scenario 1: Analyze the dynamic linkages in global economy by using the significant indicators which have a power across the world, and

Scenario 2: Consider the current and future trends and linkages in Southeast Asian market by addition the variables of Southeastern Asian market including Singapore and Indonesia to scenario 1 variables.

2 Data and Methodology

2.1 Datasets in Scenario 1

In this paper, the authors deal with a world model in Scenario 1, and the key indicators in each region are selected as variables as follows:

North America: Canadian Dollar (CAD/USD), NASDAQ (GSPC)

Europe: Germany Mark (DEM/USD), U.K. Pound (GBP/USD), Swiss Franc (CHF/USD), FTSE (FTSE)

Asia: Japanese Yen (JPY/USD), Nikkei 225 (N225), Hong Kong Hang Seng Index (HSI)

Commodity markets: West Texas Intermediate as crude oil (XCT/USD), Gold (XAU/USD)

Term: Jan 1987–Dec 2012

Quantity: 312

Frequency: Monthly

We chose Germany Mark before 1999 and then converted them into EURO after that by using exchange coefficient. The authors don't adopt the Chinese Yuan which is currently one of the most important currencies, because of the fixed exchange rate until 2005 As well as the HK dollars which also adopts a dollar peg.

2.2 Datasets in Scenario 2

In scenario 2, in addition to variables in Scenario 1, the indicators of Singapore and Indonesia are adopted. However, after the Asian financial crisis, Indonesia had adopted the dollar peg until July 1997. Therefore, it is difficult to add this period until July 1997. In Scenario 2, the period set from August 1997, on which Indonesian rupiah has already shifted to a floating exchange rate system, to December 2012.

Southeast Asia: Singapore Dollar (SGD/USD) Indonesia Rupiah (IDR/USD) Straits times index (STI) Jakarta composite index (JCI)

Term: Aug 1997–Dec 2012

Quantity: 185

Frequency: Monthly

2.3 Time Series Analysis Method

In the time series analysis, stationary of the data is the most important factor, since the shock stays permanently and the spurious correlation becomes apparent when non-stationary is involved. Therefore, it is necessary to check the data condition first.

As one of the methods measure the stationary of datasets, there are some well established procedures. As the unit root tests, Augmented Dickey-Fuller Test (ADF), Phillips-Perron Test (PP) is well known. In this paper, the authors find the absence of unit root in 10 % level except Indonesian Rupiah by ADF. The table of unit root test in Scenario 2 is following (see Table 1).

Table 1 Unit root test in scenario 2

Variables	T-value	*P* value	Variables	T-value	P-value
CAD/USD	−0.625	0.861	GSPC	−2.186	0.212
DEM/USD	−1.360	0.601	FTSE	−2.000	0.288
GBP/USD	−2.010	0.282	N225	−2.187	0.212
CHF/USD	−0.721	0.838	HSI	−1.453	0.555
JPY/USD	−1.345	0.608	STI	−0.812	0.813
SGD/USD	−0.302	0.921	JCI	−0.349	0.914
IDR/USD	−6.169*	0.000	XAU/USD	0.125	0.967
			XCT/USD	−1.285	0.636

* the variable is rejected in 1 % level

Before we start the analysis, it is necessary to check which model is most suitable. In the time-series analysis, if the dataset has both the cointegration and unit root, the most suitable model for analyzing the dynamic linkage is VECM.

The cointegration is one of the indicators showing relationships between datasets. When the presence of cointegration can be confirmed, the objective variable might has a relationship with explanatory variables. As cointegration test, Johansen cointegration test is famous. In this paper, authors can find at most 2 cointegration in Scenario 1 and at most 11 cointegration in Scenario 2 by Johansen cointegration test. There are cointegration and unit root. Thus, in this paper VECM is adopted.

When the presence of cointegration is accepted in datasets, we can know the causal relationship. Granger devised a Granger Causality Test to be able to get Granger Causality by F test of the coefficient (Granger 1969).

3 Analysis

3.1 Analysis in Scenario 1

In the Scenario 1, the authors adopted lag-2 based on Akaike Information Criterion (AIC) and Schwartz Criterion (SBIC) (see Table 2).

As a results of Granger Causality Test Using VECM(2), it is shown that Swiss franc, FTSE and Nikkei 225 have no self-correlation. This may indicate that these markets be strongly influenced from other markets by dynamic linkages.

In currency market, it shows that Canadian dollar has an impact on many indicators. Canadian dollar has a relevance to the currency except JPY and affects stock markets such like FTSE and HSI (see Table 3). However, it is known that Canadian dollar has a strong relationship with the U.S. Dollar. Hence, it is expected that U.S. dollar has had a significant impact on other markets.

Table 2 Lag decision

Lag		2	3	4	5	6
Scenario 1	Akaike information criterion	1.717143	1.966077	2.24305	2.450815	2.760428
	Schwarz criterion	5.3055	7.028356	8.786278	10.48208	12.28687
Scenario 2	Akaike information criterion	26.64379	26.94945	26.14073	24.8449	23.23195
	Schwarz criterion	40.63931	44.97413	48.22535	51.02064	53.53039

In commodity markets, each indicator has autocorrelation, but they seem to have not been explained so much from other markets. There are significant linkages between crude oil and Japanese Yen and NASDAQ.

In addition, as a result of prediction, NASDAQ, FTSE, HSI and England Pound have upward trend, and Swiss franc, Japanese yen, Nikkei 225, Gold and Crude oil have downward trend. In particular, there is a depreciation tendency of currency against the U.S. dollar, therefore it is expected that U.S. dollar will be high. In commodity market including gold and oil prices, substantial decline is expected. However, since these predictions cannot reject Lucas criticism, it is difficult to consider the macro factors such as policy changes. Thus, authors note that these prediction is a simple result calculated by dynamic linkages among markets.

3.2 Analysis in Scenario 2

In this Scenario, authors adopted lag 2 by using Schwartz Criterion (SBIC) (see Table 1).

The result shows that U.K. Pond, Swiss franc, FTSE and Crude oil have no self-correlation. We must note that Swiss franc and FTSE have no self-correlation in scenario 1 as well as scenario 2.

In currency market, Western currencies are influenced by themselves and Asian currencies are also influenced by themselves (see Table 4). This result may evidence that the dynamic linkage advances in each regions, i.e. Western region and Asian region. For instance, Canadian Dollar influences all of Western currencies including Germany Mark, U.K. Pound and Swiss Franc as well as Scenario 1. U.K. Pound has no self-correlation, but it also influenced all of Western currencies. On the other hand, Japanese Yen doesn't have a strong power for driving Western Currencies, but it effects all of Asian currencies including Japanese Yen, Singapore Dollar and Indonesia Rupiah.

In stock market, Western index including NASDAQ and FTSE has a strong power driving all of currencies. Influence of Nikkei 225 may be week comparing these indexes, but although Western indexes have no influence to Asian stock market, Nikkei 225 widely influences to Asian stock markets. Thus Japanese indicators have a strong power to Asian market instead of no-influence to Western markets.

Table 3 Coefficients about Canadian dollar in scenario 1

Coefficients	Currency market					
	D(CAD_USD)	D(DEM_USD)	D(GBP_USD)	D(CHF_USD)	D(JPY_USD)	
D(CAD_USD(−1))	1.94595**	1.81652**	2.99301*	1.84624**	1.11808	
D(CAD_USD(−2))	0.56007	0.61602	0.71009	0.11267	0.5431	
	Stock market				Commodity market	
	D(GSPC)	D(FTSE)	D(N225)	D(HSI)	D(XAU_USD)	D(XCT_USD)
D(CAD_USD(−1))	1.45608	2.32937*	1.23001	1.69456**	0.55377	0.08257
D(CAD_USD(−2))	0.80748	1.17325	2.12117*	0.13342	0.18808	1.20079

* the relation is significant in 10 % level
** the relation is significant in 5 %

Table 4 Currency relationship in developed countries

Coefficients		Currency market						
		Westrn countries				Asian countries		
		D(CAD_USD)	D(DEM_USD)	D(GBP_USD)	D(CHF_USD)	D(JPY_USD)	D(SGD_USD)	D(IDR_USD)
Western Countries	D(CAD USD(-1))	1.604	1.85749**	1.71003**	1.58013	0.31841	0.42701	0.83649
	D(CAD_USD(-2))	0.22033	0.33298	2.09139*	1.07777	1.51883	0.45485	0.57555
	D(DEM_USD(-1))	0.17326	2.4996*	2.00276*	2.1224*	0.16516	1.49074	0.58674
	D(DEM_USD(-2))	0.29923	1.38026	0.1284	0.2889	1.4493	0.07803	0.37544
	D(GBP USD(-1))	1.60545	2.7704*	0.77473	2.93051*	0.02092	1.81371**	1.09204
	D(GBP_USD(-2))	0.32117	1.06288	0.57231	1.86925**	0.64428	0.94582	1.06056
Asian Countries	D(JPY_USD(-1))	0.49689	1.17259	0.43759	1.40506	3.25121*	1.34817	1.76999**
	D(JPY_USD(-2))	0.71088	0.59841	0.35027	0.77469	1.81256**	1.9446**	1.9981*

* the relation is significant in 10 % level
** the relation is significant in 5 %

Table 5 Dynamic linkage in Southeastern Asian market

Coefficients		Currency market							
		D(CAD_USD)	D(DEM_USD)	D(GBP USD)	D(CHF USD)	D(JPY USD)	D(SGD_USD)	D(IDR USD)	
Currency market	D(SGD USD(−1))	0.33394	0.5994	0.47211	1.17719	0.33757	0.57367	0.40256	
	D(SGD USD(−2))	1.23997	1.7973**	1.67387**	1.36971	0.69604	1.50104	1.32803	
	D(IDR USD(−1))	0.45931	1.42981	0.19642	2.4726*	1.96192*	0.01666	2.77496*	
	D(IDR USD(−2))	1.2771	0.15384	0.80634	0.07286	2.58164*	1.38145	0.50468	
Stock market	D(STI(−1))	1.16183	0.1872	1.14439	0.26166	2.46663*	1.49838	1.45135	
	D(STI(−2))	1.04279	1.0826	1.12691	1.2431	0.19052	1.08728	2.01226*	
	D(JCI(−1))	0.68477	0.15252	0.59573	0.29101	0.21774	0.29027	0.00295	
		Stock market						Commodity market	
		D(GSPC)	D(FTSE)	D(N225)	D(HS)	D(ST)	D(JCI)	D(XAU USD)	D(XCT_USD)
Currency market	D(SGD USD(−1))	1.11315	1.36677	0.50726	0.40816	0.7832	0.09321	1.33825	1.33404
	D(SGD USD(−2))	1.16515	0.78825	0.43618	0.93921	0.36029	0.47975	1.25581	1.39715
	D(IDR USD(−1))	0.07297	0.75452	1.61562	0.42727	0.13287	0.01689	0.52226	0.42479
	D(IDR USD(−2))	1.49869	0.96814	1.03901	0.19672	0.9079	0.83366	0.61211	1.3531
Stock market	D(STI(−1))	1.05932	1.7912B**	0.20288	0.18819	0.44737	0.76281	1.74602**	1.20981
	D(STI(−2))	1.90932**	1.81751**	1.67301**	0.41118	2.02272*	0.43676	0.15946	0.93647
	D(JCI(−1))	1.58068	1.69791**	1.32701	1.87813**	0.79594	0.66737	0.37451	1.10452

* the relation is significant in 10 % level
** the relation is significant in 5 %

In commodity market, Gold is effected from Crude oil and FTSE, and Crude oil is effected from Japanese Yen and NASDAQ. In Scenario 2 the variables which explain crude oil same with Scenario 1.

From the view of Southeastern Asian market, currency and index influence stock market and currency market respectively (see Table 5). This result also shows that there is no strong market integration which overcomes each commodity sector like dynamic linkage between stock market and currency market. In addition, the number of variables which explain STI and JCI is small. Hence, these indexes contribute portfolio-diversification for investment.

4 Conclusions

In this paper, the authors analyzed the dynamic linkage among various market indicators assuming two different scenarios employing the time series analysis. The results would give the investors and policy makers some new perspectives for decision making.

The authors evidenced that there is a dynamic linkage over each commodity sector in Western indicators. For instance Western indexes influence Western currency market while the results did not show that Southeastern Asian markets have strong linkages with developed countries. It is however suggested that the dynamic linkage in Asia including Japan, China and Southeastern Asia may have been advancing.

Since the analysis in this paper fails to contain Chinese currency which is one of important indicators as well as Indian and Brazilian indicators, further the challenges will be needed to investigate the dynamic linkages focusing on developing countries expected the strong future growth.

References

Amoateng KA, Kargar J (2004) Oil and currency factors in middle east equity returns. Manag Financ 30:3–16

Granger CWJ (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37:424–438

Hedi Arouri ME, Khuong Nguyen D (2010) Oil orices, stock markets and portfolio investment: Evidence from sector analysis in Europe over the last decade. Energ Policy 38: 4528–4539

IEA (2004) Analysis of the impact of high oil prices on the global economy. Leonardo Energy Organization. http://www.leonardo-energy.org/sites/leonardo-energy/files/root/Documents/2009/high_oil_prices.pdf. Accessed 11 May

Lucas Robert (1976) Econometric policy evaluation: a critique. Carnegie-Rochester Conf Ser Pub Policy 1:19–46

Matsui K, Ito H, Yamada A (1995) Simulation analysis by a model projecting world energy supply and demand over the very long term—a case study on China. INSS J 2:77–103

Wilson D, Stupnytska A (2007) The N-11: more than an acronym. Goldman Sacks Global Economics Paper 153

Effects of Cooling and Sex on the Relationship Between Estimation and Actual Grip Strength

Chih-Chan Cheng, Yuh-Chuan Shih and Chia-Fen Chi

Abstract Handgrip strength is essential in manual operations and activities of daily life, but the influence of cold on estimation of handgrip strength is not well documented. Since direct measurement of force is often somewhat difficult, estimations are frequently applied, and these estimations are sometimes used as a criterion for employee selection and screening. Therefore, the aim of the present study is to investigate the relationship between estimated and actual handgrip strength at various target force levels (TFLs, in percentage of MVC) for both sexes under hand was cooled or not. A cold pressor test in a 14 °C-water bath was used to lower the hand skin temperature, and this served as the cooled condition. The uncooled condition, without cold immersion, was the control condition. Ten males and 10 females were recruited. The results indicated that cooling the hand could result in lighter estimation, which could increase the risk of musculoskeletal disorders. Furthermore, females tended to be less reliable than males in the estimation, and greater absolute deviations occurred in the middle range of TFLs for both sexes.

Keywords Cold immersion · Hand manipulation · Handgrip strength estimation

C.-C. Cheng (✉) · C.-F. Chi
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: damn0623@yahoo.com.tw

C.-F. Chi
e-mail: chris@mail.ntust.edu.tw

Y.-C. Shih
Department of Logistics Management, National Defense University, Taipei, Taiwan, China
e-mail: river.amy@msa.hinet.net

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_98,

1 Introduction

The hands offer the most effective means of accomplishing complex work, given their ability to perform specialized tasks that require dexterity, manipulability, and tactile sensitivity. Handgrip force is one of the most important forces required in both daily life and the workplace. Additionally, overexertion has been shown to be one of the critical factors causing musculoskeletal disorders in the workplace, especially in cold environments. Since direct measurement of force is often somewhat difficult, estimations are frequently applied, and these estimations are sometimes used as a criterion for employee selection and screening. Recently, numerous studies have investigated the relationship between estimation and actual force. Unfortunately, the influence of cooling the hands on the estimation of handgrip force is still not well documented, even though working in a cold environment is unavoidable. Therefore, the main goal of the present paper is to explore whether the relationship between the estimated and actual hand grip strength is different between cooled and uncooled hands for both sexes.

2 Literature Survey

Handgrip force is one of the most essential forces for manual operation. Besides poor postures and repetitive motions, force demands have been consistently considered as main risk factors associated with work-related musculoskeletal disorders (Silverstein et al. 1987). In addition, several epidemiologic studies have shown that cold may be a risk factor for the occurrence or aggravation of musculoskeletal disorders, such as in the fish-processing industry (Chiang et al. 1993; Nordander et al. 1999) and meat-processing factories (Kurppa et al. 1991; Piedrahíta et al. 2004). Wiggen and colleagues indicated that even petroleum workers must often be exposed to harsh and extreme environments while performing not only heavy lifting tasks but also tasks demanding grip strength and dexterity, for which such workers have to remove their gloves (Wiggen et al. 2011). Therefore, it is unavoidable that bare hands will be exposed in a cold environment. A report by the European Agency for Safety and Health at Work also noted that the risk of musculoskeletal disorders increases with work in cold environments (Schneider et al. 2010).

Exposure in a cold environment reduces the skin temperature of uncovered parts, especially the forearm/hand. Hand/finger skin temperature is considered the vital factor in the reduction in tactile sensitivity (Enander 1984), hand dexterity (Enander and Hygge 1990; Heus et al. 1995; Riley and Cochran 1984; Schiefer et al. 1984), tracking performance (Goonetilleke and Hoffmann 2009), and handgrip strength (Brajkovic and Ducharme 2003; Chen et al. 2010; Chi et al. 2012; Enander 1984; Enander and Hygge 1990; Schiefer et al. 1984).

The differences in findings about selected models could be due to different postures, exertion intensities, muscles involved, and/or experimental protocols (e.g. training or not, MVC measured prior or post to exertion estimated). Due to the deficiency for cooling hand on the relationship between estimated and actual grip strength, therefore, the aim of the present study is to try to determine the relationship between estimation and actual exertion.

3 Methods

3.1 Participants

A convenience sample of 20 volunteers, including 10 males and 10 females, was recruited for this study. All were right-handed, healthy and free of musculoskeletal disorders in the upper extremities. The means (standard deviation, SD) for age, weight, and height for males and females were 28.7 (5.5) and 24.2 years (3.6); 68.8 (6.9) and 53.9 kg (4.7); 172.8 (2.1) and 162.7 cm (4.6), respectively. During the experiments, each participant was dressed on a short-sleeve T-shirt, short pants, and sports shoes.

3.2 Apparatus and Materials

The cold pressor test was employed. The apparatus and materials used in this study included a water bath, a submersible cooler, a digital thermometer and hygrometer, a digital 4-channel thermometer, and a grip gauge with a load cell. They were the same as those used in Chen et al. (2010) and Chi et al. (2012). The handles of the grip gauge, which had a 5-cm grip span, were wrapped in bandages to prevent slippage during exertion.

3.3 Experimental Procedures and Data Acquisition

First, the experimental procedure was explained, and all participants signed an informed consent. Additionally, participants' demographic datexposed and non-cold exposed workers.a were collected. Two sessions associated with two HSTs (cooled (14 °C) and uncooled) were scheduled randomly on two different days, and each session contained three stages: grip MVC measurement, training, and the main experiment. Cooled HST meant the participant had to immerse the dominant hand into a 14°C-water bath up to the elbow joint, and uncooledRiley MW, Cochran DJ (1984) HST meant the forearm was uncooled by cold water.

Prior to formal measurement, the probes of the thermometer were attached by sponge tape on the dorsal side of the middle phalanx of the middle finger (FST), on the middle of the third metacarpal of the dorsal side of the hand (HST), and on the muscles of the extensor digitorum (ED) and flexor digitorum superficialis (FDS) of the forearm (named FAST-E and FAST-F, respectively). When thermometer probes were attached properly and the cooled condition was selected, participants were first asked to immerse their dominant hands into the 14° C-water bath up to the elbow joint for 30 min, and then the grip MVC was measured. After 30-min immersion, the mean HST (SD) was 14.4 °C (0.2) for both sexes, and the mean FSTs (SD) were 13.7 °C (0.3) and 13.8 °C (0.2) for males and females, respectively. Additionally, the corresponding mean FAST-Es (SD) for males and females were 19.3 °C (0.4) and 19.0 °C (0.9), and the mean FAST-Fs (SD) were 19.6 °C (0.6) and 19.4 °C (0.6), respectively.

For handgrip MVC measurement, each participant sat erect in a chair with the elbow at 90° flexion and the upper arm parallel to the trunk. Handgrip MVC was replicated three times, and a 2-min rest was given between successive trials to avoid muscular fatigue. The maximal value of each contraction was recorded, and these three maximal values were averaged to serve as the personal MVC.

Next was the training stage, in which 30, 60, and 90 %MVC, calculated according to each participant's MVC, served as the target force levels (TFLs). For a given TFL, a horizontal marker line appeared and remained in the same central position of the monitor for visual guidance to maintain the required TFL. The 30 %MVC TFL was first practiced, in which participants were informed how much TFL, in terms of percentage of MVC, they were to exert. During exertion, they were asked to reach the TFL for 3 s and to try to perceive it. The same procedure was applied then for 60 %MVC, and finally for 90 %MVC. Here also, 2-min rests were given between successive trials.

In the main experiment, the procedures were the same as those in the training stage, but participants had no idea about how high the TFLs (15, 30, 45, 60, 75, 90 %MVC) were. They were just instructed to exert to match the TFL line demonstrated on the same central position of the PC monitor, and to try to perceive and estimate how much the TFL was in terms of a percentage of their own maximal strength. Then they reported the value to the instructor immediately, which was recorded and denoted by F_{Est}. All six TFLs were arranged randomly, and 2-min rests were given between successive trials.

In the uncooled condition, participants performed the trials at the initial skin temperature. The mean HST (SD, min–max) was 31.5 °C (1.2, 30.3–33.7) and 31.9 °C (1.3, 30.1–33.6) for males and females, respectively.

3.4 Experimental Design and Data Analysis

A combined design of nested-factorial and split-plot was employed. Independent variables, all fixed, included HST (uncooled and cooled (14 °C), the whole-plot), TFL (15, 30, 45, 60, 75, and 90 %MVC, the sub-plot), sex, and participant (nested within sex and serving as a block effect). To precisely examine the main effects and interactions, the variations associated with each participant were extracted and the highest interaction of each participant served as the error term. Furthermore, the responses were force estimations reported by participants (F_{Est}), and the absolute value of Er_{Est} ($F_{Est} - TFL$), denoted by $Abs(Er_{Est})$.

In addition, both Pearson product-moment correlation analysis and intra-class correlation (ICC) were used to test the agreement of grip force estimation among participants. The software Statistica 8.0 was used for data analysis, and a post hoc Bonferroni test was used to test paired differences for significant main effects and interactions. The level of significance (α) was 0.05.

Results indicated that the uncooled hand generated greater MVC (40.9 kgw) than the cooled HST (36.5 kgw, with 11 % MVC reduction); male MVC was greater than female MVC (47.1 vs. 30.3 kgw); and female MVC was about 64 % of male MVC. This reduction in grip strength caused by cooling is consistent with past studies (Brajkovic and Ducharme 2003; Chen et al. 2010).

4 Results and Discussion

For the estimation reliability, the agreement among participants in using %MVC to evaluate the strength they perceived needed to be examined. To do so, the correlation analysis and intra-class correlations (ICCs) were employed. The correlations between actual force (TFL) and estimated force (F_{Est}) were also calculated. Under uncooled HST, the correlation coefficients were 0.98–0.99 ($p < 0.05$) for males and 0.91–0.99 ($p < 0.05$) for females. Under cooled HST (14 °C), they were 0.96–0.99 ($p < 0.05$) for males and 0.92–0.99 ($p < 0.05$) for females. Importantly, the ICCs for males and females under both HSTs were close to 1. That is, there was consistent agreement between participants when they assessed their perceived effort.

As to validity, a paired *t* test was used to test the F_{Est} s against the TFLs for both sexes at different HSTs. The results showed that not all were significantly different; only that of females under uncooled HST at 45 %MVC was significantly overestimated (mean = 51.7 %MVC; 95 % C.I. = 45.4–58.0 %MVC). The trend of F_{Est} association with TFLs and descriptive statistics are presented in Table 1.

Table 1 Descriptive statistics and paired t-test between actual and estimated forces

Actual (%MVC)	Estimation							
	Uncooled				Cooled			
	Male		Female		Male		Female	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
15	16.1	4.6	17.7	6.9	15.0	4.7	15.6	4.1
30	29.1	5.0	34.8	11.0	27.8	7.3	29.5	7.8
45	46.5	6.3	51.7*	8.8	43.0	10.1	46.1	15.5
60	61.2	7.6	62.3	14.0	53.7	9.7	60.2	13.3
75	77.0	9.8	78.3	8.0	75.0	6.2	70.7	11.9
90	93.1	5.4	90.0	10.5	89.0	7.7	87.0	7.2

*$p < 0.05$

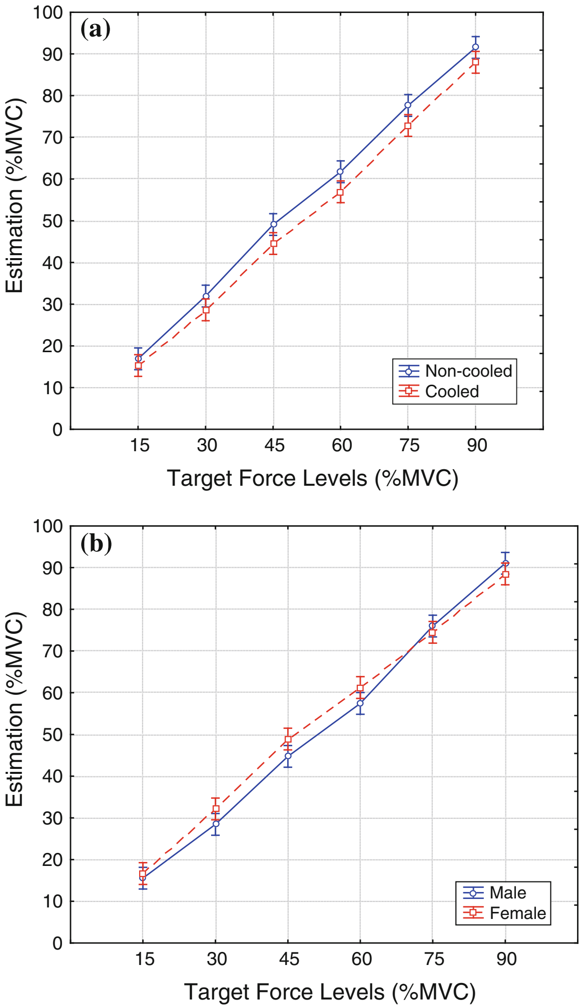


Fig. 1 **a** The TFL effect on estimation for HST **b** The TFL effect on estimation for sex

Figure 1a and b illustrate the TFL effect for different sexes and HSTs. Both the photos demonstrate that the increased force estimation followed the increase of TFL (actual exertion). Additionally, Figure 1a and Table 1 indicate that participants tended to overestimate in the uncooled condition and to underestimate in the cooled condition. On the other hand, the absolute error of estimation ($Abs(Er_{Est})$) was considered. Figure 2 displays the TFL effect on $Abs(Er_{Est})$ for both sexes. Most importantly, both sexes had greater $Abs(Er_{Est})$ in the middle range of TFL than at both ends of TFLs. Figure 2 further showed that females had a larger $Abs(Er_{Est})$ than males at all TFLs.

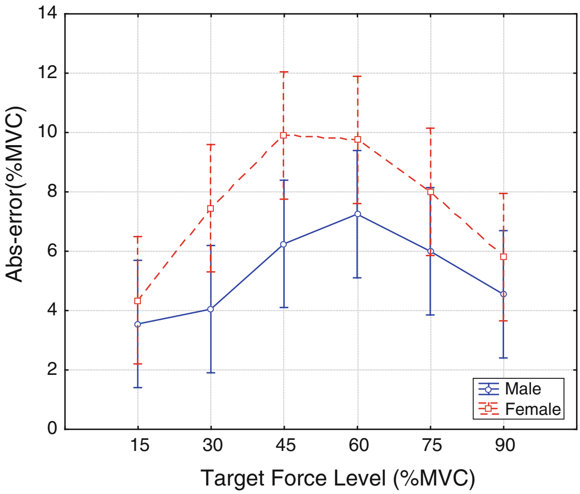


Fig. 2 The TFL effect on absolute error for both sexes

5 Conclusions

For estimation of grip strength, cooling the hand could result in lighter estimation and also cause underestimation. This underestimation could increase the risk of musculoskeletal disorders in the cold. Unfortunately, working in a cold environment is still unavoidable; therefore, how to keep the hands warm and maintain tactile sensitivity is important in avoiding underestimations of hand strength. On the other hand, females tended to be less reliable than males in the estimation. Of interest is that the middle range of TFLs in terms of percentage of MVC produced greater deviations from the TFLs for both sexes.

Acknowledgments This paper presents the results from Project No. NSC97-2221-E-606-026, sponsored by the National Science Council of Taiwan, the Republic of China.

References

Brajkovic D, Ducharme MB (2003) Finger dexterity, skin temperature, and blood flow during auxiliary heating in the cold. J Appl Physiol 95(2):758–770

Chen WL, Shih YC, Chi CF (2010) Hand and finger dexterity as a function of skin temperature, EMG, and ambient condition. Hum Factors J Hum Factors Ergon Soc 52(3):426–440

Chi CF, Shih YC, Chen WL (2012) Effect of cold immersion on grip force, EMG, and thermal discomfort. Int J Ind Ergon 42(1):113–121

Chiang HC, Ko YC, Chen SS, Yu HS, Wu TN, Chang PY (1993) Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. Scand J Work Environ Health 126–131

Enander A (1984) Performance and sensory aspects of work in cold environments: a review. Ergonomics 27(4):365–378

Enander AE, Hygge S (1990) Thermal stress and human performance. Scand J Work Environ Health 44–50

Goonetilleke RS, Hoffmann ER (2009) Hand-skin temperature and tracking performance. Int J Ind Ergon 39(4):590–595

Heus R, Daanen HAM, Havenith G (1995) Physiological criteria for functioning of hands in the cold: a review. Appl Ergon 26(1):5–13

Kurppa K, Viikari-Juntura E, Kuosma E, Huuskonen M, Kivi P (1991) Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. Scand J Work Environ Health 17(1):32–37

Nordander C, Ohlsson K, Balogh I, Rylander L, Pålsson B, Skerfving S (1999) Fish processing work: the impact of two sex dependent exposure profiles on musculoskeletal health. Occup Environ Med 56(4):256–264

Piedrahíta H, Punnett L, Shahnavaz H (2004) Musculoskeletal symptoms in cold exposed and non-cold exposed workers. Int J Ind Ergon 34(4):271–278

Riley MW, Cochran DJ (1984) Dexterity performance and reduced ambient temperature. Hum Factors J Hum Factors Ergon Soc 26(2):207–214

Schiefer R, Kok R, Lewis M, Meese G (1984) Finger skin temperature and manual dexterity—some inter-group differences. Appl Ergon 15(2):135–141

Schneider E, Irastorza X, Copsey S, Verjans M, Eeckelaert L, Broeck V (2010) OSH in figures: work-related musculoskeletal disorders in the EU—facts and figures. Luxembourg Eur Agency Saf Health Work

Silverstein BA, Fine LJ, Armstrong TJ (1987) Occupational factors and carpal tunnel syndrome. Am J Ind Med 11:343–358

Wiggen ØN, Heen S, Frevik H, Reinertsen RE (2011) Effect of cold conditions on manual performance wearing petroleum industry protective clothing. Ind Health 49:443–451

Data Clustering on Taiwan Crop Sales Under Hadoop Platform

Chao-Lung Yang and Mohammad Riza Nurtam

Abstract Hadoop is one of the most promising cloud computing platforms to execute a Big Data analytics task which is a process of discovering hidden patterns, unknown correlations, and other valuable information from an extremely large distributed dataset. In this paper, a data clustering was implemented under Hadoop platform to study a large crop sales dataset collected distributedly in Taiwan. Hadoop infrastructure was built to give access of the distributed data centers. An online clustering algorithm utilizing Mahout, a scalable machine learning library, was performed to analyze crop price and yield data from the distributed datasets. This clustering analysis is usually exhausting and time consuming if a single machine is in charge of the whole process. Therefore, in this research, the clustering jobs will be handled under an experimental distributed Hadoop environment. The result can be used to help decision making of crop planning by forecasting or detecting demand changes in the market as early as possible.

Keywords Big data analytics · Hadoop · Mahout · Clustering · Distributed computing

C.-L. Yang (✉) · M. R. Nurtam
Department of Industrial Management, National Taiwan University of Science and Technology, No. 43, Sec. 4, Keelung Rd, Da'an District, Taipei 10607, Taiwan, Republic of China
e-mail: clyang@mail.ntust.edu.tw

M. R. Nurtam
e-mail: muhammadriza@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_99,

1 Introduction

Nowadays, more and more data is collected and stored every day in the world (Gopalkrishnan et al. 2012) and the trend of data size growth has been closer to Moore's Law (Fisher et al. 2012). That means that the volume of collected data will be almost doubled every year. How to analyze the collected huge dataset and create values from it has catch a lot of attentions. Big data is a term coined by data scientists to name this huge dataset. However, the definition of big data is varied. The simple definition to describe big data is a dataset that is too large to fit in a single drive, so it has to be stored in distributed storage (Fisher et al. 2012). Moreover, IBM defines that big data have 3 characteristics called V3 (Volume, Variety, and Velocity). These characteristics simply state that we have data that are so big in size, comes in structured or unstructured form and gets bigger over time with speed (IBM, Zikopoulos et al. 2011). To extract valuable information from big data, a special tool sets for analyzing big data is needed to handle the relatively large data repository by utilizing fast data computation resource. Big data analytics is an emerging research area to perform the process of examining large amounts of data of a variety of types to uncover hidden patterns, unknown correlations and other useful information (Rouse 2012).

In Taiwan, the crop sales data including vegetable and fruit price and sale volume is collected daily in the distributed crop sales markets geographically (AFA 2013). In each market, there are huge amounts of crop sales transactions are processed manually. Regarding the variety of crops, understanding the crop sales pattern and further predicting the price of crop in the coming year or season are important for farmers to conduct the crop cultivation plan. In this research, we utilize the public database to study the crop sales data. A Hadoop platform was built to analyze Taiwan crop sales data using clustering algorithm in Mahout to perform data clustering analysis on crop sales data to study and discover hidden pattern in the data.

The reminder of this paper is organized as follows. Section 2 introduces Hadoop platform and the basic operation of MapReduce. Section 3 describes how the Mahout under Hadoop platform was utilized to perform a data mining analysis on Taiwan crop data and the experimental results. Finally, summary and managerial implications are concluded in Sect. 4.

2 Literature Review

2.1 Hadoop

Hadoop is a distributed computing platform developed by open source community to work with large dataset. Hadoop enables data scientist to store and analyze data by using multiple computing machines as a cluster. The development of Hadoop was initially inspired by a paper presented in 2004 by Google about MapReduce (Dean and Ghemawat 2004, 2008). That contributive research inspired open source community to implement the map-reduce paradigm that exists in functional programming (Hughes 1989) into open source project, and Hadoop is the result (Harris 2013).

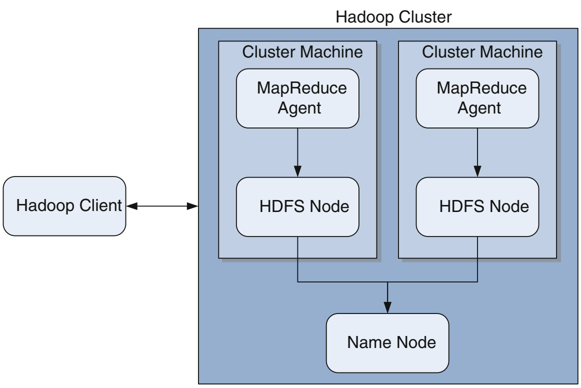
Hadoop consists of several core components: Hadoop common, Hadoop YARN, Hadoop Distributed File System (HDFS), and Hadoop MapReduce (Hadoop 2013). Hadoop common is a set of utilities for working with Hadoop platform, while YARN is a framework for computational job scheduling and cluster management. HDFS is a data management service to handle the distributed storage, and Hadoop MapReduce is a divide-conquer system to perform large-scale data computation. The typical architecture for Hadoop cluster is shown in Fig. 1.

A cluster of Hadoop consists of several machines and services. At least one node of Hadoop cluster should have HDFS service and MapReduce service. In HDFS, a name node is a service which handles the task management, data assignment, and scheduling. Usually, the secondary name node is also established in case the primary name node fails to work properly. In the same manner, each node is able to take over other node when a failure occurs. For security reason, the data copied onto HDFS will be duplicated to multiple data nodes to increase the reliability. This replication process also allows the ability of retrieving data from the nearest node (Shvachko et al. 2010).

Hadoop uses map-reduce paradigm to provide the distributed and parallel processing of large data set. This programming model consists of the *Map* function that performs filtering and sorting on the dataset. On the other hand, the *Reduce* function performs summary routines to aggregate the data from distributed data note. The output of map function is an intermediate <key,value> pairs and this pairs will be the input of reduce function.

An example of the MapReduce operation shown in Fig. 2 which is a process of counting average demand of vegetables (cabbage, broccoli and carrot) from HDFS data source (Dean and Ghemawat 2008; Leu et al. 2010; Espinosa et al. 2012). The data stored in HDFS has to split into several partitions and assigned to mapping

Fig. 1 Typical Hadoop cluster



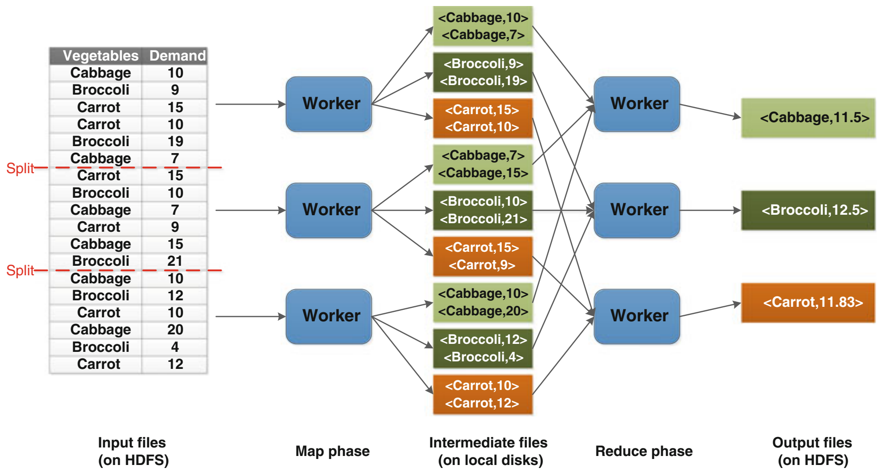


Fig. 2 MapReduce operation

workers. Mapping worker nodes processes the input data and map it into <key,-value> intermediate pairs. Then, the pairs are shuffled and stored into local files, where each file holds data with one specific key. After the mapping process finished, reducing worker retrieve the mapping files from remote machine and start the reducing process and finally store the result to output files.

2.2 Mahout

Mahout is a scalable data mining and machine learning library that can be run on Hadoop distributed platform or the local system (Esteves and Chunming 2011; Esteves et al. 2011). Mahout can be used to process large data set with many data mining algorithms that are already implemented by Java language. Mahout supports four different data mining tasks currently: classification, clustering, recommendation mining, and frequent itemset mining. Mahout is developed based on the multicore MapReduce algorithm (Chu et al. 2006).

The input and result file of the data mining process is saved into sequence file format. To be able to read this result, we need to convert the result file with utility programs called *clusterdump* and *seqdumper* that are provided with Mahout, to dump the result file to readable files.

3 Experiment and Result

Taiwan crop sales data are provided by Taiwan Agriculture and Food Agency at http://amis.afa.gov.tw. This web-based database has multiple query pages and the data has several attributes such as city, crop category, weather, sales price, and sales volumes, and so on. Taiwan crop sales data are collected from major Taiwan markets every day, from 1st January 1996 (85-01-01 in Minguo calendar format) and from 2,767 crop commodities from three categories: vegetables, fruits, and flowers. By using the automatic data retrieval program, we retrieve the data from public database and store the data in a MariaDB database. From this database, a text file in vector format can be created by using SQL query, and sent to HDFS for analyzing. This collected data was used for data analysis and Mahout experiments which will be addressed in the following sections.

3.1 Preliminary Data Analysis

To have better understanding about crop sales data, a preliminary data analysis was conducted. For this analysis, we selected a particular crop, persimmon tomato, with crop ID 'FJ1' to demonstrate the preliminary analysis. Persimmon tomato is a variant of tomato, a big size tomato with some lines on the body of the fruit.

In Fig. 3, two datasets are plotted together. The red curve indicates time series data of the sales price of persimmon tomato in 1999; the blue dashed-line curve indicates another time series data of sales volume of persimmon tomato in the

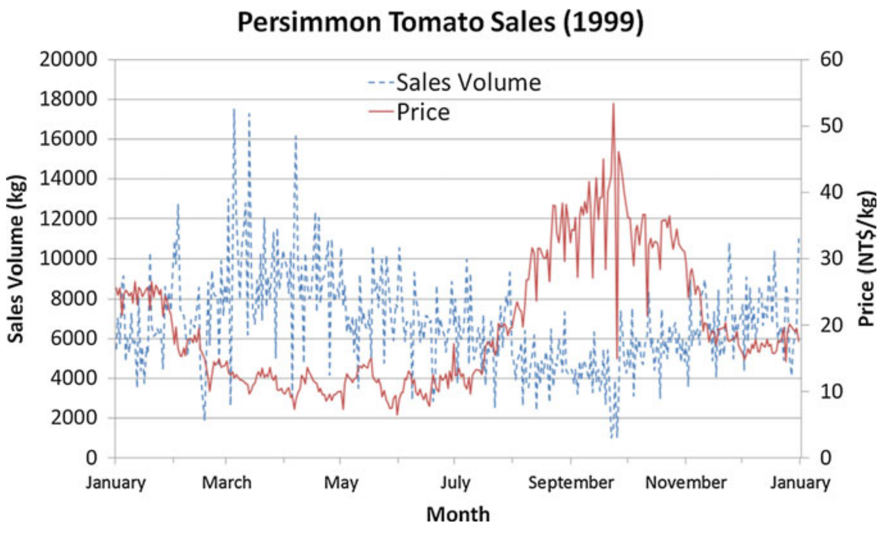


Fig. 3 Sample data of persimmon tomato sales

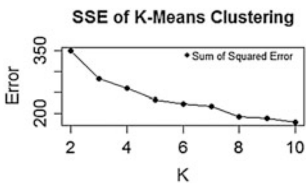
same year. As can be seen, the sales price for this tomato is relatively low from February to July. The sales price tends to increase in the middle of summer and reach the top price around October (at the beginning of winter in Taiwan). On the other hand, sales volume data has different type of trend and is not that steep as price data. The Sales tend to increase in the beginning of the year but with very larger fluctuation day by day. The volume slightly decreases through a year until October. After passing October, the volume starts to increase. Obviously, the seasonal effect is clear on sales price and demand of persimmon tomato. If looking at the data carefully, it can be found that the trend of sales price data is the opposite of sales volume. It means the demand decreases in higher price market, while demand increases if the price is low. To summarize, persimmon tomato are available in large stock and traded in large volume during the beginning of spring and the price are cheaper when compared with the price in summer (Fig. 4).

3.2 Data Clustering on Crop Sales Data

The seasonal pattern is discussed in Chap. 98, but this analysis heavily relies on domain expert's judgment and sometime it is very difficult to separate the data, especially in large scale dataset like Taiwan crops sales data. By using Mahout k-means algorithm under Hadoop (3 nodes in this case), the clustering analysis was performed 5 times. The average of Sum of Squared Error (SSE) of each run with different number of cluster, K, was computed and the results are shown in Fig. 4. As shown in the plot, the SSE is dropping from K = 2 to K = 10. However, the dropping of SSE when K = 3 seems largest. In order to visual data clustering, the scatter plots of K = 3 are shown in Fig. 4.

In Fig. 5, different colors and symbols are used to indicate 3 different clusters. As can be seen, three clusters is revealed by price–volume combination. The cluster 1 is high-volume–low-price; cluster 2 is middle-volume-middle-price. Interestingly, cluster 3 is a low-volume group across all price range. These grouping of price–volume data actually provide another aspect of tomato sales beyond the time series data. The clustering results can easily indicate the sales patterns where might be correlated with other factors such as the weather or market. The further data analysis is needed to find the influential factors which can causes these clustering results (Fig. 6).

Fig. 4 SSE on various number of K in Mahout K-means clustering



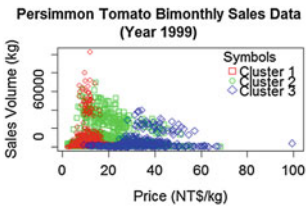


Fig. 5 Bimonthly sales data

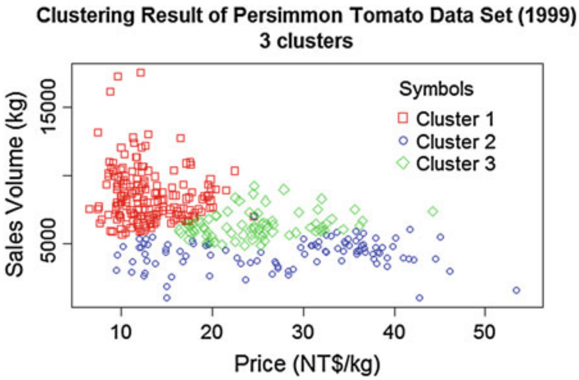


Fig. 6 1,999 crops sales data in 3 clusters

The k-means method is performed with different number of computational node as shown in Fig. 7. Obviously, the more computational node we use, the faster the algorithm is. The number of K for K-means algorithm seems not influential on running time. Although it is intuitive, this scalable structure in fact is the advantage of Hadoop platform because once the more computational effort is needed, the more nodes can be assigned to the job for shortening the processing time.

In this research, we focus on applying the Hadoop platform to demonstrate the data mining capability on Taiwan crop sales data. Mahout that is utilizing MapReduce framework can be applied to perform data mining work across different

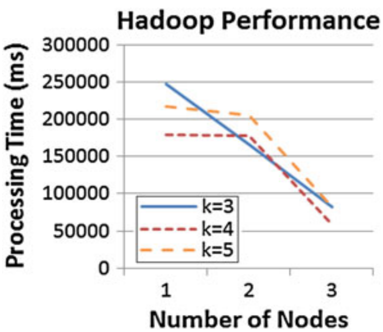


Fig. 7 Hadoop performance

computational notes. Once the data is very big, the Hadoop platform is useful to empower the data analysis simultaneously which has been demonstrate by this experiment.

4 Conclusions

Nowadays, Hadoop is a prominent platform for data scientists that work with big data. Hadoop implements map-reduce programming paradigm and provides the distributed and parallel processing of big data. To be able to analyze the data, an analysis program should be provided and run under MapReduce framework. Mahout is one of promising tool of machine learning and data mining on big data. By running upon Hadoop framework, Mahout can utilize the distributed and parallel processing to enhance analysis performance.

In this research, we used Taiwan crops sales data as a sample of big data, which can be difficult to analyze in a single computer because of its big size. The Mahout under Hadoop was applied to analyze one experimental example, persimmon tomato data, from Taiwan crop sales dataset which collected from public agriculture database. The k-means clustering was used to perform clustering analysis on sales price and volume. The result of the analysis shows that Taiwan crop sales data have seasonal effect in sales price and volume, and the sales can be grouped into multiple clusters in which deferent patterns can be revealed.

Acknowledgments This study was conducted under the "Project Digital Convergence Service Open Platform" of the Institute for Information Industry which is subsidized by the Ministry of Economy Affairs of the Republic of China.

References

AFA (2013) Agriculture market information system. Retrieved July 2013. http://amis.afa.gov.tw

Chu C, Kim S, Lin Y, Yu Y, Bradski G, Ng A, Olukotun K (2006) Map-reduce for machine learning on multicore. NIPS, MIT Press

Dean J, Ghemawat S (2004) MapReduce: simplified data processing on large clusters. In: Proceedings of the 6th conference on symposium on operating systems design and implementation, vol 6. San Francisco, CA, USENIX Association: 10-10

Dean J, Ghemawat S (2008) MapReduce: simplified data processing on large clusters. Commun ACM 51(1):107–113

Espinosa A, Hernandez P, Moure JC, Protasio J, Ripoll A (2012) Analysis and improvement of map-reduce data distribution in read mapping applications. J Supercomputing 62(3):1305–1317

Esteves RM, Chunming R (2011) Using Mahout for clustering Wikipedia's latest articles: a comparison between K-means and fuzzy C-means in the cloud. In: 2011 IEEE third international conference on cloud computing technology and science (CloudCom)

Esteves RM, Pais R, Chunming R (2011) K-means clustering in the cloud: a Mahout test. In: 2011 IEEE workshops of international conference on advanced information networking and applications (WAINA)

Fisher D, DeLine R, Czerwinski M, Drucker S (2012) Interactions with big data analytics. Interactions 19(3):50–59

Gopalkrishnan V, Steier D, Lewis H, Guszcza J (2012) Big data, big business: bridging the gap. In: 1st international workshop on big data, streams and heterogeneous source mining: algorithms, systems, programming models and applications, BigMine-12: held in conjunction with SIGKDD conference, August 12, 2012: Beijing, China, Association for Computing Machinery

Hadoop (2013) Welcome to Apache™ Hadoop®! Retrieved 15 May 2013. http://hadoop.apache.org/

Harris D (2013) The history of Hadoop: From 4 nodes to the future of data. Retrieved 15 May 2013. http://gigaom.com/2013/03/04/the-history-of-hadoop-from-4-nodes-to-the-future-of-data/

Hughes J (1989) Why functional programming matters. Comput J 32(2):98–107

IBM, Zikopoulos P, Eaton C, Deutsch T, Lapis G (2011) Understanding big data: analytics for enterprise class Hadoop and streaming data, McGraw-Hill Education

Leu J-S, Yee Y-S, Chen W-L (2010) Comparison of map-reduce and SQL on large-scale data processing. In: 2010 international symposium on parallel and distributed processing with applications (ISPA)

Rouse M (2012) Definition; big data analytics. http://searchbusinessanalytics.techtarget.com/definition/big-data-analytics

Shvachko K, Hairong K, Radia S, Chansler R (2010) The Hadoop distributed file system. In: 2010 IEEE 26th symposium on mass storage systems and technologies (MSST)

Control with Hand Gestures in Home Environment: A Review

Sheau-Farn Max Liang

Abstract With many advances made in the area of automatic gesture recognition, gestural control has gradually gained its acceptance and popularity. However, the research to date has tended to focus on recognition technologies rather than human behaviors. With an emphasis on users, this paper reviews recent research literature on hand gestural control in home environment. The aim is to summarize and analyze current development processes of gesture vocabularies for commanding home appliances. A semiotic dual triadic model is proposed for the review of the control commands for the appliances, the types of hand gestures, the derivation processes of designer-defined and user-defined gestures. A typical derivation process for a user-defined gesture set was first collecting raw data by inquiring potential users to perform the most suitable gestures that they thought for triggering the given commands or functions, and then applying algorithms for the selection of final gesture vocabularies. A brief comparison among the research results of user-defined freehand gestures for TV control commands was provided as an example to show a need of research in this area. Further research direction includes the exploration of broader user population and the refinement of current gesture selection algorithms.

Keywords Gestural user interface · Human computer interaction · Human centered design · Gesture set

1 Introduction

Many commercialized gestural user interfaces can be found in current home environment, such as smart TV and video game consoles. With the advances in automatic recognition technology, control with hand gestures has gradually gained

S.-F. M. Liang (✉)
National Taipei University of Technology, 1, Sec. 3, Zhong-Xiao E. Rd, Taipei, Taiwan, Republic of China
e-mail: maxliang@ntut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_100,

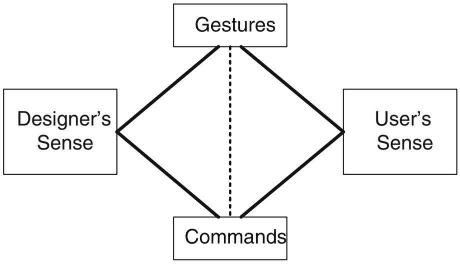


Fig. 1 Dual triadic model for gestural control (modified from Liang 2006)

its acceptance and popularity. However, the research to date has tended to be more technology-driven rather than human-centered. Hence, this paper reviews recent research literature on gestural control for home appliances with a focus on human-centered design. A semiotic dual triadic model is proposed as the framework of the review.

In a semiotic sense, a gesture is a form to represent its referent and to let the interpreter make sense on this representation. The suitability of the representation depends on the sense made of the gesture, its referent, and their relationship, known as semiotic triangle (Chandler 2002). A dual triadic model has been proposed for icon design (Liang 2006), and is also applicable to understand the gestural control. As shown in Fig. 1, the interpreters can be either designers or users. The referents in home environment are usually the control commands to home appliances. Based on their knowledge, experience, and mental models (Norman 1983) on possible control gestures and commands (solid lines in Fig. 1), designers or users define the representations, that is, the associations between each pair of gestures and commands (the dotted line in Fig. 1).

The remainder of this paper is divided into five sections. Section 2 describes the home appliances and associated control commands that have been included in the literature. Section 3 presents different types of hand gestures that have been studied. Section 4 explains the derivation procedures of gesture sets from both designers and users. Section 5 briefly summarizes and compares the research results of user-defined freehand gesture-command mappings for TV control found. Finally, Sect. 6 concludes the paper with discussions.

2 Home Appliances and Control Commands

Television was the most popular home appliance studied in literature among other appliances such as lamps/lights, blinds, curtains, air conditioners, video recorders, answering machines, radios, music players, doors, windows and even robots (Choi et al. 2012; Guesgen and Kessell 2012; Kühnel et al. 2011; Obaid et al. 2012). General control commands found in literature were turn-on/off, increase/decrease (volume or temperature), change to previous/next (channel, station or song), open/close (blinds, curtains, doors, or windows). Specific commands for video or music playback were play, stop, pause, mute, and forward/backward (Ishikawa et al. 2005; Löcken et al. 2012; Vatavu 2012; Wu and Wang 2012, 2013). Some commands for menu selection and electronic program guide (EPG) on television, such as commands for directions and numbering, have also been studied (Aoki et al. 2011b, c; Bailly et al. 2011a, b; Bobeth et al. 2012; Jeong et al. 2012; Shimada et al. 2013; Tahir et al. 2007; Wu et al. 2012). Other relevant gestural control applications include web on TV (Morris 2012) and photo sharing on TV (Freeman et al. 2012).

3 Freehand, Handheld or Hand-worn Gestures

Control with hand gestures for home appliances can be categorized into three main types: freehand, handheld, and hand-worn. While freehand gestures could be one-handed or two-handed, handheld and hand-worn gestures were often one-handed. Freehand gestures are often the gestures made in air. An exception is to use a palm as a control panel and an index finger as a pointer (Dezfuli et al. 2012). For handheld gestures, smart phones were the common devices held by hand. Users can hold the phone and make gestures in air like making freehand gestures (Kühnel et al. 2011), or they can make gestures on the screen of the phone (Aoki et al. 2011b, c). Gesture on surface is a prevalent research topic, but it is beyond the scope of this paper. Other devices held by hand were a Wiimote controller (Bailly et al. 2011a), a laser pen (Aoki et al. 2012), or some tailor-made devices (Kela et al. 2006; Pan et al. 2010; Tahir et al. 2007). Deformable devices have also been proposed with two-handed operation (e.g., Lee et al. 2011). For hand-worn gestures, rings seems the most popular devices that have been applied (Aoki et al. 2011a; Jing et al. 2011; De Miranda et al. 2010, 2011a), though other hand-wear, such as gloves and thimbles, have also been considered (De Miranda et al. 2011b).

Any gesture can be analyzed by its initial state, transition state, and end state. For example, a gesture for turning on a TV might be moving an index finger forward as if pointing a button. The initial state is a posture with the index finger pointing forward. The transition state is to keep the initial posture still and move the hand forward. The end state in this case is the same posture as in the initial state. Therefore, to define a gesture is to identify the form of hand(s), and its spatial and temporal characteristics in each state.

4 User or Designer Defined Gestures

The mappings between gestures and commands were either defined by users or designers. Designer-defined gestures were mainly influenced by the applied gesture recognition technologies (e.g., Aoki et al. 2011a, 2012; Bailly et al. 2011a; Ishikawa et al. 2005; Jeong et al. 2012; Jing et al. 2011; Pan et al. 2010;

Shimada et al. 2013), some of the studies have further conducted usability evaluations by potential users (e.g., De Miranda et al. 2010; Guesgen and Kessell 2012; Lee et al. 2011).

For user-defined gestures, a set of commands was first identified. Participants were then recruited to propose gestures that they thought best for representing the corresponding commands. If the number of participants is N, and the number of commands is M. Initially there should be N × M gestures derived from the participants. However, it is common that many proposed gestures are similar or identical, so they are considered as repeats of each other if they are proposed to the same command. Eventually, each command is associated with several gestures that have different numbers of repetition, and the command "win" the associated gesture with the highest number of repetition (Wobbrock et al. 2005). An extended approach has been proposed to include psychological and physiological measures and to treat the derivation of a gesture set as a mathematical optimization process (Stern et al. 2008).

5 User-Defined Freehand Gesture Sets

Several studies have been done on the user derivation of freehand gestures for TV commands. A brief comparison of the results was made among three studies as shown in Table 1. While agreement can be found for some gesture-command

Table 1 Results of user-defined freehand gestures for TV commands in previous research

Reference (participant)	Choi et al. 2012 (30 Koreans)	Vatavu 2012 (12 Romanians)	Wu and Wang 2012 (12 Chinese)
TV command		Suggested gesture	
Turn on	Make a square shape and increase the size with two index fingers and thumbs	Move index finger forward (air click)	Palm faces forward, fingers point up, and move the hand forward
Turn off	(1) Make a square shape and decrease the size with two index fingers and thumbs (2) Palm faces up, and move thumb to the palm	Draw an X with index finger	Wave one hand (wave goodbye)
Increase the volume	Pinch with the thumb and other fingers and then open them (as if open a mouth)	Left hand serves as the reference while move right hand up or to the right	Palm faces forward, fingers point up, and move the hand up
Decrease the volume	(1) Open the thumb and other fingers and then pinch with them (as if close a mouth) (2) Palm faces down, fingers point forward, and move the hand down	Left hand serves as the reference while move right hand down or to the left	Palm faces forward, fingers point up, and move the hand down
Select previous channel	Move right hand to the right	Move right hand to the right	Move right hand to the right
Select next channel	Move right hand to the left	Move right hand to the left	Move right hand to the left

mappings, such as gestures for selecting previous or next channel, conflicts over the mappings are common even for the basic turn-on/off commands. More empirical data seem necessary for being able to draw a conclusion on what the most appropriate gestures are for certain commands.

6 Conclusion

A review of the literature indicates that the research on hand-gestural control in home environment is still at an early stage in finding appropriate gesture vocabularies for corresponding commands. With current sparse and diverse research results, additional research in this area should prove quite beneficial. One possibility is to continue to collect data about the gesture-command mappings. In addition, issues about how individual or cultural differences effect user's selection of gestures seem worth to be further explored. Finally, the procedures of establishing a set of gestures can be refined by considering user's mental model and physical capabilities and limitations, as well as the competence of gesture recognition technology.

Acknowledgments This work is funded by the National Science Council of Taiwan (NSC 101-2221-E-027-005-MY3).

References

Aoki R, Karatsu Y, Ihara M, Maeda A, Kobayashi M, Kagami S (2011a) Gesture identification based on zone entry and axis crossing. In: Paper presented at the 14th international conference on human-computer interaction. Orlando, USA, 9–14 July 2011 LNCS 6762-2: 194–203

Aoki R, Karatsu Y, Ihara M, Maeda A, Kobayashi M, Kagami S (2011b) Unicursal gesture interface for TV remote with touch screens. In: Paper presented at the 2011 IEEE international conference on consumer electronics (ICCE). Las Vegas, USA, 9–12 Jan 2011, pp 99–100

Aoki R, Karatsu Y, Ihara M, Maeda A, Kobayashi M, Kagami S (2011c) Expanding kinds of gestures for hierarchical menu selection by unicursal gesture interface. IEEE T Consum Electr 57–2:731–737

Aoki R, Ihara M, Kobayashi T, Kobayashi M, Chan B, Kagami S (2012) A gesture recognition algorithm for vision-based unicursal gesture interfaces. In: Paper presented at the 10th European conference on interactive TV and video (EuroITV'12). Berlin, Germany, 4–6 July 2012, pp 53–56

Bailly G, Vo D-B, Lecolinet E, Guiard Y (2011a) Gesture-aware remote controls: Guidelines and interaction techniques. In: Paper presented at the 13th international conference on multimodal interfaces (ICMI'11). Alicante, Spain, 14–18 Nov 2011, pp 263–270

Bailly G, Walter R, Müller J, Ning T, Lecolinet E (2011b) Comparing free hand menu techniques for distant displays using linear, marking and finger-count menus. In: Paper presented at the 13th IFIP TC 13 international conference on human-computer interaction (INTERACT'11). Lisbon, Portugal, 5–9 Sept 2011 LNCS 6947-2: 248–262

Bobeth J, Schmehl S, Kruijff E, Deutsch S, Tscheligi M (2012) Evaluating performance and acceptance of older adults using freehand gestures for TV menu control. In: Paper presented at

the 10th European conference on interactive TV and video (EuroITV'12). Berlin, Germany, 4–6 July 2012, pp 35–44
Chandler D (2002) Semiotics: the basics. Routledge, New York
Choi E, Kwon S, Lee D, Lee H, Chung MK (2012) Can user-defined gesture be considered as the best gesture for a command? Focusing on the commands for smart home system. In: Paper presented at the human factors and ergonomics society 56th annual meeting. Boston, USA, 22–26 Oct 2012, pp 1253–1257
De Miranda LC, Hornung HH, Baranauskas C (2010) Adjustable interactive rings for iDTV. IEEE T Consum Electr 56(3):1988–1996
De Miranda LC, Hornung HH, Baranauskas C (2011a) Adjustable interactive rings for iDTV: first results of an experiment with end-users. In: Paper presented at the 14th international conference on human-computer interaction. Orlando, USA, 9–14 July 2011 LNCS 6776: 262–271
De Miranda LC, Hornung HH, Baranauskas C (2011b) Prospecting a new physical artifact of interaction for iDTV: results of participatory practices. In: Paper presented at the 14th international conference on human-computer interaction. Orlando, USA, 9–14 July 2011 LNCS 6770: 167–176
Dezfuli N, Khalilbeigi M, Huber J, Müller FB, Mühlhäuser M (2012) PalmRC: imaginary palm-based remote control for eyes-free television interaction. In: Paper presented at the 10th European conference on interactive TV and video (EuroITV'12). Berlin, Germany, 4–6 July 2012, pp 27–34
Freeman D, Vennelakanti R, Madhvanath S (2012) Freehand pose-based gestural interaction: Studies and implications for interface design. In: Paper presented at the 4th international conference on intelligent human computer interaction. IIT Kharagpur, India, 27–29 Dec 2012, pp 1–6
Guesgen H, Kessell D (2012) Gestural control of household appliances for the physically impaired. In: Paper presented at the 25th international Florida artificial intelligence research society conference. Macro Island, USA, 23–25 May 2012, pp 353–358
Ishikawa T, Horry Y, Hoshino T (2005) Touchless input device and gesture commands. In: Paper presented at the IEEE international conference on consumer electronics. Las Vegas, USA, 8–12 Jan 2005, pp 205–206
Jeong S, Jin J, Song T, Kwon K, Jeon JW (2012) Single-camera dedicated television control system using gesture drawing. IEEE T Consum Electr 58–4:1129–1137
Jing L, Yamagishi K, Wang J, Zhou Y, Huang T, Cheng Z (2011) A unified method for multiple home appliances control through static finger gestures. In: Paper presented at the IEEE/IPSJ 11th international symposium on applications and the internet. Munich, Germany, 18–21 July 2011, pp 82–90
Kela J, Korpipää P, Mäntyjärvi J, Kallio S, Savino G, Jozzo L, Di Marca S (2006) Accelerometer-based gesture control for a design environment. Pers Ubiquit Comput 10–5:285–299
Kühnel C, Westermann T, Hemmert F, Kratz S, Müller A, Möller S (2011) I'm home: defining and evaluating a gesture set for smart-home control. Int J Hum Comput St 69:693–704
Lee S-S, Maeng S, Kim D, Lee K-P, Lee W, Kim S, Jung S (2011) FlexRemote: exploring the effectiveness of deformable user interface as an input device for TV. In: Paper presented at the 14th international conference on human-computer interaction. Orlando, USA, 9–14 July 2011 CCIS 174: 62–65
Liang SFM (2006) Analyzing icon design by the axiomatic method: a case study of alarm icons in process control displays. Asian J Ergon, 7(1–2):11–28
Löcken A, Hesselmann T, Pielot M, Henze N, Boll S (2012) User-centred process for the definition of free-hand gestures applied to controlling music playback. Multimedia Syst 18:15–31
Morris MR (2012) Web on the wall: insights from a multimodal interaction elicitation study. In: Paper presented at the ACM international conference on interactive tabletops and surfaces. Cambridge, USA, 11–14 Nov 2012, pp 95–104

Norman DA (1983) Some observations on mental models. In: Gentner D, Stevens AL (eds) Mental models. Erlbaum, Hillsdale, pp 7–14

Obaid M, Häring M, Kistler F, Bühling R, André E (2012) User-defined body gestures for navigational control of a humanoid robot. In: Paper presented at the international conference on social robotics. Chengdu, China, 29–31 Oct 2012 LNAI 7621: 367–377

Pan G, Wu J, Zhang D, Wu Z, Yang Y, Li S (2010) GeeAir: a universal multimodal remote control device for home appliances. Pers Ubiquit Comput 14:723–735

Shimada A, Yamashita T, Taniguchi R (2013) Hand gesture based TV control system. In: Paper presented at the 19th Korea-Japan joint workshop on frontiers of computer vision. Incheon, Korea, 30 Jan–01 Feb 2013, pp 121–126

Stern HI, Wachs JP, Edan Y (2008) Designing hand gesture vocabularies for natural interaction by combining psycho-physiological and recognition factors. Int J Semantic Comput 2(1):137–160

Tahir M, Bailly G, Lecolinet E (2007) ARemote: A tangible interface for selecting TV channels. In: Paper presented at the 17th international conference on artificial reality and telexistence. Esbjerg, Denmark, 28–30 Nov 2007, pp 298–299

Vatavu R-D (2012) User-defined gestures for free-hand TV control. In: Paper presented at the 10th European conference on interactive TV and video (EuroITV'12). Berlin, Germany, 4–6 July 2012, pp 45–48

Wobbrock JO, Aung HH, Rothrock B, Myers BA (2005) Maximizing the guessability of symbolic input. In: Paper presented at the conference on human factors in computing (CHI). Oregon, USA, 2–7 April 2005 1869-1872

Wu H, Wang J (2012) User-defined body gestures for TV-based applications. In: Paper presented at the 4th international conference on digital home. Guangzhou, China, 23–25 Nov 2012, pp 415–420

Wu H, Wang J (2013) Understanding user preferences for freehand gestures in the TV viewing environment. AISS 5–4:709–717

Wu H, Chen X, Li G (2012) Simultaneous tracking and recognition of dynamic digit gestures for smart TV systems. In: Paper presented at the 4th international conference on digital home. Guangzhou, China, 23–25 Nov 2012, pp 351–356

An Integrated Method for Customer-Oriented Product Design

Jiangming Zhou, Nan Tu, Bin Lu, Yanchao Li and Yixiao Yuan

Abstract This paper introduces a customer-oriented design method in new product development (NPD). This method comprises of persona creation, analytic hierarchy process (AHP), quality function deployment (QFD) and usability engineering. Persona creation based on fuzzy cluster analysis is first employed to identify the typical behaviors and motivations of a broader range of customers. The customer requirements (CRs) are extracted from the persona profiles and then prioritized with a semi-fuzzy AHP approach. Using the QFD method, the prioritized CRs are translated into measurable design requirements (DRs) to set the design targets. After product prototyping, scenario-based usability testing techniques are employed to access and make recommendations to improve usability in product redesign. The above process may be repeated with several iterations until a product that more closely matches the customer needs with high usability can be designed. A new sports earphones design is given as an example to illustrate the implementation of this method.

Keywords Customer-oriented product design · Persona creation · Analytic hierarchy process · Quality function deployment · Usability engineering

1 Introduction

Throughout the new product development (NPD) process, there exist difficulties in accommodating the value elements, which leads to substantial failure rates and high risks. Extensive studies have been carried out to search for the factors that

J. Zhou (✉) · N. Tu · B. Lu · Y. Li · Y. Yuan
Research Center for Modern Logistics, Graduate School at Shenzhen, Tsinghua University, Shenzhen 518055, People's Republic of China
e-mail: jamin.zjm@gmail.com

N. Tu
e-mail: dr.nan.tu@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_101,

separates winners from losers. Karkkainen and Elfvengren (2002) concluded that the two success factors strongly pointed out in previous studies are early-phase product innovation and careful assessment of customer needs.

Customer-oriented product design aims to design products that better meet the customer requirements (CRs) to secure the competitive advantages and success of a NPD. The designer needs to define the CRs clearly and produce an appropriate design solution with a crucial connection between CRs and products (Aoussat et al. 2000).

Quality function deployment (QFD) is a commonly used tool to incorporate CRs into product design (Akao 1990), using a matrix called house of quality (HOQ) to prioritize the design requirements (DRs) based on the CRs (Hauser and Clausing 1988). As a support method in solving multiple criteria decision making (MCDM) problems (Ho 2008), the analytic hierarchy process (AHP) is employed to determine the relative importance weights of CRs in QFD for precision improvements. The combined AHP-QFD method has been applied in product design selection situations. For example, Myint (2003) proposed the approach to aid the product design where four matrices were constructed to link the CRs, assembly characteristics, main assembly components, sub-components and attributes.

Primal data for QFD is collected from interviews, claims information and even experiences of the product design team (Akao 1997). Such tools as affinity charts (K-J diagrams) and tree diagram account for most industry applications in classifying CRs in HOQ (Griffin and Hauser 1993). These qualitative methods have met some criticisms as being human subjective and imprecise. An interactive design tool called persona can be used to help designers focus on the typical behaviors and motivations of customers. Tu et al. (2010) employed quantitative fuzzy cluster analysis to address the shortcomings of subjective matters. However, we have yet found a method that integrates persona creation with QFD in NPD.

Most researches on NPD are limited to product prototyping, while product design is an iteration process and feedbacks are essential to diagnose and improve existing products. Commonly used in user interface design, scenario-based usability testing can be employed in NPD to access the customer satisfaction. Then the assessment results can be fed back to the designers for use in product redesign.

In this article, the techniques of persona creation, AHP, QFD and scenario-based usability testing are integrated to design a customer-oriented product so that customers' needs can be met with better product usability. Finally a new sports earphones design is employed as an illustrative case study to this approach.

2 Theoretical Background

The overall procedures are divided into the following six steps (Fig. 1):

Step 1: Create persona based on fuzzy cluster analysis.

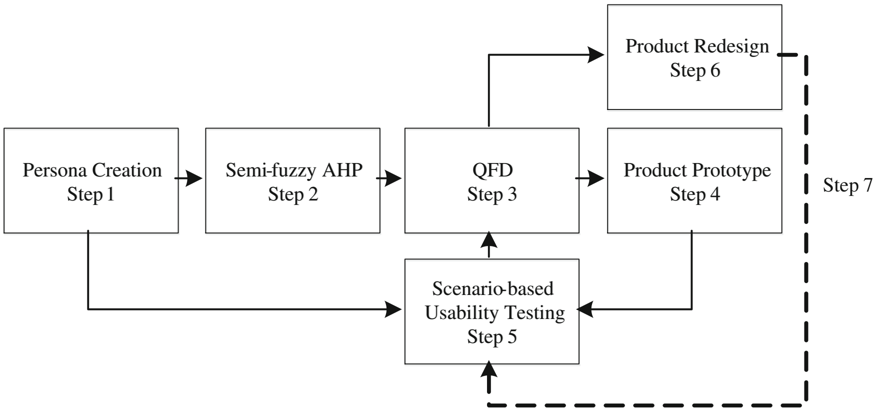


Fig. 1 Overall procedure of the integrated method

Step 2: Extract the CRs and prioritize using the semi-fuzzy AHP technique.
Step 3: Translate the prioritized CRs into DRs using QFD and set the targets.
Step 4: Create a product prototype.
Step 5: Conduct scenario-based usability testing of product prototype.
Step 6: Collect feedbacks and redesign product.
Step 7: Return to step 5 if necessary.

2.1 Persona Creation

In persona creation, questionnaires are filled out help the design team select the dimensions in classifying prototypes and perform fuzzy cluster analysis based on the fuzzy c-mean (FCM) algorithm. Respectively, typical customers from the classified groups are invited for an in-depth interview to create personas.

The target function of the FCM algorithm is to minimize the distance sum of squares between samples and clustering prototypes.

$$J = \sum_{k=1}^{n} \sum_{i=1}^{c} (\mu_{ik})^m (d_{ik})^2 \tag{1}$$

Where μ is the membership degree, m is the weighting exponent and d is the Euclidean Distance between the kth sample and the ith clustering prototype.

The constraint is that $\sum_{i=1}^{c} \mu_{ik} = 1$.

To initialize, set the number of cluster classifications c and the threshold value of iteration ε. Calculate the clustering prototypes using the density function.

In iterative operation, first update the membership degree.

$$\mu_{jk} = \begin{cases} 1 \Big/ \sum_{i=1}^{c} \left(\frac{d_{jk}}{d_{ik}}\right)^{\frac{2}{m-1}} & \forall i, k, d_{ik} > 0 \\ 1, j = i & \\ 0, j \neq i & \exists k, d_{ik} = 0 \end{cases} \quad (2)$$

Second, update the clustering prototype.

$$\boldsymbol{p}_i^{(a+1)} = \frac{\sum_{k=1}^{n} (\mu_{ik})^m \cdot \boldsymbol{x}_k}{\sum_{k=1}^{n} (\mu_{ik})^m} i = 1, \ldots, c \quad (3)$$

If $\left\|\boldsymbol{p}^{(a)} - \boldsymbol{p}^{(a+1)}\right\| < \varepsilon$, the iteration ends, otherwise set $a = a + 1$ and repeat.

2.2 Semi-Fuzzy AHP Approach

The first step is to structure the CRs into different hierarchy levels. After that, comparisons are carried out on a pairwise basis using triangular fuzzy numbers.

$$\tilde{a}_{ij}{}^{\alpha_{ij}} = [a_{ijl}{}^{\alpha_{ij}}, a_{iju}{}^{\alpha_{ij}}] = \begin{cases} [a_{ij}, a_{ij} + 2 - 2\alpha_{ij}], & a_{ij} = 1 \\ [a_{ij} - 2 + 2\alpha_{ij}, a_{ij} + 2 - 2\alpha_{ij}], & a_{ij} = 3, 5, 7 \\ [a_{ij} - 2 + 2\alpha_{ij}, a_{ij}], & a_{ij} = 9 \end{cases} \quad (5)$$

The level of uncertainty is indicated by different index α.

When selecting a value from the given interval, agreements have to be reached. In this semi-fuzzy AHP approach, fuzzy numbers are used only when the preference is significant. The index of optimism μ is employed.

$$\hat{a}_{ij}{}^{\alpha_{ij}} = \begin{cases} \mu a_{ijl}{}^{\alpha_{ij}} + (1 - \mu) a_{iju}{}^{\alpha_{ij}}, & (a_{ijl} + a_{iju})/2 \geq 1 \\ 1/\hat{a}_{ji}{}^{\alpha_{ij}}, & (a_{ijl} + a_{iju})/2 < 1 \end{cases} \quad (6)$$

The pairwise comparison matrix is constructed using the selected value.

$$\hat{\boldsymbol{A}} = \begin{pmatrix} 1 & \hat{a}_{12}{}^{\alpha_{12}} & \cdots & \hat{a}_{1n}{}^{\alpha_{1n}} \\ \hat{a}_{21}{}^{\alpha_{21}} & 1 & \cdots & \hat{a}_{2n}{}^{\alpha_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{a}_{n1}{}^{\alpha_{n1}} & \hat{a}_{n2}{}^{\alpha_{n2}} & \cdots & 1 \end{pmatrix} \quad (7)$$

The method of calculating the principle eigenvector is used. The priority vector needs to be normalized and synthesized to get the overall weights at each level.

The final step is to verify the consistency. Calculate the consistency index (CI) as $CI = (\lambda_m - n)/(n - 1)$ where λ_m is the principal eigenvalue and n is the

Table 1 Random index of AHP

n	2	3	4	5	6	7
RI	0	0.58	0.90	1.12	1.24	1.32

number of elements. Compare it to the random index (RI). It is acceptable if the ratio $CI/RI < 0.1$, otherwise the comparisons should be reviewed and revised.

The reference values of RI for different n are shown below (Winston 1994) (Table 1).

2.3 QFD

The basic idea of QFD is to translate CRs into DRs, and subsequently into parts characteristics, process plans and production requirements (Park and Kim 1998). The HOQ matrix used consists of a few components: (1) CRs in rows and DRs in columns; (2) relationship matrix between CRs and DRs; (3) weights of CRs on the right and correlations of DRs at the top; (4) weights of DRs at the bottom (Fig. 2).

The absolute importance weights of DRs are calculated as $AI_j = \sum_{i=1}^{n} x_i R_{ij}$ and normalized as $RI_j = AI_j \Big/ \sum_{j=1}^{m} AI_j$. R_{ik} denotes the relationship rating between the

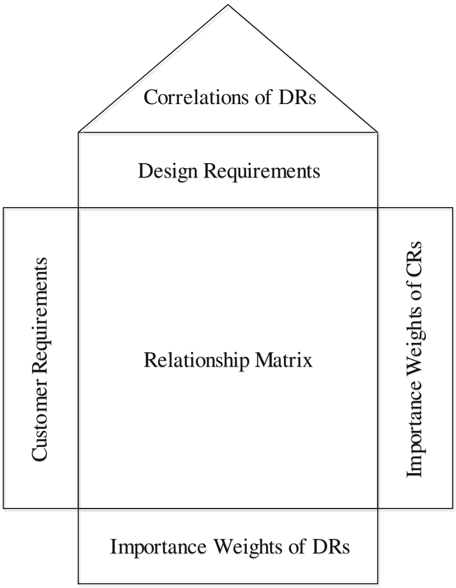


Fig. 2 HOQ matrix model

*i*th CR and the *k*th DR. x_i is the importance weight of the *i*th CR, given by the semi-fuzzy AHP.

2.4 Scenario-Based Usability Testing

After translating CRs into DRs, product prototyping is performed by the design team (step 4). In scenario-based usability testing, the scenarios are generated from the persona profiles. Evaluation forms and interview questionnaires are designed. Two or three internal staffs are asked to participate in the pre-testing to access and help modify the scenarios and tasks. After that, typical customers are invited again to try out the product prototype under the observation of usability engineers. In-depth interviews are carried out to collect customers' feedbacks.

3 A Case Study

An example of designing new sports earphones for joggers and hikers is given to illustrate this integrated method.

3.1 Persona Creation

Consulted with the persona usage toolkit by Olson (2004), questionnaires containing 33 multiple choice questions were invented for specific groups of people who are fond of jogging and hiking. 69 questionnaires were retrieved at last.

The clustering prototype matrix is calculated using the fuzzy cluster analysis. Based on their membership degree to the clustering prototypes, the 69 samples are divided into three groups. The persona (Fig. 3) of the enjoyment group is used.

3.2 Semi-Fuzzy AHP and QFD

The CRs were extracted and structured into a three-level hierarchy. Questionnaires were used to gather preferences with separate indexes of certainty. Applying the semi-fuzzy approach, the final comparison matrix is constructed and the eigenvectors are calculated using MATLAB. The eigenvectors were normalized and synthesized to prioritize the overall weights of CRs.

Specific DRs are discussed by designers and engineers concerning the company's existing technologies. The QFD matrix (Fig. 4) is constructed and the normalized importance weights of DRs are calculated.

Basic information
Name: Anna
Gender: female
Age: 30
Education background: bachelor
Occupation: mid-level management
Income per month: 8000 RMB

Characteristic: Anna loves movie, drama, coffee and music. She has a stable job and wonderful family. Anna is fashionable. She enjoys name brand products. She pursues high-quality living.

Outdoor experience: Anna has been to outdoor for a long time. She owns a complete set of branded outdoor gears. Although Anna is busy with job, she will go out once every two weeks at least.

Use's goal for listening to music in outdoor activities:

1. Music has magical power. I can inspire myself when feel tired.
2. I love music. Sport and music are indispensable parts of my life.

Fig. 3 Primary persona profile

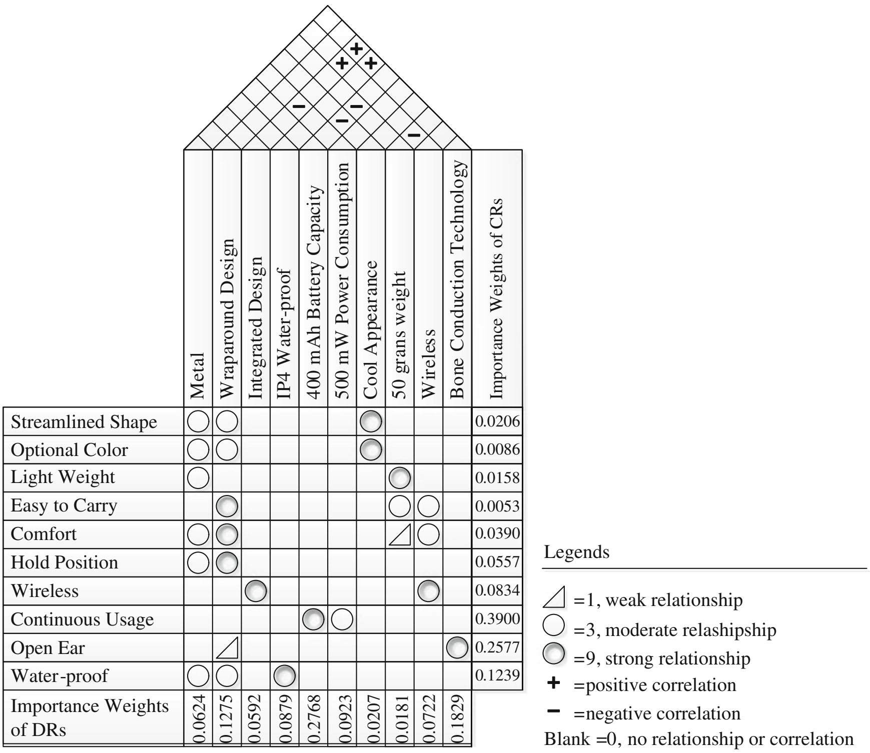


Fig. 4 QFD matrix

3.3 Product Prototype and Scenario-Based Usability Testing

Based on the importance weights of DRs and the correlations, the top five DRs (400 mAh battery capacity, bone conduction technology, wraparound design, 500 mV Power Consumption and IP4 water-proof) are selected as main instructions for the design team. The product prototype is designed.

To access the usability and user experience of the product prototype, scenarios as hiking in groups and jogging alone are generated from the persona profiles. 7 typical customers were invited to participate in the usability testing.

The feedbacks were later translated into DRs using the QFD technique for further product redesign. Through necessary iterations, the improved sports earphones are designed. Featuring major improvements are: (1) 30 % smaller, lighter in-line controller, (2) Clearer ON/OFF switch and micro USB charging port, (3) Patent pending dual suspension bone conduction with improved quality, (4) Reflective safety strip on back of wraparound headband for added safety.

Acknowledgments This work is partially supported by teams from Vtech Inc. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Akao Y (1990) Quality function deployment: integrating customer requirements into product design. Productivity Press, Cambridge

Akao Y (1997) QFD: past, present and future. In: Proceedings of the International Symposium on QFD'97

Aoussat A, Christofol H, Coq ML (2000) The new product design: a transverse approach. Eng Des 11(4):399–417

Griffin K, Hauser JR (1993) The voice of the customer. Mark Sci 12(1):1–27

Hauser JR, Clausing D (1988) The house of quality. Harvard Bus Rev 66:63–73

Ho W (2008) Integrated analytic hierarchy process and its applications: a literature review. European Journal of Operations Research 186:211–228

Karkkainen H, Elfvengren K (2002) Role of careful customer need assessment in product innovation management-empirical analysis. Int J Prod Econ 80(1):85–103

Myint S (2003) A framework of an intelligent quality function deployment (IQFD) for discrete assembly environment. Comput Ind Eng 45(2):269–283

Olsen G (2004) Persona Creation and Usage Toolkit. http://www.interactionbydesign.com/presentations/olsen_persona_toolkit.pdf

Park T, Kim KJ (1998) Determination of an optimal set of design requirements using house of quality. J Oper Manag 16:569–581

Tu N et al (2010) Combine Qualitative and quantitative methods to create persona. In: Proceedings of the 3rd International Conference on Information Management, Innovation Management and Industrial Engineering 3:597–603

Winston WL (1994) The analytic hierarchy process. Operations research: applications and algorithms, Wadsworth, Belmont, CA, pp 798–806

Discrete Particle Swarm Optimization with Path-Relinking for Solving the Open Vehicle Routing Problem with Time Windows

A. A. N. Perwira Redi, Meilinda F. N. Maghfiroh and Vincent F. Yu

Abstract This paper presents a discrete version of the particle swarm optimization with additional path-relinking procedure for solving the open vehicle routing problem with time windows (OVRPTW). In OVRPTW, a vehicle does not return to the depot after servicing the last costumer on its route. Each customer's service is required to start within a fixed time window. To deal with the time window constraints, this paper proposed a route refinement procedure. The result of computational study shows that the proposed algorithm effectively solves the OVRPTW.

Keywords Open vehicle routing problem · Time windows · Discrete particle swarm optimization · Path-relinking

1 Introduction

The goods distribution constitutes an important part of the overall operational costs of companies. The problem intensifies from a practical perspective when the companies do not own a fleet of vehicles (Sariklis and Powell 2000). In this case, outsourcing the distribution functions to third party logistic (3PL) providers is a beneficial business practice. Since the vehicles belong to the 3PL providers, they do no need to turn to the depot when they finish the deliveries. The above

A. A. N. Perwira Redi (✉) · M. F. N. Maghfiroh · V. F. Yu
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: wira.redi@gmail.com

M. F. N. Maghfiroh
e-mail: meilinda.maghfiroh@gmail.com

V. F. Yu
e-mail: vincent@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_102,

described distribution model is referred to as the open vehicle routing problem (OVRP). Other typical real-life OVRP applications include home delivery of packages and newspapers, and school buses. The goal of the OVRP is to design a set of Hamiltonian paths (open routes) to satisfy customer demands in a way that minimizes the number of the vehicles, and for a given number of vehicles, minimizes the total distance (or time) traveled by the vehicles.

In some real-life situations, arrival time at a costumer will affect the customer's satisfaction level or sales to the customer. If the vehicle's service to the customer starts later than the time required by the customer, the company may lose sales to the customer. Therefore, the company should start serve every customers within the customer's desired time windows while minimizing the total length of the vehicle routes. School bus routing is another example. In the morning, a school bus arrives at the first pick-up point where its route starts, and travels along a predetermined route, picking up students at several points and taking them to school, within predefined time windows. This type of problem can be modeled as the open vehicle routing problem with time windows (OVRPTW). The objective of this problem reflects the trade-off between the vehicle's fixed cost and the variable travel cost while considering the time windows constraints. As a variant of OVRP and vehicle routing problem with time windows (VRPTW) which are proven to be NP-hard problems, OVRPTW is also NP-hard.

The OVRPTW has been addressed only once in the literature by Repoussis et al. (2006). They developed a heuristic to solve the OVRPTW by utilizing greedy 'look-ahead' solution framework, customer selection and route-insertion criteria. They introduced a new criterion for next-customer insertion, which explicitly accounted for vehicle's total waiting time along the partial constructed routes, and enhanced different types of strategies to determine the 'seed' customers. The proposed algorithm performed very well on test datasets taken from literature, providing high-quality solutions with respect to the number of active vehicles compared to other heuristics approaches. Although optimal solutions can be obtained using exact methods, the computational time required to solve adequately large problem instances is still prohibitive (Repoussis et al. 2010). For this reason, this paper attempt to develop a new efficient metaheuristic, called discrete particle swarm optimization with path-relinking (PSO-PR), to solve OVRPTW.

The rest of the paper is organized as follows. Section 2 defines the problem. Section 3 describes the proposed PSO-PR algorithm. Section 4 discusses the computational experiment and results. Finally, Sect. 5 draws conclusions and points out future research directions.

2 Problem Definition

The OVRPTW can be described as follows. Given a complete graph $G = (V, A)$, where $V = \{0,1,\ldots,n\}$ is the set of nodes and A is the set of arcs. Node 0 represents the depot while other nodes represent the customers. Each customer i has a demand

d_i, a service time s_i and a service time window $[e_i, l_i]$ within which its service must start. There is a non-negative cost c_{ij}, a travel time t_{ij} and a distance d_{ij} associated with the travel from i to j. Let $K = \{1,2,\ldots,k\}$ be the set of vehicles. Each vehicle $k \in K$ has a maximum capacity C and a maximum route length L that limits the maximum distance it can travel. Activation of a vehicle $k \in K$ incurs a fixed cost w_k. Each activated vehicle travels exactly one route.

All routes must satisfy both the capacity and the time window constraints. Time window constraints state that a vehicle cannot start servicing a customer i before the earliest time e_i or after the latest time l_i. The routes must be designed such that each customer is visited only once by exactly one vehicle. Let *NV* denote the number of vehicles used to service all customers in a feasible manner. The objective of the OVRPTW is first to find the minimum *NV* required and second to determine the sequence of customers visited by each vehicle such that the total distance is minimized.

The basic assumptions of OVRPTW are summarized as follows:

a. All vehicles depart from a depot, have only one travel route and will not return to the depot after finishing its services;
b. Each customer's demand is known and each customer can only be served once by a vehicle;
c. Every vehicle has the same capacity;
d. Vehicles must not violate customer's time windows;
e. If a vehicle arrives before a customer's earliest time, the vehicle must wait until the customer's earliest time to start the service. On the other hand, if a vehicle arrives after a customer's latest time, the service must be assigned to another vehicle.

3 Methodology

In PSO algorithm, each particle moves from its initial position to promising positions in the search space based on its velocity, its personal best position, and the particle swarm's global best position. Since Eberhart and Kennedy (1995) introduced the algorithm, PSO has been implemented to solve many problems. Since particles are encoded using real variables in the original PSO, the algorithm is not suitable for combinatorial optimization (Xiaohui et al. 2003). Therefore, this study proposes the PSO-PR algorithm for OVRPTW.

The proposed PSO-PR follows three basic assumptions of PSO: particles move based on the updated velocity; particles moves toward its personal best position; particles are attracted to the global best particle. At each iteration of PSO-PR, a particle first move based on a local search procedure. Then the particle's movement is determined by a path-relinking procedure with its personal best as the target. Lastly, the particle moves based on another path-relinking procedure with global best as its target. The detail of PSO-PR is presented in Fig. 1.

Algorithm1. Pseudo code of the PSO-PR algorithm

Set parameters
for $i = 0$ to Nparticles do
    initialize solution X^i
    $G^i_{best} \leftarrow P^i_{best} \leftarrow X^i$
end for
while iter < Iteration do
    for $i = 0$ to Nparticles do
        $X_i \leftarrow$ localSearch(X^i)
        $X_i \leftarrow$ pathRelinking(X^i; P^i_{best})
        $X_i \leftarrow$ pathRelinking(X^i; G^i_{best})
        $P^i_{best} \leftarrow$ best among X_i and P^i_{best}
        $G^i_{best} \leftarrow$ best among P^i_{best} and G^i_{best}
    end for
    localSearch(G^i_{best})
end while
return Best G^i_{best} of all particles

Fig. 1 Pseudo code of PSO-PR algorithm

3.1 Initial Solution

Time windows constraint has a great impact in assigning customer to serve vehicles. A key determinant factor for obtaining good solutions for routing problems with time window constraints is the effective utilization of time window constraints themselves in the solution approach (Ioannou et al. 2001). Therefore, the proposed PSO-PR algorithm clearly accounts for all possible time windows related information in order to expand the set of customers that are feasible for route insertion at each stage of route construction. We designed a mechanism to ensure the customers with earlier time windows will be served first. The initial solution is generated as follows.

1. Sort the list of customers in ascending order of the earliest times of their time windows.
2. Based on the sorted list of customers, customers are assigned to service vehicles. Two feasibility checks are performed for each customer.

(a) Check vehicle capacity. If inserting a customer into a route violates vehicle capacity, the route is terminated and the customer is assigned to a new vehicle.
(b) Check the time windows constraint. If the vehicle arrives later than the latest time of a customer, the route is terminated and the customer is assigned to a new vehicle.

3. Terminate when all customers are assigned to a vehicle.

3.2 Local Search

The current solution s has a neighborhood $N(s)$ which is a subset of the search space S of the problem ($N(s) \subset S$). This neighborhood is defined by swap, insertion, and 2-opt operators. The probabilities of performing the swap, insertion, and 2-opt moves are fixed at 1/3, 1/3 and 1/3, respectively. The details of these three operators are as follows.

a. *Swap*
   The swap neighborhood consists of solutions that can be obtained by swapping the positions of two customers, either in the same route or in two different routes.
b. *Insert*
   The intra-insertion neighborhood operator removes a customer from its current position and then inserts it after another customer. The inter-insertion operator inserts the customer after another customer in another route.
c. *2-Opt*
   2-opt operator is used both for improving the route and the depot used in the solution. The 2-opt procedure is done by replacing two node-disjoint arcs with two other arcs.

At each iteration, the next solution s' is generated from $N(s)$ and its objective function value is evaluated. Let Δ denote the difference between $obj(s)$ and $obj(s')$, that is $\Delta = obj(s') - obj(s)$. The probability of replacing s with s', given that $\Delta > 0$, is $\exp(-\Delta/Kw)$. This is accomplished by generating a random number $r \in [0, 1]$ and replacing the solution s with s' if $r < \exp(-\Delta/Kw)$. K denoted the decreasing rate for inertia weight (w). Meanwhile, if $\Delta \leq 0$, the probability of replacing s with s' is 1. S_{best} records the best solution found so far as the algorithm progresses.

3.3 Path-relinking Operator

To transform the initial solution s into the guiding solution s' based on P_{best} and G_{best}, the PR operator repairs from left to right the broken pairs of $solution(s)$, creating a path of giant tours with non-increasing distance to $solution(s')$. The operator used is forward strategy by swapping from the solution s to s'. The procedure looks first for a customer i with different positions in s and s'. If i is found, it is permuted with another node to repair the difference. Do swap until the $\delta(s, s')$ is null. The path from s to s' is then guided by the Hamming distance δ, equal to the number of differences between the nodes at the same position in s and s', i.e., $\delta(s,s') = \sum_{i=1,|s|} s_i \neq s'_i$.

4 Computational Result

The proposed PSO-PR was tested on 12 R1 datasets of Solomon (1987). Each of these instances has 100 nodes which are randomly distributed with tight time windows. Vehicle capacity is 200. The algorithm was coded in Visual C++ and run on a personal computer with an iCore7 processor. The parameter setting is given in Table 1. Table 2 provides the traveled distance (TD) and the number of vehicles used (NV) in the solutions obtained by the proposed PSO-PR, respectively. This table also includes the results obtained by Repoussis et al. (2006) for comparison purpose.

Overall the proposed algorithm is effective in solving OVRPTW. It reduces the total travel distances in the solutions obtained by Repoussis et al. (2006) for all the test problems. The average total distance (TD) improves 30.1 % compared to the results of Repoussis et al. (2006). However, the number of vehicles used is slightly more than that reported in Repoussis et al. (2006). The average gap is 0.92 vehicle. This result is reasonable considering the trade-off between the total travel distance and the number of vehicles used.

Table 1 Parameters setting

Variable	Setting
Swarm size	10
w	0.01
$c1$	1
$c2$	1
k	0.992
Iteration number	500

Table 2 Comparison of PSO-PR versus other method on Solomon's R1 data set

Dataset	Repoussis et al.		PSO-PR		TD gap (%)	NV gap
	TD	NV	TD	NV		
r101	1479.9	19	1129.71	17	−31.0	−2
r102	1501.59	18	1008.2	16	−48.9	−2
r103	1281.52	13	911.239	14	−40.6	1
r104	1021.73	10	802.219	11	−27.4	1
r105	1285.94	14	1010.04	16	−27.3	2
r106	1294.88	12	950.115	15	−36.3	3
r107	1102.7	11	895.087	14	−23.2	3
r108	898.94	10	785.205	11	−14.5	1
r109	1150.42	12	889.806	12	−29.3	0
r110	1068.66	12	815.539	12	−31.0	0
r111	1120.45	11	913.005	13	−22.7	2
r112	966.64	10	750.85	12	−28.7	2
Average		12.67		13.58	−30.1	0.92

5 Conclusions

In this paper, we consider a variant of VRP, the OVRPTW, to resolve a practical issue of routing 'hired' vehicle fleets. We develop a discrete PSO-PR algorithm that integrates three basic components of PSO and the path-relinking concept. The local search and path-relinking used in the proposed PSO-PR algorithm significantly improve the solution in terms of total travel distance of vehicles. However, based on the comparison with an existing method for OVRPTW, the total vehicles used are increasing slightly.

References

Ioannou G, Kritikos M, Prastacos G (2001) A Greedy Look-Ahead Heuristic for the Vehicle Routing Problem with Time Windows. J Oper Res Soc 52(5):523–537

Kennedy J, Eberhart R (1995) Particle swarm optimization. In: Neural Networks, 1995. Proceedings, IEEE International Conference on Nov/Dec 1995, pp 1942–1948 vol.1944. doi:10.1109/ICNN.1995.488968

Repoussis PP, Tarantilis CD, Ioannou G (2006) The open vehicle routing problem with time windows. J Oper Res Soc 58(3):355–367

Repoussis PP, Tarantilis CD, Braysy O, Ioannou G (2010) A hybrid evolution strategy for the open vehicle routing problem. Comput Oper Res 37(3):443–455. doi:10.1016/j.cor.2008.11.003

Sariklis D, Powell S (2000) A heuristic method for the open vehicle routing problem. J Oper Res Soc 51(5):564–573

Solomon MM (1987) Algorithms for the vehicle routing and scheduling problems with time window constraints. Oper Res 35:254–265

Xiaohui H, Eberhart RC, Yuhui S (2003) Swarm intelligence for permutation optimization: a case study of n-queens problem. In: Swarm Intelligence Symposium, 2003. SIS '03. Proceedings of the 2003 IEEE, 24–26 April 2003, pp 243–246. doi:10.1109/SIS.2003.1202275

Application of Economic Order Quantity on Production Scheduling and Control System for a Small Company

Kuo En Fu and Pitchanan Apichotwasurat

Abstract Struggling to live in the 21 century, lots of small companies of which the production scheduling and control system (PSCS) are based on a rule of thumb. Without the precise mathematic model, the rule of thumb method may lead to inventory shortages and excess inventory. For reaching better controls of PSCS, this study intends to simulate a material requirement planning (MRP) production system with adopting an economic lot-sizing (EOQ) model to diminish varieties of costs for small sized companies under job-shop environments. The proposed EOQ adopting MRP approach is supposed to have better economics of PSCS than rule-of-thumb methods. A case analysis of a small company X in Thailand is conducted for verifying this proposition. Company X regularly relied on rules-of-thumb to handle PSCS. In this study, two kinds of materials and three types of products are traced top-down from production planning (PP), master production schedule (MPS), to MRP along a period of two months since July 2012. This study undertakes a series of data collection in the field. The analyzed results indicate that the presented model really reach more economics than rule-of-thumb methods for company X.

Keywords Production scheduling and control system (PSCS) · Economic order quantities (EOQ) · Material requirement planning (MRP)

1 Introduction

Presently, lots of small manufacturing firms of which the production scheduling and control system (PSCS) are still based on rules of thumb. The rule-of-thumb method usually cannot obtain better saving of cost due to the lack of a precise

K. E. Fu (✉) · P. Apichotwasurat
Institute of Industrial Management, Taiwan Shoufu University, Tainan, Taiwan
e-mail: gordonfu@tsu.edu.tw

P. Apichotwasurat
e-mail: m100314006@tsu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_103,

mathematical model. Economic lot sizing (ELS) is well-known in the area of production scheduling and inventory control because of varieties of application such as aggregate production planning and material requirement planning (MRP) (Lee et al. 1986; Taleizadeh et al. 2011; Wangner and Whitin 1958; Steven 2008; Silver and Peterson 1985). Thus, this study intends to apply ELS on PSCS system for better control of both replenishment/production scheduling and cost savings. ELS is raised to determine lot sizes and has two versions. One is fixed lot size that is EOQ. The other is dynamic or called heuristic (i.e., not fixed) lot size, such as Wagner-Whitin, Silver-Meal, and part period balancing heuristics (Min and Pheng 2006). These dynamic heuristics desire to find an optimum schedule not only lot size that satisfies given demand at minimum cost. Although these heuristics can achieve optimum costs, EOQ is still widespread (Cárdenas-Barrón 2010; Choi and Noble 2000; Taleizadeh et al. 2011) since fixed quantity is simple for operation and maintenance.

This study applies an EOQ model for satisfying customer demands with permission of backorders in a MRP productive system which includes MPS and MRP. The backorder can be suppressed by placing orders from outside suppliers who can deliver the same quality of ordered products as well. A case is studied by applying EOQ for determining the lot sizes of materials purchase in MRP and product manufacturing in MPS, respectively. In this case, three products and two materials are demonstrated. Finally, the studied result indicates that the EOQ model has better cost savings than rules of thumb that the company regularly used.

2 Literature Review

EOQ model was first derived by Harris in 1913 for determining order sizes under continuous demand at a minimum cost (Cárdenas-Barrón 2010). Later, the EOQ model was used in MRP for replacing the scheme of lot-for-lot under enterprise environment with time dependent demand. Afterwards, dynamic lot sizing heuristics, such as, Wagner-Within algorithm, Silver-Meal heuristic, Least Unit Cost, and Part Period Balancing were proposed for attaining optimum cost (Silver and Peterson 1985; Wangner and Whitin 1958).

In PSCS, both Just-in-Time (JIT) and Material Requirement Planning (MRP) are good at keeping adequate inventory levels to assure that required materials are available when needed. JIT developed in 1970s is based on elimination of system waste and applies primarily to repetitive manufacturing processes. MRP which begins around 1960s is used in a variety of industries with a job-shop environment and especially useful for dealing with system uncertainty. MRP is a push system, while JIT is considered as a pull system. In this study, MRP is suitable for application on the studied case of company X.

Regarding economic lot sizing on MRP productive systems, lots of the studies were presented. Biggs (1979) presented a study which was conducted by computer simulation to determine the effects of using various sequencing and lot-sizing rules on various performance criteria in a multistage, multiproduct, production-inventory system with MRP setting. Liberatore (1979) used MRP and EOQ model to relate with material inventory control with concerning safety stock. Lee et al. (1987) evaluated the forecast error in a productive system with master production scheduling and MRP settings. They suggested that within MRP environments the predictive capabilities of forecast-error measures are contingent on the lot-sizing rule and the product-components structure. Taleizadeh et al. (2011) explored the utility of MRP and Economic Order Quantity/Safety Stock (EOQ/SS) through case study on a chemical process operation.

3 Application of EOQ on a MRP Productive System

An EOQ model for a productive system with MRP settings is described herein. First, the relevant concepts of EOQ, including assumption, notation, and formula are presented. Subsequently, the application of EOQ on a MRP productive system is presented.

3.1 EOQ

EOQ model is utilized in this study for company X. The assumption of EOQ is indicated as follows (Steven 2008; Cargal 2003)

1. The demand rate is constant and deterministic.
2. Annual demand (D) is known.
3. No allowing (or relaxed to no concerning) shortage cost.
4. Costs include.
   - Setup cost (K)
   - Holding cost (H)
5. There is known constant price per unit (no concerning discount, no changing with time).

This model is the simplest among variants of EOQ model can be given as follows:

$$\mathrm{EOQ} = \sqrt{\frac{2 \times \mathrm{K} \times \mathrm{D}}{\mathrm{H}}} \tag{1}$$

where

EOQ represents ordering quantity in unit of material (or product),
H represents holding cost per unit material (or product) per unit time,
K_o represent cost per ordering setup,
D_o represent annual demand in unit of materials

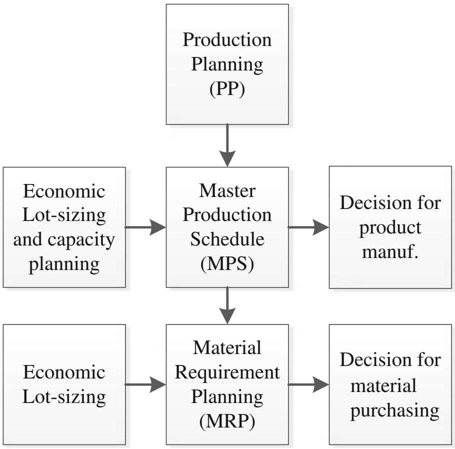


Fig. 1 The scheme of EOQ for a basic MRP productive system

3.2 The Application of EOQ on a MRP Productive System

MRP is the tool for PSCS that MRP assists to answer the basic questions of what to order, how much to order, when to order and when the delivery should be scheduled (Lee 1999). For a basic MRP productive system, three levels of operation planning can be generated. It starts with PP, then MPS and MRP in the last. PP is independent for aggregate planning of production along a medium-range period. MPS is in the following that EOQ is used in daily production scheduling for end products. The last level is MRP in that order quantity and time of placing orders for materials are planned. These three levels for the basic MRP production system are as shown in Fig. 1.

4 Case Analysis

4.1 Case Description

Company X is a small manufacturing firm which produces furniture parts such as hanger bolts, screws and rubber rings in Thailand. Capital is one million baht. There are about twenty-five persons in the company. The input materials are a variety of steels and plastics. In this company, it is the rule of thumb that is used to control the scheduling and lot sizes of both production and replenishment. Only one person in the company is responsible for ordering materials. Before ordering materials, this purchase person needs to check customer orders and stock levels of materials. Regarding manufacturing, there are eighteen persons in total. Generally, one production person takes responsibility for one work station. After a batch of production is completed, products need to be sent out for filling some chemicals to reserve.

In this study, a Hanger bolt is simulated as an example. The production of Hanger bolts, consist of three steps of machining through three respective work stations. In the first work station, materials of steel coils are fed into cutting machines for making specific sizes. In the last two work stations, fine machine thread is made on screws first and then rough machine thread is made. Passing through these three work stations, a Hanger bolt is completed. The production rate of Hanger bolt each day is about 10,000 units. As for the setup of work stations for changeover of manufacturing different products, it needs to spend 3 h at each changeover.

4.2 Estimation of EOQ for Company X

Estimation of EOQ requires knowing holding cost and setup cost first. Based on the data collection from company X, holding cost can be expressed as annual interest rate which is the sum of storage, handling, loss, taxes, and opportunity cost as shown in Table 1. The annual interest rate represents the weighting of cost for each unit product (or materials) during one year. Totally, the annual interest rate for the holding cost in product manufacturing is 12 percentages. The annual interest rate for the holding cost in material purchase is 17 percentages. The cost of each unit product during one year is 0.7 baht. Therefore, the holding cost in product manufacturing for company X is 0.084 baht in one year. For setup cost in product manufacturing, 3 h and one person is needed to setup machines. In machine setup, the mold does not change unless alternative product is to be manufactured. The setup cost is 187.5 baht at each time of machine setup as shown in Table 1.

Table 1 Cost estimation for determining EOQ of Hanger bolt

Cost items	Production scheduling	Materials ordering
Holding cost	*12 %*	*17 %*
Storage	2 %	4 %
Handling	1 %	2 %
Loss	1 %	1 %
Taxes	7 %	7 %
Opportunity cost	1 %	3 %
In total	0.084 baht per year per unit product	4.76 baht per year per kg
Setup cost	*187.5 baht*	*90 baht*
Setup time	3 h	1 h
Telephone	–	12 baht (4 times, average)
Order form	–	3 baht
EOQ	51526.6921 units of product (51,000 units of product is chosen)	368.0739 kg (370 kg is chosen)

Based on the cost estimation in both product scheduling and material ordering of Hanger bolt as shown in Table 1, EOQ_o (EOQ in material ordering) and EOQ_p (EOQ in production scheduling) can be calculated. To calculate EOQ_p for Hanger bolt, the annual demand is 5,94,720 units with the holding cost 0.084 baht per unit per year. For setup of work stations, it needs to spend 187.5 baht in average. According to Eq. (1), EOQ_p can be calculated and is 51526.6921. However, 51526.6921 must take integer value. In this study, 51,000 are chosen for representing one production lot size, as shown in Table 1. In the same way, EOQ_o can be obtained for material ordering as shown in Table 1 as well. The calculated result is 368.0739 kg for EOQ_o. Finally, 370 kg is chosen for indicating the ordering lot size instead of 368.0739 kg.

4.3 Adopting EOQ in MPS and MRP

In previous sections, MPS is based on production planning (PP). A PP for three products of planned production of company X is shown in Table 2. Table 2 shows the weekly production planning of Hanger bolt which consists of forecasted demand, planned production, and planned inventory.

A master production schedule (MPS) is a production scheduling that represented the second level for disaggregation of the overall schedules into specific products (Steven 2008). The daily MPS of company X for Hanger bolt 6 × 40, Screw 7 × 1, and Screw 6 × 1−1/4 are all created in this study for further analysis of cost. It should be noted that the MPS data have two groups, i.e., historic and EOQ adopting, for subsequent comparisons.

MRP will generate a set of net requirements that must be met if the MPS is maintained or kept on scheduled. For company X, the period of material procurement is larger than that of production scheduling. The planning period in MRP is suggested to be based on weeks. Besides, there is no necessity for this study that bill of material (BOM) is used in MRP for defining relationship between end item and subcomponents. Net requirements in MRP are directly determined through unit conversion. The week-based MRP of Hanger bolt 6 × 40, Screw 7 × 1, and Screw 6 × 1−1/4 are all created in this study for further analysis of cost as well.

4.4 The Cost Analysis of the Productive System with MRP Settings for Company X

According to the analysis described above, the total cost for both historic MPS and EOQ adopting MPS of Hanger bolt 6 × 40″ in July–August can be generated and expressed as solid and dotted lines, respectively, as in Fig. 2. It is obvious from Fig. 2 that the total cost of EOQ adopting MPS is lower than that of historic MPS

Table 2 Weekly production planning of Hanger bolt

Week		1	2	3	4	5	6	7	8	9
Forecasted demand		7,500	15,000	10,000	11,000	10,100	26,000	5,000	10,000	8,000
Planned production	Hanger bolt 6 × 40	0	35,500	0	0	57,000	0	0	0	0
	Screw 7 × 1	5,000	9,000	17,000	46,000	10,000	7,600	0	34,000	0
	Screw 6 × 1−1/4	20,000	10,000	45,000	0	0	11,000	9,000	0	5,000
Planned inventory	11,900	4,400	24,900	14,900	3,900	50,800	24,800	19,800	9,800	1,800

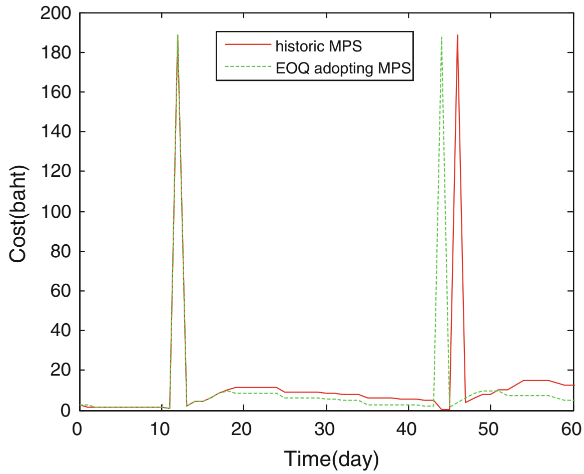


Fig. 2 Comparison of total costs between historic MPS and EOQ adopting MPS

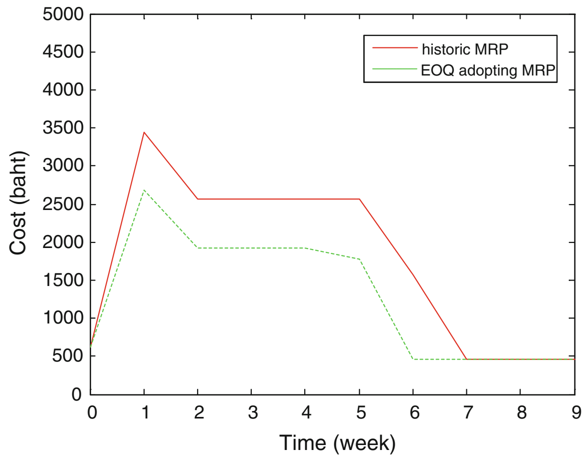


Fig. 3 Comparison of total costs between historic MRP and EOQ adopting MRP

in average. Similarly, the total cost for both historic MRP and EOQ adopting MRP of Hanger bolt $6 \times 40''$ in July–August can be generated and expressed as solid and dotted lines, respectively, as in Fig. 3. It is obvious from Fig. 3 that the total cost of EOQ adopting MRP is lower than that of historic MRP as well.

5 Conclusions

Economic order quantity (EOQ) which can balance setup cost and holding cost can be easily used in materials ordering and production scheduling especially when the adopting company is small. Many small companies may lend EOQ to improve their controls of PSCS. This study thus suggests such simple application of EOQ to company X in Thailand to gain the benefits of cost savings. In future work, other methods of dynamic lot sizing such as Silver-Meal Heuristic can be applied to compare with the EOQ method.

References

Biggs JR (1979) Heuristic lot-sizing and sequencing rules in a multistage production-inventory system. Decis Sci 10:96–115

Cárdenas-Barrón LE (2010) An easy method to derive EOQ and EPQ inventory models with backorders. Comput Math Appl 59:948–952

Choi S, Noble JS (2000) Determination of economic order quantities (EOQ) in an integrated material flow system. Int J Prod Res 38(14):3203–3226

Cargal JM (2003) The EOQ inventory formula. Math Sci, 1.31 edn

Lee Angela (1999) A study of production management (manufacture). Process Protocol II:1–14

Lee TS, Adamee EE, JR Ebert (1986) Forecasting error evaluation in material requirement planning (MRP) production-inventory systems. Manag Sci 32(9):1186–1205

Lee TS, Adam EE, Ebert JR (1987) An evaluation of forecast error in master pro duction scheduling for material requirements planning systems. Decis Sci 18:292–307

Liberatore MJ (1979) Using MRP and EOQ/safety stock for raw material inventory control: discussion and case study. Interfaces 9(2):1–6

Min W, Pheng L-S (2006) EOQ, JIT and fixed costs in the ready-mixed concrete industry. Int J Prod Econ 102:167–180

Taleizadeh AA, Widyadana AG, Wee HM, Biabani Jahangir (2011) Multi products single machine economic production quantity model with multiple batch size. Int J Ind Eng Comput 2:213–224

Steven N (2008) Production and operation analysis. 6th Revised edn

Silver EA, Peterson R (1985) Decision system for inventory management and production planning, 2nd edn. Wiley, New York

Wangner HM, Whitin TM (1958) Dynamic Version of the Economic Lot Size Model. Manage Sci 5:89–96

CUSUM Residual Charts for Monitoring Enterovirus Infections

Huifen Chen and Yu Chen

Abstract We consider the syndromic surveillance problem for enterovirus (EV) like cases. The data used in this study are the daily counts of EV-like cases sampled from the National Health Insurance Research Database in Taiwan. To apply the CUSUM procedure for syndromic surveillance, a regression model with time-series error-term is used. Our results show that the CUSUM chart is helpful to detect abnormal increases of the visit frequency.

Keywords CUSUM chart · Enterovirus syndrome · Regression analysis · Syndromic surveillance

1 Introduction

The two major epidemic peaks for enterovirus (EV) diseases in Taiwan occur in May to June and September to October yearly according to the historical statistics from Centers for Disease Control in Taiwan (Taiwan CDC). In 1998 the EV infection caused 78 deaths and 405 severe cases in Taiwan (Ho et al. 1999). Early detection of outbreaks is important for timely public health response to reduce morbidity and mortality. By early detecting the aberration of diseases, sanitarians can study or research into the causes of diseases as soon as possible and prevent the cost of the society and medical treatments. Traditional disease-reporting surveillance mechanisms might not detect outbreaks in their early stages because laboratory tests usually take long time to confirm diagnoses.

Syndromic surveillance was developed and used to detect the aberration of diseases early (Henning 2004). The syndromic surveillance mechanism is to

H. Chen (✉) · Y. Chen
Department of Industrial and Systems Engineering, Chung-Yuan University, Chungli, Taoyuan, Taiwan
e-mail: huifen@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_104,

collect the baseline data of prodromal phase symptoms and detect the aberration of diseases from the expected baseline by placing the variability of data from the expected baseline. Such surveillance methods include the SPC (statistical process control) based surveillance methods, scan methods and forecast-based surveillance methods (Tsui et al. 2008). See Sect. 2 for literature review.

In this work, we apply the CUSUM residual chart for detecting the abnormal increases of EV-like cases in Taiwan. Since the daily visits of the EV-like syndrome are time series data with seasonal effect, we use a regression model with an time-series error term to model the daily counts from ambulatory care clinic data. The residuals are then used for the CUSUM chart to detect unusual increase in daily visits. The test data are the 2003–2006 ambulatory care clinic data from the National Health Insurance Research Database (NHIRD) in Taiwan.

This paper is organized as follows. In Sect. 2, we review related literature. In Sect. 3, we summarize the data, propose a regression model whose error term follows an ARIMA model, and construct the CUSUM chart using the residuals. The conclusions are given in Sect. 4.

2 Literature Review

We review here the syndromic surveillance methods including the forecast-based, scan statistics, and SPC-based methods.

The forecast-based methods are useful to model non-stationary baseline data before monitoring methods can be applied. Two popular forecasting methods are time-series and regression models. Goldenberg et al. (2002) used the AR (Auto Regressive) model to forecast the over-the-counter medication sales of the anthrax and built the upper prediction interval to detect the outbreak. Reis and Mandl (2003) developed generalized models for expected emergence-department visit rates by fitting historical data with trimmed-mean seasonal models and then fitting the residuals with ARIMA models. Lai (2005) used three time series models (AR, a combination of growth curve fitting and ARMA error, and ARIMA) to detect the outbreak of the SARS in China.

Some works fitted the baseline data with a regression model first and then fitted the residuals with a time-series model because the baseline data may be affected by the day of the week and/or holiday factors. Miller et al. (2004) used the regression model with AR error to fit the influenzalike illness data in an ambulatory care network. The regression terms include weekend, holiday and seasonal adjustments (sine and cosine functions). Therefore, they used the standardized CUSUM chart of the residuals for detecting the outbreak. Fricker et al. (2008) applied the adaptive regression model with day-of-the-week effects using an 8-week sliding baseline and used the CUSUM chart of the adaptive regression residuals to compare with the Early Aberration Reporting System (EARS). They showed that the CUSUM chart applied to the residuals of adaptive regressions performs better than the EARS method for baseline data with day-of-the-week effects.

The scan statistics method is widely used in detecting the clustering of diseases. Scan statistics methods can be used in temporal, spatial and spatiotemporal surveillance. Heffernan et al. (2004) applied the scan statistic method to monitor respiratory, fever diarrhea and vomiting syndromes by the chief complaint data of the emergency department. They used this method in the citywide temporal and the spatial clustering surveillances. Han et al. (2010) compared CUSUM, EWMA and scan statistics for surveillance data following Poisson distributions. The results showed that CUSUM and EWMA charts outperformed the scan statistic method.

Recently the control charts have been applied in health-care and public-health surveillance (Woodall 2006). The SPC methods were first applied in the industrial statistical control (Montgomery 2005). Since the Shewhart chart is insensitive at detecting small shifts, CUSUM and exponentially weighted moving average (EWMA) charts are more commonly used in public health surveillance than the Shewhart chart. Hutwagner et al. (1997) developed a computer algorithm based the CUSUM chart to detect salmonella outbreaks by using the laboratory-based data. Morton et al. (2001) applied Shewhart, CUSUM and EWMA charts to detect and monitor the hospital-acquired infections. The result shows that Shewhart and EWMA work well for bacteremia and multiresistant organism rates surveillance and that CUSUM and Shewhart charts are suitable for monitoring surgical infection. Rogerson and Yamada (2004) applied a Poisson CUSUM chart to detect the lower respiratory tract infections for 287 census tracts simultaneously. Cowling et al. (2006) adopted the CUSUM chart with 7-week buffer interval for monitoring influenza data form Hong Kong and the United States and compared with time series and regression models. Woodall et al. (2008) show that the CUSUM chart approach is superior to the scan statistics.

3 Methods

3.1 Data Source

The data used in this study are the 2003–2006 daily counts (i.e. the number of daily visits) of EV-like cases for 160,000 people sampled from the National Health Insurance Research Database (NHIRD) by the Bureau of National Health Insurance, Taiwan. Patients' diagnoses in NHIRD were encoded using the ICD-9-CM (International Classification of Diseases, 9th Revision, Clinical Modification Reference) code. In this study, the ICD-9 codes of the EV-like syndrome are adopted from Wu et al. (2008) as listed in Appendix A.

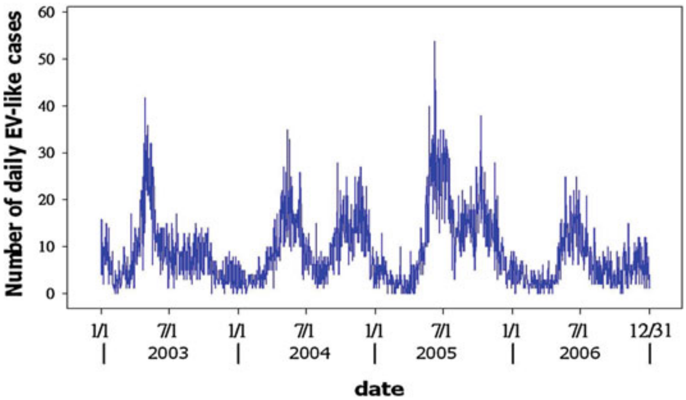


Fig. 1 The daily counts of the EV-like cases from 2003 to 2006

3.2 Data Summary

Here we summarize the daily counts of EV-like cases from 2003 to 2006 with population size 160,000. Figure 1, the run chart of the daily counts, shows that the daily counts are time-series data with seasonal variation. In general, the major epidemic peak occurs in May and June and a smaller peak occurs in September and October. Among the four years, the epidemic peaks are highest in 2005 and lowest in 2006. The day-of-the-week effect also exists. For the age effect, since more than 80 % of the EV-like cases are children younger than 6 years old, we do not consider the age effect in this study.

3.3 CUSUM Charts

Since the daily counts are time series data with seasonal variation, we use the regression model with an ARIMA error term to fit the daily counts of the EV-like cases. For normality, we first use the Box-Cox transformation to transform the daily counts data. The predictor variables are set based on the day-of-the-week, month-of-the-year, and trend effects.

The residuals calculated from the fitted regression model with an ARIMA error term can be used to construct an upper one-sided standardized CUSUM chart (Montgomery 2005) for detecting abnormal increases in daily counts of EV-like cases. Like Miller et al. (2004), we set the control limits so that the in-control average run length is 50.

To illustrate the surveillance method, we use the 2003 and 2004 daily counts data to fit a regression model and then use the 2005 data to construct CUSUM charts and forecasted values.

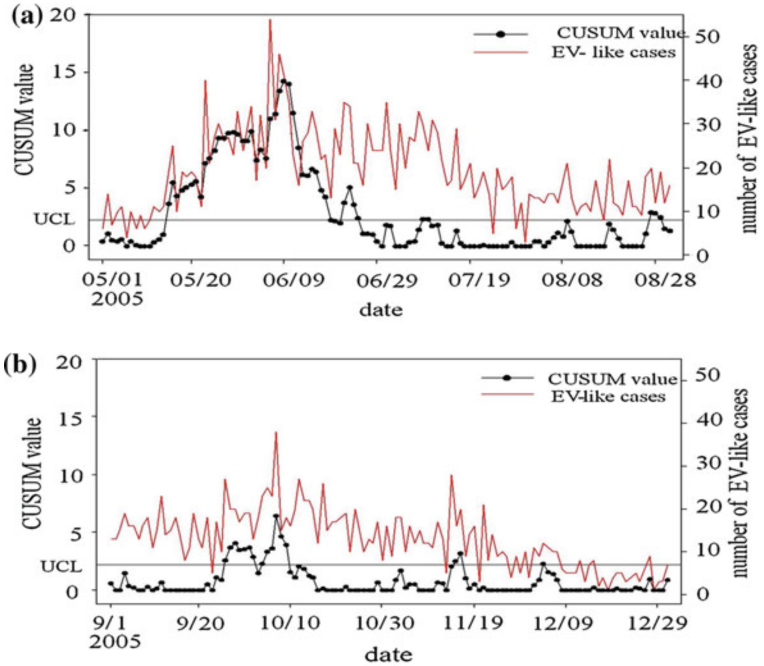


Fig. 2 The CUSUM chart for (**a**) May 1 to August 31 and (**b**) Sept. 1 to Dec. 31 in 2005

Figure 2 contain the upper one-sided standardized CUSUM charts for two periods—May 1 to August 31 in Subfigure (a) and September 1 to December 31 in Subfigure(b)—containing epidemic peaks in 2005. The number of EV-like cases and upper control limit (UCL) of the CUSUM chart are also shown. Figure 2 shows that the epidemic outbreak that occurred in May 2005 is detected quickly by the CUSUM chart. The smaller epidemic outbreak occurring at the end of September 2005 is also detected.

Using the fitted regression model, we can construct the l-steps-ahead forecast value. Figure 3 compares the 2005 actual daily numbers of EV-like cases with its forecasted values for the period (May 1 to December 31) including high seasons. The x-axis is the date and y-axis is the actual (black line)/forecasts (gray line) number of daily EV-like cases. Figure 3 shows that the difference is higher during the peak of infection than in the low season.

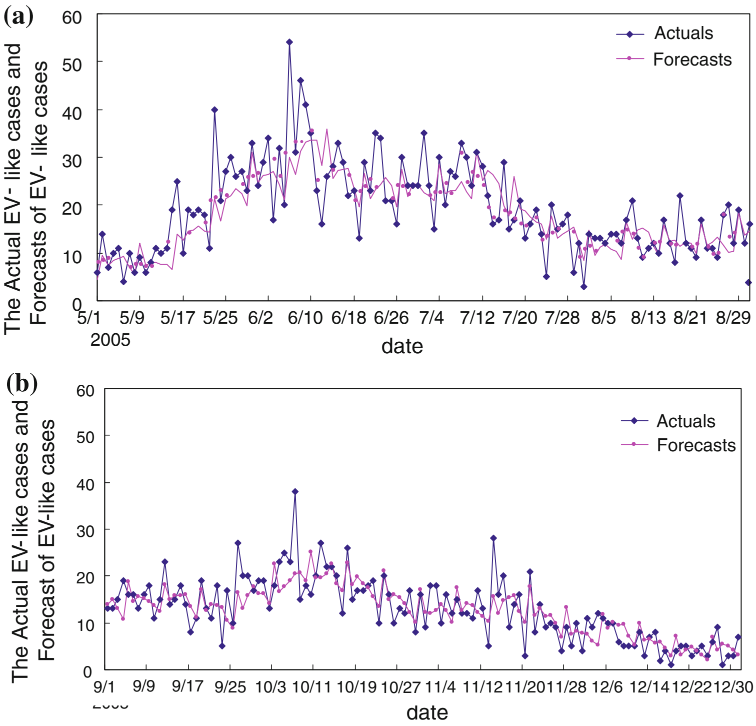


Fig. 3 The actual daily EV-like cases and its forecasts for year 2005: May 1 to Aug. 31 in Subfigure (**a**) and Sept. 1 to Dec. 31 in Subfigure (**b**)

4 Conclusions

This paper discusses the implementation of CUSUM residual charts for monitoring daily counts of EV-like cases. The population size is 160,000. Before using the CUSUM chart, we fit a regression model with an ARIMA error term to the daily counts data. The numerical results indicate that the CUSUM residual chart seems to work well in showing unusual increases in daily counts of EV-like cases.

Our fitted regression model is based on historical data of the past two years. The time window can be longer so that more data can be used for model fitting. The shortage though is that the coefficient estimates would have larger variance and hence the prediction interval would be wider. Furthermore, the behavior of daily counts may not be the same each year, using historical data occurring long ago may hurt the prediction accuracy for the future observations.

Acknowledgments This study is based in part on data from the National Health Insurance Research Database provided by the Bureau of National Health Insurance, Department of Health and managed by National Health Research Institutes. The interpretation and conclusions contained herein do not represent those of Bureau of National Health Insurance, Department of Health or National Health Research Institutes in Taiwan.

Appendix A: The ICD-9-CM code of EV-like syndrome

In this study, we adopt the EV-like syndrome definitions from Wu et al. (2008). The ICD-9 codes are listed below.

ICD9	Description
074	Specific diseases due to Coxsackie virus
079.2	Coxsackie virus: infection NOS
047.0	Coxsackie virus: meningitis
074.0	Herpangina Vesicular pharyngitis
074.1	Epidemic pleurodynia, Bornholm disease, Devil's grip; Epidemic: myalgia, myositis
074.2	Coxsackie carditis
074.20	Coxsackie carditis unspecified
074.21	Coxsackie pericarditis
074.22	Coxsackoe endocarditis
074.23	Coxsackie myocarditis, Aseptic myocarditis of newborn
074.3	Hand, foot, and mouth disease Vesicular stomatitis and exanthem
074.8	Other specified diseases due to Coxsackie virus, Acute lymphonodular pharyngitis

References

Cowling BJ, Wong IOL, Ho L-M, Riley S, Leung GM (2006) Methods for monitoring influenza surveillance data. Int J Epidemiol 35:1314–1321

Fricker RD Jr, Hegler BL, Dunfee DA (2008) Comparing syndromic surveillance detection methods: EARS' versus a CUSUM-based methodology. Stat Med 27:3407–3429

Goldenberg A, Shmueli G, Caruana RA, Fienberg SE (2002) Early statistical detection of anthrax outbreaks by tracking over-the-counter medication sales. Proc Natl Acad Sci USA 99:5237–5240

Han SW, Tsui K-L, Ariyajunya B, Kim SB (2010) A comparison of CUSUM, EWMA, and temporal scan statistics for detection of increases in Poisson rates. Qual Reliab Eng Int 26:279–289

Heffernan R, Mostashari F, Das D, Karpati A, Kulldorff M, Weiss D (2004) Syndromic surveillance in public health practice, New York City. Emerg Infect Dis 10:858–864

Henning KJ (2004) What is syndromic surveillance? Morb Morality Wkly Rep 53(Supplement):7–11

Ho M, Chen ER, Hsu KH (1999) An epidemic of enterovirus 71 infection in Taiwan. Medicine 341:929–935

Hutwagner LC, Maloney EK, Bean NH, Slutsker L, Martin SM (1997) Using laboratory-based surveillance data for prevention: an algorithm for detecting Salmonella outbreaks. Emerg Infect Dis 3:395–400

Lai D (2005) Monitoring the SARS epidemic in China: a time series analysis. J Data Sci 3:279–293

Miller B, Kassenborg H, Dunsmuir W, Griffith J, Hadidi M, Nordin JD, Danila R (2004) Syndromic surveillance for influenzalike illness in an ambulatory care network. Emerg Infect Dis 10:1806–1811

Montgomery DC (2005) Introduction to statistical quality control, 5th edn. Wiley, New York
Morton AP, Whitby M, Mclaws M, Dobson A, Mcelwain S, Looke D, Stackelroth J, Sartor A (2001) The application of statistical process control charts to the detection and monitoring of hospital-acquired infections. J Qual Clin Pract 21:112–117
Reis B, Mandl KD (2003) Time series modeling for syndromic surveillance. BMC Med Inform Decis Mak 3:2
Rogerson PA, Yamada I (2004) Approaches to syndromic surveillance when data consist of small regional counts. Morb Morality Wkly Rep 53:79–85
Tsui K-L, Chiu W, Gierlich P, Goldsman D, Liu X, Maschek T (2008) A review of healthcare, public health, and syndromic surveillance. Qual Eng 20:435–450
Woodall WH (2006) The use of control charts in health-care and public-health surveillance. J Qual Technol 38:89–104
Woodall WH, Marshall JB, Joner MD Jr, Fraker SE, Abdel-Salam A-SG (2008) On the use and evaluation of prospective scan methods for health-related surveillance. J R Statist Soc A 171(1):223–237
Wu TSJ, Shih FYF, Yen MY, Wu JSJ, Lu SW, Chang KCM, Hsiung C, Chou JH, Chu YT, Chang H, Chiu CH, Tsui FCR, Wagner MM, Su IJ, King CC (2008) Establishing a nationwide emergency department-based syndromic surveillance system for better public health responses in Taiwan. BMC Public Health 8:18

A Study on the Operation Model of the R&D Center for the Man-Made Fiber Processing Industry Headquarter

Ming-Kuen Chen, Shiue-Lung Yang and Tsu-Yi Hung

Abstract The global strategy layout for the activities of R&D is naturally the important decision making for the survival and competition of business entities in Taiwan. Based on these background and motives, this research aims to investigate and construct the reference models for the operation of R&D center within the business headquarters and we also focus our effort onto the textile sub-industry—Man-made fiber processing industry. This research is adopted with IDEF0 for processing analysis and model construction methodology. During the construction, the processes associated with the R&D center within business headquarters is constructed via literature survey and practical expert interview. By means of the factor analysis, we can extract the key items of ICOM (Input, Control, Output, Mechanism) from the activities related to the R&D processes. This research result will be meant to depict the overall profile for the operation of R&D centers from the textile industries. Hopefully, we can offer the reference basis for the planning phase of business headquarter R&D center so that the planning can thoroughly meet the demand of business strategy execution and management characteristics.

Keywords Business Headquarter · R&D Center · Factor Analysis · IDEF0

M.-K. Chen (✉) · T.-Y. Hung
Graduate Institute of Services and Technology Management, National Taipei University of Technology, Taipei, Taiwan
e-mail: mkchen@ntut.edu.tw

T.-Y. Hung
e-mail: tyhung@ntut.edu.tw

S.-L. Yang
Department of Management Information Systems, National Chengchi University, Taipei, Taiwan

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_105,

1 Introduction

This research is aimed to investigate and construct the reference models for the R&D centers of business headquarters. In overview of the past research about business headquarters (Ghoshal 1997; Kono 1999; Young 1998), most research efforts are spent onto the major advanced nations located in USA, Europe and Japan for the internal management operation investigation of the local business entities. This is unavailable to offer the effective aid to plan the strategy and operation of business headquarter.

The structure of this paper is as follows. Firstly, we make the systematic arrangement for the literature review. Next, the IDEF0 is meant for the methodology of process analysis and model construction. Thirdly, the questionnaires are used for further researching with the respondents mainly from managerial levels and R&D staffs from the textile sub-industries—the Man-made Fiber Processing Industry. Finally, by using the factor analysis, we can extract the key items of ICOM (Input, Control, Output, Mechanism) from the activities related to the R&D processes.

2 Literature Review

2.1 Business Headquarter

Ghoshal (1997) proposed that the current business globalization seems to be an inevitable issue for the multinational business entities. Birkinshaw et al. (2000) suggested that the task for business headquarters is not only intended to ensure the future development and growth of business but also add the values of business. Thus, Young (1998) supposed that within the process for business globalization, how to create a powerful business headquarter for the effective management and control over the overseas branching offices has become the critical factor for successful business management. Kono (1999) supposed the business headquarter must consist of below three functions: business strategy projection, clearly creating the professional management department, developing the business core competence, and providing central service with the available affairs. Goold et al. (2001) revealed that a wholesome and powerful business head quarter must experience with three stages for execution: the role playing to act as the most minor headquarter, the role for value creation and service share. Regarding the management strategies of business management headquarters, Desouza and Evaristo (2003) had proposed three strategies available for business headquarters: the business headquarter centrally unify the commands and executions; the business headquarter can command the regional units for execution; and the regional units can further command the subordinated districts for execution.

To sum up, the business head quarter is exactly the business center for the decision making of globalization and the operation base for value creation. It is well performing its diversified functions and outstretches the global strongholds for logistic management so that it is available for business entities to create much more values.

2.2 The Globalization Management for R&D

Pearce (2003) revealed that the investment for overseas R&D is functioned to execute the company strategies and the relevant efforts shall be paid during the posterior stage of product life cycle by accompanying with exodus of production lines together. Dunning (1992) supposed when the multinational company is outstretching its R&D activities to offshore areas, it will naturally bring with the ownership advantage edging over its competitors with much more favorable trends to keep or enhance its own competence. Kuemmerle (1997) used to classify the overseas R&D strongholds as: the Home-Base-Augmenting Site and the Home-Base-Exploiting Site. Ronstadt (1978) classified the R&D units into three types: Support Laboratory (SLs), Locally Integrated Laboratories (LILs), and Internationally Inter-dependent Laboratories (IILs). Bartlett and Ghoshal (1995) classified the R&D activities according to the locations of R&D and globalization with the regional correlation as below: R&D Center, Local R&D and Local R&D and Multi-national Application and Globally Linked R&D Centers.

Within the issue of R&D globalization management, Gassmann and Zedtwitz (1999) proposed five strategies for R&D globalization: ethnocentric centralized R&D, geocentric centralized R&D, R&D centralized R&D, polycentric decentralized R&D and integrated R&D network.

3 The Globalization Management for R&D of Man-Made Fiber Processing Industry

3.1 The Design of Business Headquarter

Based on the proposals of (Goold et al. 2001; Kono 1999) for researching, we have developed the orientation for this research. The structures of R&D centers and processes are mainly based on the proposals of Cooper and Kleinschmidt (1997) to create the R&D processes and structures suitable for man-made fiber processing industries. We also adopt the proposal from Gassmann and Zedtwitz (1999) for R&D globalization management models to use as reference so that we can understand the types and models suitable for man-made fiber processing industries and also realize the interaction between R&D center and other functional centers during different stages. How to effectively integrate global units and quickly response to the regional demands for best balance is exactly the ultimate pursuit for headquarter. This research is proposed by referring to the works of (Goold et al. 2001; Kono 1999). The management centers included within the business headquarter is divided into two modules of basic function and value creation. The contents related to each module are: (1) Basic Function Module: It is mainly aimed to keep the basic functions and activities inevitable for the normal operation of business such as Financial Management Center, Human Resource Management Center. (2) Value Creation Module: This module contains of the creation and execution of organizational strategy, the relevant activities about development of core competence, etc.: (a) Proprietary Management Center; (b) R&D Management Center; (c) Marketing Management Center; (d) Production Center; (e) Procurement Center.

3.2 The Design for the R&D Center Within Man-Made Fiber Processing Industries

This research is amassed with the research results from (Bartlett and Ghoshal 1995; Cooper and Kleinschmidt 1997; Dhillon 1985; Kuemmerle 1997; Marquis and Myers 2004; Ronstadt 1978). We propose that the flow chart models for man-made fiber processing industries' R&D can be divided into 5 stages of operational processes: (1) Commodity Projection Stage; (2) Design Test & Projection Stage; (3) Mass Production Stage; (4) Marketability Stage; (5) The Resource Output during Processing Stages.

3.3 Questionnaire Sample Design

Within the first part of questionnaires, it is combined with the business headquarter functional structures mentioned by Sect. 3.2 within this research and the product development processes. We also design the questionnaire contents with the purpose to investigate the interaction for each center ruled by business headquarters for the product development processes within the man-made fiber processing industries. The questionnaire option contents consist of three levels of response: high involvement, general involvement and no involvement. The responding results of this part can be used as the basic reference for IDEF0 structure models and the design contents and results of questionnaires are shown as Table 1.

In the descriptive statistics, [★] means the highest identification degree from a single operation. Namely, the center within the corresponding operation will naturally come with the absolute predomination right. ★ means the identification degree above 70 %. ● means the identification degree between 69 and 60 %. By using this result, we can combine the conclusions from the 2nd part of questionnaires and

Table 1 The interaction for the R&D processes of man-made fiber industries

Process item	Tasking activity	Business head quarter					Each region	
		Financial center	Marketing center	Procurement center	R&D Design center	Production center	R&D units	Production units
Commodity projection stage	Fiders market trend analysis	★	[★]		★			
	Regional innovation creation & selection		[★]		●		●	
	Facilities/know-how feasibility analysis		●		[★]	●		
	Competitor analysis		[★]		●			
	Financial/costs evaluation	[★]	●		★			
	Environmental protection regulation		●	●	[★]		●	●
	Proposing the new product strategy		[★]		★			
	Ensure the market target—global market		[★]		●			
Design test & projection stage	Development concept and projects		[★]	●	●			
	Choices main suppliers and sub-suppliers	●	★	●	★	●		
	Physical analysis and design		●		[★]	●	★	
	Production process programming			●	[★]	★	●	
	Silk sampling				★	●	●	●
	Verification and quality examination				[★]	●	●	
	Definition for QC processes				[★]	★	●	
Mass production stage	Composed of production system design for manufacturing centers				●	[★]	●	
	Small quantities of marketing and trial sales		[★]		●	★	●	●
	Feedback and revision projects		★		★	●		
	Improvement for manufacturing processes				[★]	★	●	●
	Production evaluation (time, capacity, predict prices, cost)		●		★	★	●	
	Normal mass production				★	[★]	●	●
	Technique transfer				[★]	★	●	●

(continued)

Table 1 (continued)

Process item	Tasking activity	Business head quarter					Each region	
		Financial center	Marketing center	Procurement center	R&D Design center	Production center	R&D units	Production units
Commodity marketability stage	Commodity introduction of processing silk (global or regional markets)		★		★			
	Market and customer complaint response (global or regional markets)		★		●		●	
	Sales feedback analysis		★		★		●	●
	The production improvement for processing silk, function correction and the functional development	●	★		[★]	★		
Waste output processing stage	Record of waste output of all stages and analysis				★	●		
	Feedback to research procedure			●	[★]	●		
	Amends the textile specification and alternative project selection		●	●	★		●	

construct the operation model for the R&D center of fiber weaving industries by IDEF0 with the detailed analysis shown in Table 1.

From Table 1, we find that within the commodity projection stage of man-made fiber processing industries, the marketing center is responsible to audit the budget regulation for local and overseas strongholds form conglomerate members and the filtering for marketing strategies. The remaining operations are all under the duty of marketing centers within the projection and execution. Within the design test and projection stages, the R&D center is authorized with the leadership of technology and R&D activities. The main operation items are naturally focused on initial sample trial production and cloth applicability. Except the projection for global (regional) marketing strategies, the remaining operations are all under the control of R&D center for projection and execution. Within the mass production stage, the marketing center, after the completeness of small-quantity trial production, will send the fiber samples to customers for trial sales. After receiving the responses from the result analysis of trial sales and customer complaints, the R&D center must modify and correct the product design by focusing on the analysis results and customer complaints till the company finally receives the confirmed orders from customers. The production system design will be transferred to the regional R&D units. The regional production unit will finish the trial production of small quantities and trail sales, feedback and correction review, improvement for QC process, production timing, capability, price forecast, cost evaluation and the finalized mass production. Within the commodity marketability stage, the R&D center controls the operations like information analysis and design correction with the purposes partially for increasing the market acceptability of current products and partially for the new development reference in preparation for the next stage. Within the waste processing stage, the regional production center will lead the relevant operations for removal, recycle and R&D feedback. As in the production for large quantities, the production center will cause much major (cloth) and minor (labeling/packing materials) material residue. It is naturally required for further improvement on production patterns, mark design, and the re-design for material consumption structure so that the factory can fulfill its responsibility and give positive feedback to the social public.

4 The Analysis of the R&D Center at a Business Headquarter

4.1 Sample Analysis

There were 35 sets of valid samples collected. This research data was collected through on face-to-face interview and telephone interviews. We mainly adopted with the factor analysis to extract the ICOM key items from each R&D process with the results shown as Table 2. Within the questionnaire, we investigate the

Table 2 Sample analysis

Product development stage	Input/Output/Control item		The variance value of variables (%)
Commodity projection stage	Input item	Specifications development proposal	41.378
		Budget allocation project	26.643
	Control item	Equipment/Capacity analysis report	36.321
		The environmental protection codes from various national governments	33.694
	Output item	Projects	71.239
Design test &projection stage	Input item	Technology & production process improvement report	34.548
		Material testing report	28.962
	Control item	Capital demand & risk evaluation	73.621
	Output item	Physical analysis & technique transfer specifications	35.256
		Laboratory examination reports	29.592
Mass production stage	Input item	Alternative material report	46.266
		Regional production & sales coordination plan	30.289
	Control item	Texturing machine operation specifications	71.23
	Output item	Production layout & parameter setting for production process	45.533
		Production efficiency & product reliability analysis table	27.872
Commodity marketability stage	Input item	Marketing Tactic and Trademark patent proposal	64.419
	Control item	The environmental protection codes from various national governments	65.678
	Output item	Regional production & sales coordination plan	37.143
		Design alternation measures	29.363

55 question items by means of Principal Components Analysis so that we extract the factor dimensions for each product development stage.

Within the product projection stage, there are totally 5 variables included within the Input Items, 3 variables within Control Items and 6 variables within Output Items. Within the design test and projection stage, the Input Items totally include 3 variables. Control Items consist of 5 variables and the Output Items include 7 variables. Within the mass production stage, there 4 variables included within Input Items, 3 variables within Control Items and 8 variables within Output Items. Within the commodity marketability stage, there are 3 variables included within Input Items, 3 variables within Control Items, and 5 variables within Output Items. Within the waste output stage, there are 2 variables for each item. Thus, within the data analysis, each variable is viewed as the key item.

4.2 The Operation Modes of the R&D Center

The interview questionnaire analysis is extracted from the items such as input, output and control variable during the product developing procedures. It also accounts the interactions between the headquarter and its regional units during the new product R&D stages (cf. Table 1) by adopting the IDEF0 flow models to establish the reference models for the R&D center of the man-made fiber processing headquarter.

5 Conclusions

The results of this research depict the overall operation profile for R&D and design centers of man-made fiber processing industries. This study is adopted with IDEF0 for processing analysis and model construction kits. The industries of artificial fiber especially emphasize the R&D of basic and applicable operations. Under the product projecting stages, it is required to integrate the information from various markets and thus to create the proposals for product development. However, the operation of plausibility evaluation is vital for manufacturing facilities.

This article focuses on various industrial aspects to insightfully know about the operation contents of strategic projections and each function centers when the business entities are engaging in projection. It is available to use other analysis kits to demonstrate the operational reference models of each function center at a business headquarter to subsequently work as the future research orientation.

References

Bartlett CH, Ghoshal S (1995) Building the entrepreneurial corporation: new organizational processes, new managerial tasks. Eur Manag J 13(2):139–155
Birkinshaw J, Thilenius P, Arvidsson N (2000) Consequences of perception gaps in the headquarters—subsidiary relationship. Int Bus Rev 9(3):321–344
Cooper RG, Kleinschmidt EJ (1997) Winning businesses in product development: the critical success factors. Res Technolo Manag 39(4):18–29
Desouza K, Evaristo R (2003) Global knowledge management strategies. Eur Manag J 21(1):62–67
Dhillon BS (1985) Quality control, reliability, and engineering design. Marcel Dekker, New York
Dunning J (1992) Multinational enterprises and the globalization of innovatory capacity. Wiley Chichester
Gassmann O, Zedtwitz M (1999) New concepts and trends in international R&D organization. Res Pol 28(2–3):231–250
Ghoshal S (1997) The individualized corporation: an interview with Sumantra Ghoshal. Eur Manag J 15(6):625–632
Goold M, Pettifer D, Young D (2001) Redesigning the corporate centre. Eur Manag J 19(1):83–91
Kono T (1999) A strong head office makes a strong company. Long Plann 32(2):225–236
Kuemmerle W (1997) Building effective R&D capabilities Abroad. Harv Bus Rev 75(2):61–71
Marquis RG, Myers S (2004) NEC Folds Japan R&D Activities into Two Units. Elect Eng 6
Pearce R (2003) Industrial research institute's 5th annual R& D leaderboard. Res Technolo Manag 46(6):157–178
Ronstadt RC (1978) International R&D: the establishment and evolution of R&D abroad by seven US multinationals. J Int Bus Stud 9(1):7–24
Young JD (1998) Benchmarking corporate headquarters. Long Plann 31(6):933–936

Planning Logistics by Algorithm with VRPTWBD for Rice Distribution: A Case BULOG Agency in the Nganjuk District Indonesia

Kung-Jeng Wang, Farikhah Farkhani and I. Nyoman Pujawan

Abstract This paper addresses a vehicle routing problem with time windows encountered in BULOG (Government National Agency) specialized for distribution of rice with subsidy by government in Nganjuk East Java. It concern the delivery of rice with subsidy from central BULOG to home family that have been chosen by government as poor family in Nganjuk, delivery from central to warehouse, and from warehouse to government district also from district to village (the poor family target living). The problem can be considered as a special vehicle routing problem with time windows, with bender's decomposition as solver to minimize the total cost of distribution with still consider about time delivery and total of vehicle used. Each village is visited by more than one vehicle at one time delivery. Two mixed-integer programming models are proposed. We then proposed a Genetics Algorithm (GA) and exact method of VRPTWBD, and these approaches are tested with compare the result from four experiments with real data from BULOG, such as: Exact VRPTW, exact VRPTW-BD, Naïve GA, and Genetics Algorithm-BD.

Keywords BULOG · Vehicle routing problem · Time windows · Bender decomposition

K.-J. Wang (✉) · F. Farkhani
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: kjwang@mail.ntust.edu.tw

F. Farkhani
e-mail: farikhah.farkhani@gmail.com

F. Farkhani · I. N. Pujawan
Department of Industrial Engineering, Institute Technology of Sepuluh Nopember, Surabaya, East Java, Indonesia
e-mail: pujawan@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_106,

1 Introduction

Poverty in Indonesia is very complex; an increasing number of poor people can go up very sharply at a time of the economic crisis in Indonesia. The numbers of poor peoples in the city are generally lower than the number of poor people who live in the village. Therefore, Indonesia's government made policies to build the institutions main food subsidies; it is rice institutions of rice for rural areas known with the name of BULOG (National Agency of rice distribution).

There are many various constraints and problems faced by BULOG, including (1) There is no planning in the distribution process to balance with the existing resources (example: vehicle, driver) by demand changes every year due to increase the number of poor families. Now currently planning done by manual method which estimates individual leadership responsible for the delivery of the goods, so this is based on willingness. (2) There is delay occurs time during the process of delivery of rice to villages destination, as well as trucks are sent late back to the warehouse because there is no supervision tight. (3) There is a variety of criminal acts during trip distribution shipments of rice because there is no checking the amount of rice being sent, for example (a) A rice is not sent to the target, that poor family. But, lost by someone that not take a responsibility when delivery shipments, (b) there's some rice sold by illegal activity with high price to other people, or the targeted people should pay more that subsidy price to the shipper, (c) the distribution of rice was not evenly distributed across the target the targeted villages, still there is some poor families that include in the data of government did not get the subsidy of rice because of delivery shipment system.

Nganjuk is a district which in 2012 had a high crime rate for subsidized shipping problems to the area that has been determined, it is because the district Nganjuk very difficult to access reach because it is located in the mountainous region and there is no public transportation that can be used as a transport facility for distribute subsidized rice to stricken remote villages. And the government statistic report in 2012, Nganjuk is a top three of highest total of poor families in East Java.

In this research we try to solve the BULOG problems, with the real data from BULOG we can try to solve this case with Vehicle routing problem with time windows algorithm approach, and use upper and lower bound by bender's decomposition to more specific calculate the minimum cost not only taken by distance, the vehicle, the driver, but also the total demand that sub district region should pay on it with subsidy price. We use the Genetic Algorithm to solve the problem, and improve the Genetic Algorithm with Bender's Decomposition.

2 Solution Methodology

In this paper we use VRPTW approach (Toth and Vigo 2002) to solve BULOG case and especially for cost we use Bender's Decomposition to minimize the total cost of distribution (Van Roy 1986), and for solution method we use Genetic Algorithm compute the results.

2.1 Permutation Coding

Candidate selections of objects for the VRPTW can be represented by permutations of integers that represent the objects. A decoder scans the objects in their order in a permutation and places in the VRPTW every object that fits. The sum of the included objects' individual and joint values is the permutation's fitness. A mutation operator independently swaps values at random positions in a chromosome; the maximum number of swaps is a parameter of the operator. Crossover is alternation (Larranaga et al. 1999), which interleaves two parent permutations, preserving only the first appearance of each integer.

2.2 Heuristics Steps

Heuristic initialization seeds the GA's population with one chromosome generated by placing a random object in the VRPTW, then repeatedly appending to the permutation the object the VRPTW can accommodate that has the largest value density relative to the objects already chosen.

Similarly, *heuristic alternation* builds one offspring from two parents, beginning with the first object in the first parent. It the repeatedly examines the next unexamined objects in both parents. If only one fits, it joins the offspring. If neither fits, neither joins the offspring. If both fit, the next one to join the offspring is the object with the larger value density relative to the objects already listed in the offspring. In both operations, when the VRPTW can accommodate no more objects, the chromosome is completed by listing the unused objects in random order.

2.3 Genetics Algorithm Procedure

Genetic algorithms are inspired by Darwin's theory about evolution. Solution to a problem solved by genetic algorithms is evolved. Algorithm is started with a set of solutions (represented by chromosomes) called population. Solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one. Solutions which are selected to form new solutions (offspring) are selected according to their fitness—the more suitable they are the more chances they have to reproduce.

The genetic algorithm proposed in this paper combines the following features: a permutation chromosome, exact fitness computation by splitting, improvement by local search, diversity of the population and multi-start with partially replaced population. These ingredients for designing efficient GA for vehicle-routing like problems.

In this paper, the chromosome is a permutation of all villages that give order of visits in different routes. An exact split algorithm will be presented to split the permutation into sub-strings of village to be visited by a vehicle and the vehicle return to warehouse then BULOG.

Algorithm 1: the Genetics Algorithm used

1. Generate an initial population Ω of chromosomes

Main GA exploration phase

2. Select two parents P1 and P2 roulette wheel selection;
3. Crossover (P_1, P_2);
4. Evaluate the two resulting children by Splitting;
5. Repeat 2–4 if no child is feasible. Otherwise, select randomly a feasible child C;
6. Improve C by Local Search, with probability P_m;
7. Insert C in Ω to replace a randomly selected individual among the half worst of Ω, if C is not the current worst and C has a distinct fitness value than those in Ω;
8. Repeat 2–7 for N_1 iterations or till N_2 iterations without improving the current best;

End of the main GA phase

9. Restart the main GA phase 2–8 with a partially replaced population, for N_3 phases or till N_4 phases without improving the best solution

The overall structure of the GA is illustrated in Algorithm 1. It starts with the generation of an initial population with insertion of good heuristic solutions to be presented. The central part of our GA is an incremental GA exploration phase in which only one chromosome is replaced at each iteration. It starts with the selection of two parents by roulette wheel selection.

Then the next step is applied to generate two child chromosomes. These child chromosomes are evaluated by the exact split algorithm. The selection and crossover operations are repeated till obtaining a feasible child chromosome, i.e. a chromosome for which a feasible split solution exists. With some probability, this feasible child chromosome is further improved by Local Search to be presented. The new child chromosome is inserted in the current population under two conditions: (1) it is better than the current worst and (2) it does not have identical fitness as an existing chromosome.

It has been proven that perverting the diversity of GA population can diminish the risk of premature convergence (Sorensen and Sevaux 2006). A simple and stricter rule is imposed in this paper to keep the diversity of the population, i.e. the fitness of any two feasible chromosomes must be different. For this reason, a child chromosome *C* is inserted during each main GA phase only if it has a different fitness than existing individuals. Diversity is also checked in the generation of the initial population and the partially replaced population for restart.

The remaining of this Section is devoted the detailed presentation of the fitness evaluation, generation of initial solutions, and local search.

Lai et al. (2010) introduced a hybrid Benders/Genetic algorithm which is a variation of Benders' algorithm that uses a genetic algorithm to obtain "good" sub problem solutions to the master problem. Lai and Sohn (2011) conducted a study applying the hybrid Benders/Genetic algorithm to the vehicle routing problem. Below is a detailed description of the algorithm.

Step 1. Initialization. We initialize the iteration counter k to zero, select initial trial values for the vector of binary variables Y which selects the plants to be opened.

Step 2. Primal Subsystem. We evaluate the value of v(Y) by solving a transportation linear programming problem whose feasible region is independent of Y.

Step 3. Generation of Benders'Cut. We compute a new linear support using the dual solution of the transportation sub problem and increment k by 1.

Step 4. Primal Master system by GA. A trial location plan Y is to be computed by implementing a GA whose solution delivers both a feasible investment plan and a lower bound to the minimal cost for the equivalent program.

- 4a Initialization. We initialize the variable Y as a string of binary bit with the position #i corresponding to the plant #i. We generate initial population and their fitness functions are evaluated as well.
- 4b Genetic Operations. We perform a standard single-point crossover approach. The mutation operation to guarantee the diversity of the population is performed as well. The current population is replaced by the new population through the incremental replacement method.
- 4c Termination. We terminate the GA if no improvement within 100 iterations. The traditional method branch and bound, which were used in the master problem. It will search the solution space in parallel fashion and take advantage of the "easy" evaluation of the fitness function.

3 Computational Result

In this section we present the result of computational experiments for BULOG case with VRPTW BD and Genetics algorithm BD algorithm described in previous section. The proposed method algorithm is coded in Java NetBeans IDE 7.3 on a laptop with Intel(R) Core(TM) i5-3210M CPU @ 2.50 GHz 2.50 GHz, RAM 8.00 GB with System type, x64-based processor, under the windows 8 operating system.

Table 1 Computational result of exact VRPTW—Bender's decomposition

Number of chromosome = 100

Single case different number of iteration	Exact VRPTW—Bender's Decomposition				
	Total time delivery	Number of truck	Total cost	% found	CPU (seconds)
500	3,944 min	256	IDR 11,157,595,500.00	10.37 %	5
600	3,893 min	256	IDR 11,157,519,000.00	10.34 %	6
700	3,887 min	256	IDR 11,157,510,000.00	10.30 %	7
800	3,884 min	256	IDR 11,157,505,500.00	9.97 %	8
900	3,881 min	256	IDR 11,157,501,000.00	9.83 %	10
1,000	3,878 min	256	IDR 11,157,496,500.00	9.80 %	11
…	…	…	…	…	…
3,500	3,767 min	256	IDR 11,157,307,500.00	9.19 %	37
4,000	3,752 min	256	IDR 11,157,307,500.00	9.18 %	43
6,000	…	…	…	…	…
6,080	OOM	OOM	OOM	OOM	OOM

3.1 Parameter Selection

Parameter selection may influence the quality of the computational results. Thus, an extensive computational testing was performed to determine the appropriate value of experimental parameters. The following parameter as follows;

C 20, 40, 60, 80, 100
I 100, 200, 300, 400, 500, 600, . . ., 6100

where, C is a total generate of chromosome and I as number of iteration, and the results indicate that the best parameters C is 100 and I is 4,000 total generate of chromosome.

3.2 Results of Computation

This is the results of computation by coded, and in this section OOM means "Out of Memory", the complete results as follow.

3.2.1 Exact Method

See Table 1.

3.2.2 Meta-Heuristics

See Table 2.

4 Conclusions

We have demonstrated that VRPTW and Benders' decomposition algorithm for solving the BULOG case by Genetic Algorithm method can be accelerated substantially when the master problem is solved. The Benders/GA algorithm is a variation of Benders' algorithm in which, instead of using a costly branch-and-bound method, a genetic algorithm is used to obtain "good" sub problem solutions to the master problem. The computational result by Java shows that the algorithm is effective to solve the BULOG case. The results imply that the algorithm is much more practical when only near-optimal solutions are required. Future work could extend the proposed algorithm to other location problems.

Table 2 Computational result of genetic algorithm—Bender's decomposition

Number of chromosome = 100

Single case different number of iteration	Genetic algorithm—Bender's decomposition				
	Total time delivery	Number of truck	Total cost	% found	CPU (seconds)
500	3,845 min	256	IDR 11,157,600,000.00	10.11 %	8
600	3,863 min	256	IDR 11,157,751,500.00	10.14 %	10
700	3,848 min	256	IDR 11,157,947,000.00	10.08 %	14
800	3,836 min	256	IDR 11,158,133,500.00	9.98 %	15
900	3,830 min	256	IDR 11,158,224,500.00	9.93 %	17
1,000	3,824 min	256	IDR 11,158,315,500.00	9.75 %	17
…	…	…	…	…	…
5,000	3,719 min	256	IDR 11,160,998,000.00	9.13 %	92
5,500	3,695 min	256	IDR 11,161,022,000.00	9.13 %	102
6,000	3,689 min	256	IDR 11,161,513,000.00	9.13 %	111
6,080	OOM	OOM	OOM	OOM	OOM

Acknowledgments This work is partially supported by Prof Kung Jeng-Wang as the advisor; the authors would like to thank anonymous reviewers for their detailed and constructive comments that help us to increase the quality of this work.

References

Lai M, Sohn H (2011) A hybrid algorithm for vehicle routing problems. working paper

Lai M, Sohn H, Tseng T, Chiang C (2010) A hybrid algorithm for capacitated plant location problems. Expert Syst Appl 37:8599–8605

Larranaga P, Kuijpers CMH, Murga RH, Inza I, Dizdarevic S (1999) Genetic algorithms for the traveling salesman problem: a review of representations and operators. Artificial Int Rev 13:129–170

Sörensen K, Sevaux M (2006) MAPM: Memetic algorithms with population management. Comput Oper Res 33:1214–1225

Toth P, Vigo D (2002) The vehicle routing problem. SIAM monographs on discrete mathematics and applications, Philadelphia

Van Roy TJ (1986) A cross decomposition algorithm for capacitated facility location. Oper Res 34:145–163

A Systematic and Innovative Approach to Universal Design Based on TRIZ Theories

Chun-Ming Yang, Ching-Han Kao, Thu-Hua Liu, Hsin-Chun Pei and Yan-Lin Lee

Abstract Continual expansion of the population and its diversity has increased the demand for products that take into account the elements of universal design. Universal design has been widely studied; however, a lack of all-encompassing systematic design processes makes it difficult for designers and engineers to transform universal design intent into product realization. This paper proposes a systematic approach to UD based on TRIZ theories. We begin with a UD assessment to identify design problems, followed by a PDMT analysis to determine possible directions through which to resolve the problems. The directions were mapped directly to Effects for appropriate resolutions. For complex problems, it is suggested that Functional Attribute Analysis be employed to analyze the problems, before searching for resolutions from the effects. A case study was conducted to demonstrate the effectiveness and efficiency of the proposed approach in the design and development of products with greater usability, accessibility, and creativity.

Keywords TRIZ · Knowledge effects · Functional attribute analysis · Universal design

C.-M. Yang (✉) · C.-H. Kao · T.-H. Liu · H.-C. Pei · Y.-L. Lee
Department of Industrial Design, Ming Chi University of Technology, 84 Gungjuan Rd, Taishan District, New Taipei, Taiwan, Republic of China
e-mail: cmyang@mail.mcut.edu.tw

C.-H. Kao
e-mail: kaoch@mail.mcut.edu.tw

T.-H. Liu
e-mail: thliu@mail.mcut.edu.tw

H.-C. Pei
e-mail: peimimimi@gmail.com

Y.-L. Lee
e-mail: leeu04xup6@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_107,

1 Introduction

Significant improvements in healthcare and the standard of living have increased the average lifespan of Taiwanese leading to a higher proportion of elderly individuals. According to statistics from the Ministry of the Interior (2013), Taiwan qualified as an aging society in 1993. The percentage of elderly people stood at 11.2 % in 2012 and is continually increasing. The aging index has risen by 32 % points in the past ten years and although these figures are significantly lower than the 100 % in developed countries, it is still considerably higher than the 20.6 % in developing countries (Ministry of the Interior 2013). These changes in the structure of the population have led to increased demand for products that are broadly accessible and flexible. In endeavoring to satisfy user requirements, product designers must remain aware of changes to the physical senses and psychological factors of users. It is only through the appropriate application of universal design (UD) that products that are adaptive, assistive, and accessible can be produced. Unfortunately, many current products based on UD do not fully meet the actual needs of users. Designers must be able to anticipate the needs of the end user, considering that user experience in interacting with a product determines its success or failure. Designers should also consider whether the product satisfies the principles and concepts emphasized in UD. Therefore, this study endeavors to develop an appropriate methodological model that could be referred to by designers or other professionals in the process of product design.

This research proposed an innovative, systematic approach to Universal Design based on TRIZ theories. The proposed approach started with a UD assessment to locate the design problems, followed by a PDMT analysis to generate potential problem solving directions. The directions were mapped directly to Knowledge Effects for appropriate resolutions. For complex problems, Functional Attribute Analysis is suggested to help analyze the directions, before searching for resolutions from effects. Finally, a case study was provided.

2 Literature Review

2.1 Universal Design

The concept of universal design was first proposed in 1970 by Ronald L. Mace. Although initially focused on improving the environments inhabited by physically disabled people, UD was later expanded to include broader design concepts in the development of products and services for use by as many people as possible. In recent years, interest in UD has grown and a number of researchers have expressed their viewpoints on the concept. Steinfeld and Danford (2006) indicated that UD is a normative concept used in the design of products, environments, services, and communications systems. Nieusma (2004) stated that designers should consider what types of design can be universalized to accommodate a wide audience, including disadvantaged or disabled groups. To define and clarify UD, the Center for Universal Design at North Carolina State University proposed the most representative and frequently quoted/applied principles of UD, serving as the means to assess the accessibility of current products and incorporate the UD philosophy into the early stages of design (Center for Universal Design 1997). Based on the seven UD principles, Nakagawa (2006) developed an evaluation system, called Product Performance Program or PPP, comprising 37 guidelines for research on UD products. He also proposed three supplementary principles to compensate for the inadequacies of the existing seven principles. These principles provide definitive criteria and objectives in the design of accessible products.

2.2 Triz

TRIZ is the Russian acronym for the "Theory of Inventive Problem Solving" and proposed by Genrich Altshuller. By studying a large number of patents, Altshuller and his research team formed the fundamental principles of TRIZ theory. In studying the evolution of innovation and invention, Altshuller (1999) proposed that humans frequently encounter three types of obstacles in their thought processes: psychological inertia, limited domain knowledge, and the trial and error method. As a reliable innovations theory, TRIZ is an important tool that enables one to progress beyond established paths of thought without becoming lost in a mental maze. TRIZ is a problem-solving instrument capable of systematizing and generalizing problems (Terninko et al. 1998; Busov et al. 1999; Mann 2007). It includes situational analysis, contradiction analysis, substance-field analysis, the ARIZ problem-solving system, 40 inventive principles, separation principles, the evolution patterns of the technical system, and scientific/technological effects. Although TRIZ includes a wide range of techniques, its main problem solving method focuses on Functionality, Contradiction, Ideality, Resources, and Shifting Perspective (Domb 1999; Ideation International 2006; Mann and Hey 2003).

2.3 Knowledge Effects and Functional Attribute Analysis

Altshuller claimed that the best solutions generally involve the incorporation of knowledge from other domains; therefore, he proposed an enormous effects database, including physical, chemical, and geometric characteritics, to accomplish this purpose (Altshuller 1984; Mann and Hey 2003). Stimulating innovation requires interdisciplinary knowledge, and the point of an effects database is to facilitate thinking that transcends current views by considering whether the problem at hand is similar to other problems solved in the past or in the various domains (Mann 2002; Litvin 2005). A relatively small number of knowledge effects applications, such as CREAX's effects database, have been developed; however, no comprehensive application procedure has been established. As a result, the maximization of knowledge effects has yet to be realized.

Functional attribute analysis (FAA), first proposed by Miles in 1960, is a systematic approach to describing the relationships among system components, particularly those with complex functions. Mann (2002) claimed that establishing the necessary functions and attributes of the current system should be the first step in innovative design and provide a number of different perspectives to facilitate the derivation of useful rules. FAA helps to define the relationships among system components and can overcome the influence of time-dependent issues during analysis so that users can reveal the core of the problem (Sung 2009). After identifying the functions or attributes required by the system, the TRIZ effects database is then used to generate solutions capable of achieving the objectives (Sung 2009).

3 A TRIZ-Based Product Design

This study established a systematic process of product development and innovation using TRIZ as the core. The distinguishing feature of the proposed approach is its provision of a comprehensive set of procedures to facilitate the development of products using FAA and the effects database of TRIZ tools. The detail of this TRIZ-based systematic UD process is described as follows.

Step 1. This study first administered a PPP questionnaire to rate the target product, to identify the universal principles most in need of improvement as problem points. Initially, it is preferable to have the participants actually operate the product before filling out the PPP questionnaire. The questionnaire contains 37 question items in which satisfaction is expressed using a Likert scale with the scores of 40 points, 30 points, 20 points, 10 points, and 0 points; the highest 40 points indicating the most satisfaction and the lowest 0 points indicating the least. The UD principle with the lowest score indicates the area in which the product is least universal. This principle is then set as the design target and incorporated into the process of analyzing the PDMT problem in the following step.

Step 2. We then applied the four processing steps to propel the problem-solving process forward sequentially. Purpose, direction, method, and tool (PDMT) is a preliminary problem-solving approach used to extrapolate the direction of design development through deduction (Chen 2008). Targeting the product requirements requires applying the first three phases of PDMT to deduce the purpose (P), direction (D), and method (M). Possible directions are then determined according to the purpose to serve as a preliminary design reference.

Step 3. This step involves seeking a solution. One method is to match the results of the PDMT analysis in the previous step directly to the function database to search for feasible or usable solutions one at a time. Thus, a manual search of the database is used to derive ideal solutions. Another approach is to first conduct FAA and then match the components, functions, and attributes to the effects database. With consideration of time-dependent scenarios, the problem can be divided into both static and dynamic scenarios. After initiating analyses of the components and writing process of the problem system, the key components and functions of the system are used to identify the necessary functions, the attributes to be manipulated, and the improvements to be applied to the system. Finally, these are matched to the online effects database to search for a solution. This method is significantly less time-consuming and makes more effective use of the effects tools.

Step 4. Finally, the solution derived from the effects database is applied to the design concept in order to create an innovative product with UD.

4 Results and Discussion

4.1 Product Design Analysis

The research subject in this study was a regular ballpoint pen. From the pen questionnaire, we perceived that the UD principle of "Low physical effort" is the main shortcoming in pen design. We applied "Low physical effort" for PDMT, subsequently determined four possible directions for the problem and proceeded to generate the eleven terms. The results of PDMT deduction are displayed in Table 1. We then matched the methods discovered by PDMT directly to the effects

Table 1 Deduction results from PDMT

UD principle	Purpose	Direction	Method
Low physical effort	Not be fatigue in long-term used	Weight	Material
			Friction
			Plasticity
		Ergonomics	Size and shape
			Change in shape
			Pen grasp
		In use	Not to used paper
			Not to used pen
		Alert	Vibration
			Sound
			Time to reminder

Table 2 Matching results from the function and attributes databases

Directions	Methods	TRIZ Tool: knowledge effects
Weight	Material	/
	Friction	F13 control friction
	Plasticity	F16 energy transfer
Ergonomic	Size and shape	F19 change size of object
	Change in shape	F23 modify volume
	Pen grip	/
In use	Not to used pen	F06 control displacement of object
	Not to used paper	F13 control friction
Alert	Vibration	E47 resonance
	Sound	/
	Time to reminder	F01 measure temperature

Table 3 Analysis of writing tool component

Function attribute analysis: components of writing tool	
Storage space	Desk, pen holder, pencil case, shirt pocket
Pen grasp	Normal tripod grasp, thumb wrap, cross thumb grasp, static tripod grasp, thumb tuck grasp, thumb wrap
Pen	Tip, refill, shaft, casing, ball, ink tube, plastic grip, cap
Writing surface	Horizontal, vertical

database to seek a suitable effects solution. The results of effects matching are presented in Table 2. The directing matching method quickly provides an effective solution; however, the results are also influenced by personal experience. When one wishes to think outside the box or when the problem is more complex, FAA can be applied. After analyzing the attributes and functions of a pen, we divided the process of pen usage into three stages: the grasping of the pen, pressing the end to eject the pen point, and writing with the pen on paper. The third was most directly related to the problem that we wanted to solve. Through FAA, the results are shown in Table 3. We then analyzed the dynamic process of users using pens, which require them to apply force to write. To achieve the process of writing, the component applying the force is the hand, the component subjected to the force is the shaft of the pen, and a holding action is used to grip the solid shaft. We thus matched the function of hold with the status of the shaft, solid, and derived 20 solutions from the online effects database (CREAX 2013), including adhesive, adsorption, hot-pressing, and osmotic pressure.

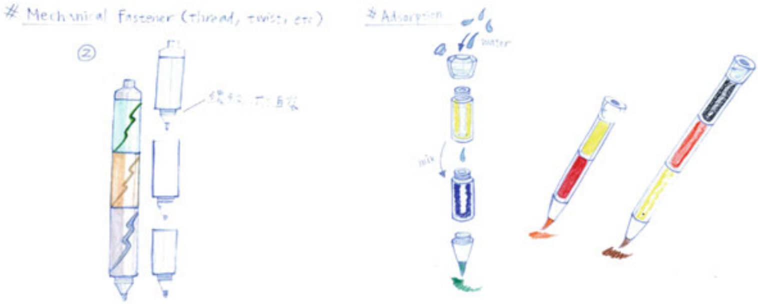


Fig. 1 Pen with replaceable casing (*left*) and palette pen (*right*)

4.2 Application of Effects Principles to Pen Design

From the solutions obtained from the effects database, we selected two principles, which are Mechanical Fastener and Adsorption, for the development of design concepts.

- Application of Mechanical Fastener in pen design—pen with replaceable casing (Fig. 1): Users can select from among a number of casings of different shapes according to their writing habits and type of grasp. Using screw patterns on the casing and shaft, users could assemble their pen at different angles to prevent issues of spinning and fatigue.
- Application of Adsorption in pen design—palette pen (Fig. 1): This study replaced the traditional ink used in pen refills with a powdered substance to alleviate the issue of ink smearing on the hands or paper during writing. Before using this pen, users inject water into the pen to absorb the color. Users can select shafts with different colors and mix a wide range of colors when combining them.

5 Conclusion

This study applies TRIZ tools to UD principles to construct an innovation process that is more systematic, efficient, and easier to use. This process deconstructs a design problem by means of identifying its goals, directions, and initial steps as well as the system's components, attributes, and functions. Thus, the "designers" of other fields may also use this process to solve their own problems. The case study demonstrates that the TRIZ tools offer some level of step-by-step procedures in the application of UD principles to product development. The Effect Database used in this study contains knowledge from many different disciplines, thus allowing the designers to "think outside of the box" and be "inspired" by these principles and knowledge. For professionals in the domain of product design and development, this model provides fresh stimulus and creativity, helping them to design more innovative, flexible, and assistive products.

Acknowledgments The authors are grateful for support of the National Science Council, Taiwan under grant NSC101-2221-E-131-002-MY2.

References

Altshuller G (1984) Creativity as an exact science. Gordon and Breach, New York

Altshuller G (1999) The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical innovation center, Worcester

Busov B, Mann D, Jitman P (1999) Case studies in TRIZ: a novel heat exchanger. TRIZ J. http://www.triz-journal.com/archives/1999/12/. Accessed 9 Jan 2012

Chen CH (2008) Introduction to TRIZ and CREAX. Workshop (Pitotech Co., Ltd.). 2 Oct 2008

CREAX (2013) Function/Attribute database. https://www.creax.com. Accessed 13 Mar 2013

Domb E (1999) Tool of classical TRIZ. TRIZ J. http://www.triz-journal.com/archives/1999/04/default.asp. Accessed 13 Jan 2012

Ideation International (2006) History of TRIZ and I-TRIZ. http://www.ideationtriz.com/history.asp. Accessed 21 Nov 2012

Litvin SS (2005) New TRIZ-based tool—function-oriented search (FOS). TRIZ J. http://www.triz-journal.com/archives/2005/08/04.pdf. Accessed 24 Nov 2012

Mann D (2002) Axiomatic design and TRIZ: compatibilities and contradictions. Paper presented at the second international conference on axiomatic design. Cambridge MA, 10–11 June 2002

Mann D (2007) Hands-on systematic innovation. Tingmao, Taipei

Mann D, Hey J (2003) TRIZ as a global and local knowledge framework. TRIZ J. http://www.triz-journal.com/. Accessed 20 Nov 2012

Ministry of the Interior (2013) Population structure. http://www.moi.gov.tw/stat/news_content.aspx?sn=7121&page=1. Accessed 9 Mar 2013

Nakagawa S (2006) Textbook for universal design. Longsea press, Taipei

Nieusma D (2004) Alternative design scholarship: working toward appropriate design. Des Issues. doi: 10.1162/0747936041423280

Steinfeld E, Danford S (2006) Universal design and the ICF. Paper presented at the promise of ICF conference on the living in our environment, living in our environment, Center for Inclusive Design and Environmental Access (IDEA Center), Vancouver, 4–5 June 2006

Sung MH (2009) Systematic innovation: an introduction to TRIZ. Tingmao, Taipei

Terninko J, Zusman A, Zoltin B (1998) Systematic innovation-introduction to TRIZ. CRC Press, USA

The Center of Universal Design (1997) http://www.ncsu.edu/project/design-projects/udi/. Accessed 3 Nov 2012

Wireless LAN Access Point Location Planning

Sung-Lien Kang, Gary Yu-Hsin Chen and Jamie Rogers

Abstract With the fast-growing demand for mobile services, where to place the access points (APs) for providing uniformly and appropriately distributed signals in a wireless local area network (WLAN) becomes an important issue in the wireless network planning. Basically, AP placement will affect the coverage and strength of signals in a WLAN. The number and locations of APs in a WLAN are often decided on the basis of the trial-and-error method. Based on this method, the network planner first selects suitable locations to place APs through observation, and then keeps changing the locations to improve the signal strength based on the received signal. Such process is complicated, laborious and time-consuming. To overcome this problem, we investigate the back-propagation neural network (BPNN) algorithm to improve over the traditional trial-and-error method. Without increasing the number of APs, our approach only needs to adjust AP locations to overcome weak signal problems and thus increase the signal coverage for the Internet connection anywhere within the area. In our experiment, we established a WLAN on a *C* campus. Our experiments also indicate that placing APs according to the BPNN provided better signal coverage and met the students' demands for connecting to the Internet from anywhere in the classroom.

Keywords Access point placement · Wireless LAN planning · Back-propagation neural network · Threshold

S.-L. Kang (✉) · G. Y.-H. Chen
Industrial and Systems Engineering, Chung Yuan Christian University, Chung Li, Taiwan, Republic of China
e-mail: slkang@mail.chihlee.edu.tw

G. Y.-H. Chen
e-mail: yuhsin@cycu.edu.tw

J. Rogers
UT-Arlington, Industrial and Manufacturing Systems Engineering, Arlington, TX 76019, USA
e-mail: jrogers@uta.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_108,

1 Introduction

With the advent of network and mobile technology era, the public have become more and more relying on the electronic devices, such as personal device assistant (PDA), laptop computers, tablet PC, and smart phones. The traditional fixed land-line networks have no longer met most people's needs; mobility, always-on-demand, and wide band-width are the essential characteristics of latest trends in network connectivity. Therefore, the craving for the wireless local area network (LAN) has grown in leaps and bounds, resulting in the demand for high quality of signal strength and reception. The IEEE 802.11 protocol, a set of standards for implementing wireless local area network, with the flexibility and integration with the current network setting, is becoming the primary choice of network technology for schools, corporations, and public areas (IEEE 1997). Case in point, according to the network statistics in May 2011 at *C* School with an estimated total student population of 10,000, one out of two students accessed the wireless network each day. From the case, it is quite obvious that the wireless network demand from the students is quite strong.

Although wireless networks have numerous advantages over the traditional fixed line networks, the signal propagation in a wireless environment is significantly more complex. Among those the signal interference, signal fading, and path loss are some issues that network planners must carefully consider when it comes to the planning and configuration of wireless networks. The insulation materials in buildings, interior layout settings, and surroundings can easily lead to the exposure to those types of issues. The setup layout of access points (APs), a device that allows wireless devices to connect to a wired network such as WiFi, would impact the financial costs, number of people accessing the wireless network, and the coverage areas. Typically, the information technology specialists or network planners would place more than one access point on each floor of buildings to ensure the network coverage is adequate. However, the network planners typically decide number of APs and selection of locations based on their preferences or experiences, or so-called "trial-and-error" method. The traditional approach is to select the coverage area of a particular signal as the benchmark to determine the AP number and their locations (Cheung 1998; Chiu 1996; Panjwani 1996). Due to the structural considerations of buildings and surroundings, the network planners need to consider several layout options for placing APs in order to improve the network coverage.

This paper is divided into five sections. Section 1 provides the introduction, background as well as the motivation. Section 2 discusses the related work and literature review; this section can be further divided into two sub-sections: (Sect. 2.1) the application of wireless network applications and standards, (Sect. 2.2) the concepts relevant to the solution proposed in this study. Section 3 provides the case under study, constraints and the environment setting. Section 4 presents the result analysis from the experiment. Section 5 summarizes and concludes the entire research and proposes future work.

2 Related Work

2.1 Wireless LAN and Access Point

The Institute of Electrical and Electronic Engineers (IEEE) in 1997 defined the wireless LAN in the 802.11 technical specification (IEEE 1997). At the beginning the specification only covered 2 Mbps, and extended to both 802.11b at 11 Mbps and 802.11a at 54 Mbps later in 1999. The frequency bandwidth covered by 802.11 Wireless LAN belongs to the Industrial Scientific Medical Band (ISM) high frequency bandwidth in the frequency spectrum. 802.11 covers the frequency bandwidth (2.4–2.4835 GHz); 802.11b covers the frequency bandwidth (2.4–2.4835 GHz); 802.11a encompasses the frequency bandwidth (5.150–5.850 GHz). In Comparison of both 802.11a and 802.11b, the latter is poor in terms of signal penetration and high in costs. Consequently, in 2003 the third version of specification, 802.11 g covering bandwidth 54 Mbps (2.4–2.4835 GHz), has been brought to fruition. Even with high throughput at 54 Mbps, the WLAN standards around that time were half-duplex and with high overhead in the packet data; the WiFi network can easily reach its maximum throughput for downloading a file around 17–18 Mbps. Therefore, IEEE in 2009 came up with the latest version 802.11n for handling bandwidths from 54 to 300 Mbps, allowing the throughput of wireless LAN to be at least as high as the fixed land-line (around 100 Mbps) (Table 1).

The wireless LAN in general consists of two types of equipments: wireless transceiver and access point (AP). The wireless transceiver is a laptop or mobile device with WiFi capability. The main components of an AP include a wireless transceiver and fixed land-line network card. The primary function of an AP is the bridge or interface between the wired and wireless networks. All wireless transceivers must be connected to the access point in order to access the services from the wired networks.

The traditional approach to select the suitable location for the access point is done firstly through the observation. Next, after several runs of measuring the signal strength of the WLAN, the network engineers applied to the algorithms to

Table 1 Wireless LAN 802.11 specifications

Protocol	Release	Frequency bandwidth (GHz)	Actual throughput (average) (Mbit/s)	Actual throughput (maximum) (Mbit/s)	Indoor range (m)	Outdoor range (m)
802.11	1997	2.4–2.5	1	2		
802.11a	1999	5.15–5.35/5.47–5.725/5.725–5.875	25	54	30	45
802.11b	1999	2.4–2.5	6.5	11	30	100
802.11 g	2003	2.4–2.5	25	54	30	100
802.11n	2009	2.4 or 5	300	600	70	250

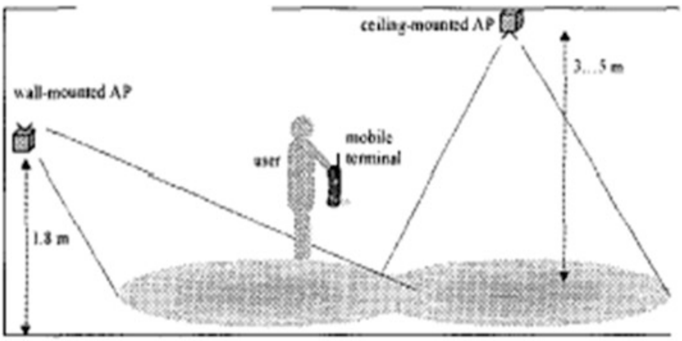


Fig. 1 Impact of deployment methods on the coverage area (Unbehaun and Zander 2001)

determine the network layout. The entire process is overly repetitive, tedious and inefficient (Kamenetsky and Unbehaun 2002). Hills (2001) proposed another method that could be applied for quick deployment and very suitable for indoor use. However, the method could not handle the problem of obstacles (such as a walls or trees). Wang (2003) analyzed the characteristics of AP and relationship between the obstacles and signals and came up with three AP deployment methods: 90-degree angle split deployment method, 60-degree angle split method and various half-diameter ratio method. Those methods provide the guidelines for quick access point deployment without going through tedious procedures and measurements, resulting in cost saving and quality improvement.

The main concern over the placement of access points is the signal separation of the access points—the network engineers strive for wide coverage area from each AP. The typical place for AP is at the highest point of a space. For the indoor deployment of AP is normally at the highest point directly overhead. With the signal projecting from top to the bottom, the coverage area naturally forms a circle as shown in the Fig. 1. In terms of signal quality and reliability, the ceiling-mounted AP will score higher than the wall-mounted AP (Unbehaun and Zander 2001). Nevertheless, due to other factors such as easy access, wiring, appearance and so on, the network engineers may choose to mount the AP on the wall instead.

2.2 *Artificial Neural Network*

In the past some researchers have applied the artificial neural network (ANN) and other heuristic methods to investigate the impact factors on the signal quality of wireless LAN. In this study the authors applied the neural network approach to investigate the effective placement of APs in order for the mobile devices to get connected to the networks. In the following description, the basic introduction on the concept of artificial neural network will be provided.

The artificial neural network was first proposed by two mathematicians, McCulloh and Pitts, in 1943. Modeled after human's brain, the neural network is consists of interconnected nodes or neurons with inputs and output and can be used for information processing or computation. In 1957 Perceptron was developed in artificial neural network for solving classification problems. In 1969 the ANN entered the "dark period" when Perceptron was proven to solve only the linear classification problems. Not until 1985 have the interests in the neural network picked up again when the Hopfield and back-propagation network were introduced. Through the application and modification of hidden layers and units, the ANN can be used to solve more complex problems. The neural network can be divided into two types: supervised and unsupervised learning. To evaluate the quality of the neural network, the indicator, root mean square error (RMSE), is typically used; the smaller RMSE is, the better is the quality of the neural network. Before selecting the neural networks, the RMSE of a training sample is first analyzed. If the RMSE of the training sample cannot indicate the quality of the network, the RMSE of the testing sample must also be taken into consideration. The objective is to have small yet converged RMSEs of both training and testing samples to reflect the actual scenario. Figure 2 illustrates an artificial neural network.

3 Case Study and Methodology

In this research, the researchers studied the case of *C school* as an example for wireless LAN deployment. The general classroom floor plan on campus is shown in Fig. 2. Classroom dimensions are 8.8 m long and 7.3 m wide. The classroom layout and structural materials are just like typical classrooms. General furniture including study desks and chairs are placed in the classroom. There is no obstruction above the desks and chairs. Flanking the classrooms are several large pane windows which allow high signal penetration. The front and back of the classroom consists of walls 0.6 m thick. Currently, there are six classrooms on each floor of a particular building on campus. Two wireless APs are mounted 3.3 m above the classroom hallway at the top of a column 2.7 m away from the classroom for students to access the Internet. Although the current wireless signals

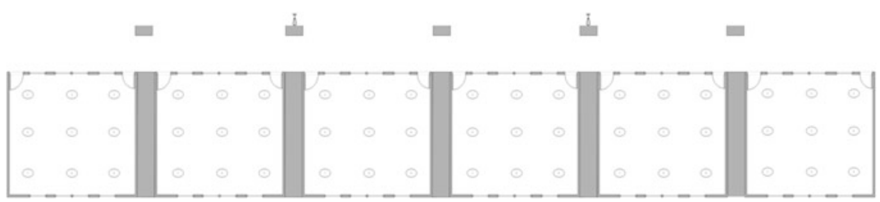


Fig. 2 The floor plan of classroom

are sufficient to cover six classrooms, existing blind spots still block students' access to the Internet anywhere in the classroom. The researchers wished to improve the signal coverage through an efficient selection of wireless AP locations and minimum required APs.

The researchers detected the wireless AP signal strength with the WiFi monitoring software, WirelessMon, and designated 9 detection points in each classroom. The researchers also set a signal strength threshold τ and designates if the signal strength is less than the threshold, the wireless communication cannot be established (Fig. 3).

$$\forall k \in A, Si(k) \geq \tau \qquad (1)$$

where

A	the experimental area,
τ	signal strength threshold,
$Si(k)$	signal strength at the k point,
k	the coordinates above the signal strength threshold.

The experiment can be divided into two scenarios. The first scenario is to simulate the actual testing objective function value through the back propagation network. The researchers divided 55 data sets into training and testing sets. Three input variables are considered: distance, door and wall obstruction coefficients. The output variable is the signal strength. By varying the hidden layers as well as the two parameters, learning rate and momentum, the researchers expected to find a pattern in which the RMSE is within the acceptable range.

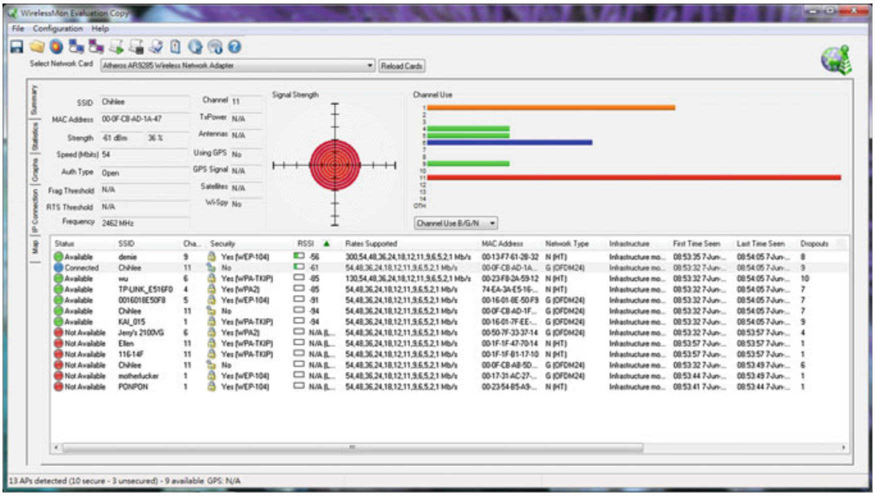


Fig. 3 wirelessmon wireless LAN detector

Table 2 Results after the experiment

AP location	Structure	Learning rate	Momentum	Sample size	Training RMSE	Testing RMSE	Over threshold	Under threshold
(9.7, −2.7) (−9.1, −2.7)	(3, 4, 2, 1)	0.1	0.9	14	0.032	0.026	41	14
(−13.8, −2.7) (14.4, −2.7)	(2, 5, 3, 1)	0.1	0.8	17	0.074	0.073	51	4

In the second scenario, the researchers moved the AP placements, hoping to the change will improve overall signal strength and help pass the threshold. Due to the factors such as the appearance, the researchers could only place APs on 5 designated wall columns; from those 5 columns, the researchers tried to determine the effective AP deployment locations.

4 Result Analysis and Discussion

Based on the aforementioned experimental assumption, the authors fed the data and actual signals into the Q-NET software which executed the back propagation network to train a model that reflected the real-world scenario. The threshold value was set at −80 dBm; if the signal strength exceeded the threshold value, the wireless communication is not established; otherwise, the wireless communication is established. The experimental results are shown in Table 2.

The table provides the before and after AP locations and their related data. The structure is set according to the whole neural network model: input node and first hidden layer node, second hidden layer node and output node. The first three are set empirically to allow more accurate prediction. In regards to the training and testing values, the researchers divide the data set into 2:1 or 7:3 ratio based on existing literatures. The ANN simulation showed that 41 data passing the threshold with AP location before the location update and 14 data failed to pass the threshold; the entire RMSE is 0.032. After the AP location update, 51 passed the threshold and only 4 failed; the entire RMSE is 0.074.

5 Conclusion

The research aims at improving the classroom AP deployment at *C* school to provide students a coverage area with sufficient signal strength for network connection. At the hallway and classrooms flanked with pan windows, the proposed wireless AP placement can achieve better network coverage with sufficient signal strength for network connection based on the ANN simulation.

In this study the researchers collected the data from the standard wireless AP with the transmitted (TX) power at 3 dB; for future work, APs with powers at other dB values can also be investigated. Additionally, how to find the balance point between the number of APs and the construction costs is also something to be pondered about.

Acknowledgments This work is partially supported by the grant NSC 100-2221-E-033-030. The authors are grateful to the anonymous reviewers for their comments.

References

Cheung KW (1998) A new empirical model for indoor propagation prediction. IEEE Trans Veh Technol 47(8):996–1001

Chiu CC (1996) Coverage prediction in indoor wireless communication. IEICE Trans. Commun. 79(9):1346–1350

Hills A (2001) A large-scale wireless LAN design. IEEE Commun Mag 39(11):98–107

IEEE (1997) WIRELESS LAN medium access control(MAC) and physical layer(PHY)specification. IEEE STD 802.11 IEEE Society, Piscataway, NJ, USA

Kamenetsky M, Unbehaun M (2002) Coverage planning for outdoor wireless LAN systems. In: IEEE International Zurich Seminar on Broadband Communications, Zurich, Switzerland. IEEE Society, pp 491–496

Panjwani MA (1996) Interactive computation of coverage regions for wireless communication in multifloored indoor environments. IEEE J Sel Areas Commun 14(3):420–429

Unbehaun M, Zander J (2001) Infrastructure density and frequency reuse for user-deployed wireless LAN system at 17 GHz in an office environment. IEEE Int Conf Commun 2535–2539

Wang CT (2003) IEEE 802.11 WLAN access point (AP) deployment. Master, National Central University, ChungLi, Taiwan

The Parametric Design of Adhesive Dispensing Process with Multiple Quality Characteristics

Carlo Palacios, Osman Gradiz and Chien-Yi Huang

Abstract In recent years, electronic industry trend moves toward miniaturizing its electronic components. Nevertheless, the functionality of these electronic components has grown stronger in order to keep up with the world's technology advances and demand. The electronics manufacturing companies are always searching for new and better ways to make their products more efficiently, while protecting the environment in accordance to the restriction of hazardous substance (RoHS) directive, which was announced by the European Union. However, the implementation of such directive generated some setbacks in the electronics assembly process with surface-mount technology. This paper focuses on the quality performance of the component's glue adhesion strength, considering multiple quality characteristics such as the vertical and horizontal thrusts at low and high temperatures. The Taguchi method assisted in designing and implementing the experiments. Process factors considered include the dispensing position, thermoset temperature and reflow conveyor speed. The multi-criteria analysis methods, the order preference by similarity to the ideal solution (TOPSIS) together with the principal component analysis (PCA), are employed to analyze the experimental data acquired. The optimal process parameters are thus determined. Lastly, a confirmation test is conducted to verify the results of the optimal process scenario.

Keywords Quality control · Parametric design · Surface mount technology

C. Palacios (✉) · O. Gradiz · C.-Y. Huang
Department of Industrial Engineering and Management, National Taipei University of Technology, 1, Sec. 3, Zhongxiao E. Rd, Taipei 10608, Taiwan, Republic of China
e-mail: Sless_28@hotmail.com

O. Gradiz
e-mail: osman1430@hotmail.es

C.-Y. Huang
e-mail: jayhuang@ntut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_109,

1 Introduction

1.1 Background

The modern civilized society; electronic products have become an integral part of human life. In recent years, the global electronics industry have had a rapid development and progress, the manufacturers are committed to product innovation and process improvement. China's electronics industry has gradually become in the world's main production and supply, and thus led to the middle reaches of the electronic components industry and the vigorous development of the upstream raw material.

The entire information, communication, and consumer electronics industry, Printed Circuit Board (PCB) is indeed one of the indispensable components, all electronic products are required to be used PCB, The application areas including information, communications and consumer products, the main application of products including TV, VCR, computer peripherals, fax machines, notebook computers, mobile phones and chipsets.

The electronic products in recent years have been moving towards the light, thin, short, small, meaning even more functions are placed in the same area of the circuit board, to maintain the same functionality, but the area is narrow. In response to market demands, the development of the miniaturization of electronic components lead to the developed of a surface-mount technology (SMT) to replace the traditional parts plug-in process (the Dual the Inline Package; DIP).

1.2 Rationale

The Restriction of Hazardous substance (RoHS) directive was announced in 2003 by the European Union; which gradually made lead-free solder replace the traditional lead based solder paste, On the other hand the electronics industry's technical factors were subject to limitations, the welding technology face lead-free reliability problems. For example, SAC305 (Sn96.5 %/Ag3.0 %/Cu0.5 %) lead-free environmentally friendly solder makes easy the SMT process temperature significantly elevated, which cause the circuit plate board-bending phenomenon; using a tin–bismuth alloy (Bi 58 %/Sn42 %; also known as low-temperature lead-free solder paste) can contra rest the plate bending phenomenon, but the tin–bismuth alloy with hard and brittle nature restricts its use only to less reliability and more flexible requirements consumer electronics product. Using low temperature solder paste and the dispensing baking reflow process causes reflow temperature decreases and may affect the adhesive strength of the solder paste. Therefore, to break through the technical aspects of these limitations, there is need of in-depth understanding of the product composition (raw materials, alloy and process set) and preventive measures and parametric design.

1.3 Objectives

- Use the technique for order of preference by similarity to ideal solution (TOPSIS) and Principal component analysis (PCA) statistical methods, to determine the optimal process parameters combination.
- In accordance with the best combinations of parameters from the methods applied, present a set of test samples, simultaneously conduct a series of thrust experiments and obtain from each of these a set of optimal parameters combination.
- Direct the process' optimal parameters combination to conduct a experiment confirmation data analysis, to verify whether or not the outcome of measuring the quality characteristics fall within the confidence interval, to asses if the conclusions are correct, that is to see if the adhesive dispensing process parameters combination make it difficult for the components to detach.

1.4 Research Structure

To establish research direction, we start by using certain tools of the Taguchi method into planning and execution experiment. Analyzing the data, we prepare the information in order to use the technique of order of preference similarity to Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) with principal component analysis (PCA) to determine the optimal parameter combination, accordingly prepare sample tests of the optimal process parameter combination, consequently conduct a confirmation experiment to assess its quality characteristics optimal process parameter combinations, finally conclusions and recommendations.

2 Experiment Planning and Analysis

2.1 Experiment Preparation

The Taguchi's method orthogonal array tool will set the best combination array between the four factors and the three different levels to analyze and also signal to noise ratio will normalize data to make data less sensitive to noise. The factors to take into account, the first one is the Dispensing position: Consider the glue concentration at the bottom of the components. If the glue is slightly exposed at the bottom side of the components, the components side could withstand external force better. The second factor is the crimping time: increase the pressing time of the components in the dispensing process to ensure the full contact of glue and components. Crimping long time may result in the glue overflow at the bottom of the components. Set the time in 0.00 s, 0.01 s, and 0.02 s. Thirdly the Glue thermosetting temperature: select the low-temperature of solder paste melting

Table 1 Factors and levels

Factors/Levels	Level 1	Level 2	Level 3
Dispensing position (DP)	The element is covered	1/3 Expose	1/2 Expose
Crimping time (CT)	0.00 s	0.01 s	0.02 s
Thermosetting temperature (TT)	140 °C	150 °C	160 °C
Reflow conveyor speed (RCS)	1 M/min	1.15 M/min	1.3 M/min

point of 138 °C, the reflow of thermostat temperature zone are chosen in the 3 different levels 140, 150, and 160 C, respectively. And lastly the Reflow oven conveyor speed: conveyor speed will affect the time of the PCB stay in the reflow zone and affect the glue adhesion strength after baking. Table 1 has a more visual appreciation of how the factors and levels are interconnected.

2.2 *Experiment Process*

Initially we must prepare and produce the experimental sample of the Printed Circuit Board (PCB) using the Surface Mount Technology (SMT) process Fig. 1, which in itself consists of four manufacturing process. Primarily we have to set the Glue point position for adhesive components using the machine's computer, secondly Component adhesive dispensing, thirdly the placement of the components on to the PCB and to finish we have the reflow of PCB in the oven.

2.3 *Thrust Measurement Specification*

Vertical and horizontal thrust (VTh, HTh) will be conducted for the components in room temperature and high temperature (RT, HT) using a hand held thrust-meter Fig. 2.

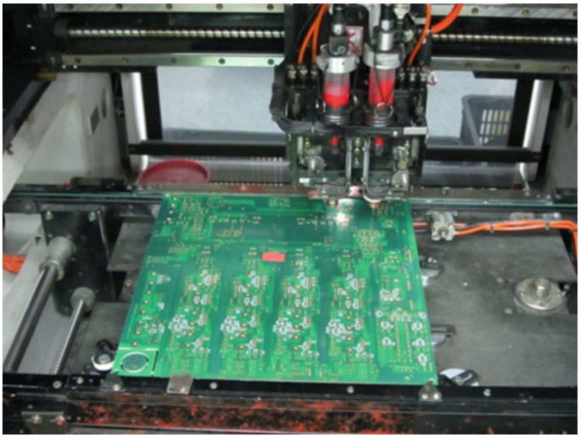


Fig. 1 PCB preparation

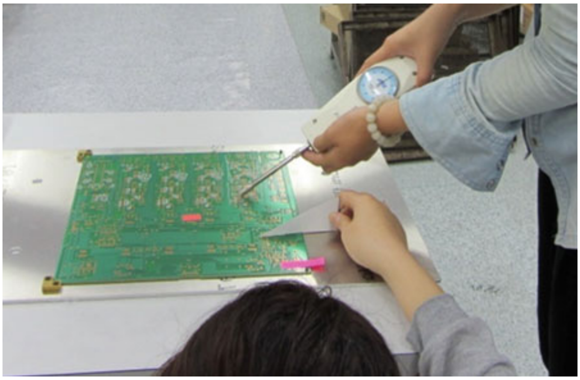


Fig. 2 Thrust measurement. *Angle* maintain 30 degrees relative to the board. *Temperature* room temperature was controlled at 20–25 degrees. Oven temperature was set at 210 °C for 90 s (temperature 170–190 °C)

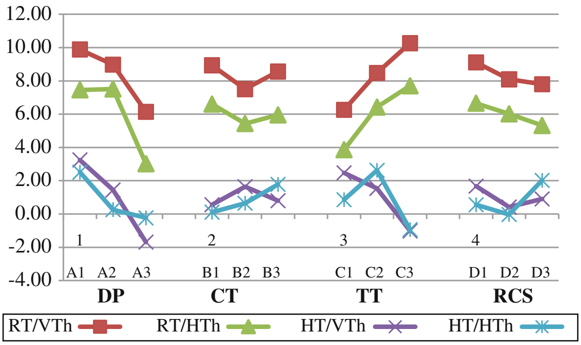


Fig. 3 Reaction chart

2.4 Thrust Experimental Data Analysis

Using Taguchi's signal to noises ration bigger the better formula given by Eq. 1

$$S/N = -10\log\left[\frac{1}{n}\sum_{i\sim 1}^{n}\left(\frac{1}{y_i^2}\right)\right] \tag{1}$$

Which was the appropriate formula for this research to gain the most robust ratio; the data acquired on the experiments is analyzed and processed according to the established steps to find the S/N ratio for each of our relevant quality characteristics where we obtain the data that will be the starting point for our parameter optimization. In addition to the reaction of each quality characteristic for the four factors reflected on Fig. 3.

3 Parameter Optimization

3.1 TOPSIS

First the signal to noise ratio data table is represented in a matrix form, and then we construct the normalized decision matrix, transforming the various attributes dimension into non-dimensional attributes, which allows comparison across the attributes. The Third step is to construct the weighted normalized decision matrix using the given weights, for room temperature thrust: 0.17 and High temperature thrust: 0.33. Next we determine the positive and negative ideal solution, after doing so we must determine the relative closeness to the ideal solution. To finalize we establish the optimal parameter combination using the orthogonal array of Taguchi method.

3.2 PCA

To begin we must Transform a number of posible correlated variables into a small number of uncorrelated variables to do this we must first standarize the S/N ratio data, secondly we need to obtaining a correlation coefficient matrix, accordingly the characteristics value [λ], and eigenvalues [C] are attained. Followed by obtaining a principal component point [Φ ip] and multi-quality characteristics indicator [Ω i] MPCI. To finish we determine the optimal parameter combination using the orthogonal array of Taguchi method.

3.3 Optimal Process Parameters

The combination of the optimal process parameters obtained in the two kinds of analysis methods (TOPSIS and PCA) are shown in Table 2, further the production of four PCB samples, and the foregoing steps for dispensing adhesive strength thrust test.

Table 2 Optimal process parameters

	Dispensing position	Crimping time (s)	Thermosetting temperature (°C)	Reflow conveyor speed (M/min)
TOPSIS	The element is covered	0.02	150	1.3
PCA	1/3 Expose	0.00	160	1

3.4 Confirmation Experiment and Analysis

According TOPSIS and PCA the combination of the optimal process parameters obtained, the production of four PCB samples to confirm the experiment. Consequently we predict the optimal conditions for the SN ratio, in order to not overestimate optimal conditions, we will only use the factors of strong effect and use the square of the weak factors as merge error, obtaining Table 3. Accordingly In order to effectively estimate the value of each observation, we must verify the prediction of the quality characteristics of the S/N ratio with a 95 % confidence interval using Eq. 2.

$$CI_1 = \sqrt{F_{\alpha:1,v_2} \times V_e} \times \left(\frac{1}{n_{eff}}\right) \tag{2}$$

where,

$F\alpha{:}1,v2$	F value with significance level α,
α	Significance level, confidence level = $1-\alpha$,
V2	Pooled Error Variance degrees of freedom,
Ve	(Pooled Error Variance) Obtained through ANOVA analysis,
n_{eff}	Valid observations.

The results show that the quality characteristics of the measurement results falls within the confidence interval, since the impact of the addition of the control factor model has established parameters, and there was no significant interaction. The analytical data is shown in Table 4.

Table 3 Total SN ratio

Factors	SN
Room temp/Vertical thrust	11.8167
Room temp/Hori. thrust	9.21407
High temp/Vertical thrust	4.72090
High temp/Hori. thrust	4.28661

Table 4 Confidence interval compliance

Quality characteristics (push force measured)	Predictive value (S/N ratio)	95 % confidence interval	TOPSIS measured value (S/N ratio)	PCA measured value (S/N ratio)
RT/VTh	11.82	9.25–14.38	9.30	9.46
RT/HTh	9.21	6.96–11.46	8.40	7.79
HT/VTh	4.72	2.56–6.88	2.64	2.11
HT/VTh	4.28	0.84–7.72	0.94	0.84

4 Conclusion and Recommendation

Firstly in order to solve the problem of multiple quality characteristics (the analog production process medium wave soldering process molten tin disturbance caused by the multi-directional erosion on the PCB components and may cause PCB handling stress, so the experiment consider room temperature vertical, horizontal push and high temperature vertical, horizontal push our four quality characteristics.), the research takes advantage of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and the statistical method of Principal Component Analysis (PCA), respectively, decided the process of optimal combination of parameters. By the above method of optimal combination of parameters to produce a test sample and thrust experiments confirm experimental data analysis, and finally for optimum process parameters combination, to assess the results of the measurement of each quality characteristic falls within the confidence interval, in order to verify the obtained conclusion is correct that this point dispensing process parameter combinations is not easy to make the components fall off.

After the experimental results, we get TOPSIS with four quality characteristics of the PCA method S/N ratio both fall into the 95 % confidence interval, that the two methods can solve the issue of multiple quality characteristics and these two sets of points dispensing process parameter combinations are not easy to make the components off. Secondly, the experimental results show that multiple quality characteristics can be of TOPSIS with the PCA method to solve the problem, so we recommend that manufacturers can do further comparison (experimental), and so are two ways to choose the better parameter combinations, to reduce the shedding of electronic components probability.

Our point dispensing process as much as quality parameters design based on Taguchi experimental design and planning experiments, use the Order Preference Law and main component analysis to solve multiple quality characteristics, but on the analysis of multiple quality characteristics optimization still there are many other possible methods, for example, data envelopment analysis, genetic algorithms, fuzzy theory, etc., so the future can learn more about the advantages and disadvantages of each method, and compare and discuss the proposed two design methods.

References

Cheng YP (2008) Usage patterns tree constructed SMT solder paste printing process quality control mode. National Cheng Kung University, Industrial and Information Management Master Program, Shuo essays

Hu HJ (2011) Taguchi method is used to investigate the optimization process of the solder paste stencil. Thesis, Department of Electronic Engineering, National Kaohsiung University of Applied Sciences

Huang GY, Caixin L (2006) Green and Pb-free solder stencil printing process parameter optimization. J Technol XXI: 227–236

Li KJ (2007) Application Taguchi tin furnace welding process parameters optimization. Master's thesis, Department of Industrial Engineering and Enterprise Management, Huafan University

Su CD (2002) Quality project. Chinese Society for Quality

Su RR (2004) Taguchi method in the 0201 process parameter optimization of passive components. Thesis, Industrial Management, University Huafan

Wang Q (2011) Improve SMT dot dispensing process. Thesis, Department of Industrial Engineering and Enterprise Information, Huafan University

Wu PY (2012) Using neural networks and TOPSIS SMT point optimization of the parameters of the thrust of the dispensing process. Thesis Hua Fan University, Industrial engineering and management information system 2012; Environmental point of the dispensing process R&D and innovation parameters design. Thesis, Department of Industrial Engineering and Management, National Taipei University of Technology

Yan JY (2011) Multiple quality characteristics Taguchi method to construct a key factor selection algorithm. Master's thesis, Asia-Pacific Industrial and Business Management, National Kaohsiung University

Ye PX (2005) Solder paste printing process parameter optimization. Thesis, Department of Business Management, Shuter University of Science and Technology

The Shortage Study for the EOQ Model with Imperfect Items

Chiang-Sheng Lee, Shiaau-Er Huarng, Hsine-Jen Tsai and Bau-Ding Lee

Abstract The traditional economic order quantity (EOQ) model assumes that all the ordered items are "perfect" enough to be consumed by the customers, but some of these items could be impaired or damaged in the process of production or transportation. For such items, we might call them "imperfect items" and they need to be considered in the EOQ model. In this paper, we focus the study on the shortage problem for the EOQ model with imperfect items since the shortages are inevitably caused by the imperfect items. Consider that the imperfect probability $\boldsymbol{p}$ is a random variable with probability density function $\boldsymbol{f(p)}$ and the good quantity $\boldsymbol{Y}$ comes from the Hypergeometric distribution. Consequently, the sufficient condition to ensure the occurrence of non-shortages is obtained and a mathematical discussion is provided to construct an optimal inventory model for dealing with the possibilities of the shortage problem.

Keywords EOQ model · Imperfect items · Incoming inspection · Shortage

C.-S. Lee (✉) · B.-D. Lee
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: cslee@mail.ntust.edu.tw

S.-E. Huarng
Department of Statistics, Iowa State University, Ames, IA, USA

H.-J. Tsai
Department of Information Management, Fu-Jen Catholic University, New Taipei, Taiwan, Republic of China
e-mail: sai.fju@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_110,

1 Background

The traditional EOQ model has been widely used and studied by many researchers today. It assumes that all the ordered units are "perfect" enough to be consumed completely by the customers (Silver et al. 1998) and that the shortage problem will not occur. In general, there is an incoming inspection process (Montgomery 2001) when the ordered items are delivered. A fair guess for the reason of inspection process is imperfect items. Consequently, shortage problems could happen when the percentage of defective items is large and it results in extensive studies.

Salameh and Jaber (2000) incorporated "imperfect items" into EOQ inventory model and assumed that the imperfect probability p is a random variable with probability density function $f(p)$. To avoid of shortages, they assumed that the number of good quantity $N(y,p)$ is least equal to the demand during the screening time and found the optimal order quantity under this assumption.

Based on the thought of imperfect items and EOQ inventory model built by Salameh and Jaber (2000), Rezaei (2005) proposed the assumption of "shortage backordering" for EOQ model to find the optimal order quantity under the consideration of shortages. Chang (2004) regarded both p and D, demand per unit time, as fuzzy numbers to build a Fuzzy EOQ model, then used the method of defuzzification and ranking method for fuzzy numbers to get the optimal order quantity. Chung and Huang (2006) considered the EOQ model with the idea of permissible credit period and aimed for the optimal order cycle and quantity. Yu et al. (2005) developed an optimal ordering policy for a deteriorating with imperfect quality and included partial backordering for shortage problem, they tried to build up a model for generality and solve the optimal policy under various conditions.

Although most authors developed their researches from the EOQ model built by Salameh and Jaber (2000), Papachristos and Konstantaras (2006) pointed out some unrealistic assumptions under the modified EOQ model from Salameh and Jaber (2000) and the one of the unrealistic assumptions is non-shortages. Regrettably, they did not provide the correct conditions for non-shortage and a remedial method to solve the problem.

2 Introduction to Salameh and Jaber's (2000) EOQ Model

Since our study for EOQ model with imperfect items is based on Salameh and Jaber (2000), we adopt some of the assumptions and the definitions of the notations in that paper, we first introduce Salameh and Jaber's (2000) EOQ model and it follows the definitions of the notations and assumptions:

y	the order size of a lot
c	purchasing price per unit
K	fixed cost of placing an order
p	percentage of defective items in a lot
x	screening rate, the number of units which can be screened per unit time
u	unit selling price of good quality
v	unit selling price of defective items, $v < c$
t	the total screening time of y units, $t = y/x$
D	demand per unit time
$N(y,p)$	the number of good quality of y units, $N(y,p) = y(1-p) \geqq Dt$
T	cycle length
d	unit screening cost
$f(p)$	probability density function of p
h	holding cost per unit time

- A lot of size y is delivered instantaneously at the purchasing price c per unit and an fixed ordering cost K
- Each lot will receive a 100 % screening process with screening rate x and screening cost d per unit
- The defective probability p is a random variable with probability density function $f(p)$
- The defective items will be kept in the stock and sold as a single batch at the price v per unit before next shipment
- To avoid shortages, It is assumed that the number of good quantity $N(y,p)$ is at least equal to the demand during screening time t, *i.e.*, $N(y,p) = y(1-p) \geqq Dt$

Denote $TR(y)$ as the total revenue per cycle, then $TR(y)$ will be the sum of selling prices of good items and defective items. i.e., $TR(y) = uy(1\text{-}p) + vyp$. Let $TC(y)$ be the total cost per cycle, hence $TC(y)$ is the total of the fixed cost of placing an order K, purchasing price per cycle cy, unit screening cost per cycle dy, and holding cost per cycle $h\ (y(1-p)T/2 + py^2/x)$, and it is given as $TC(y) = [K + cy + dy + h\ (y(1-p)T/2 + py^2/x)]$. Therefore, the total profit per cycle $TP(y)$ equals the total revenue per cycle minus the total cost per cycle. i.e.,

$TP(y) = TR(y) - TC(y) = uy(1-p) + vyp - [K + cy + dy + h(y(1\text{-}p)T/2 + py^2/x)]$. The total profit per unit time $TPU(y)$ is obtained by dividing the total profit per cycle length T. Since $T = (1-p)y/D$, we have $TPU(y) = D\ (u - v + hy/x) + D\ (v - hy/x - c - d - K/y)\ (1/(1-p)) - hy(1-p)/2$.

The *objective* of Salameh and Jaber's (2000) EOQ model is to find the optimal order quantity y^* such that y^* will maximize the expected value of the total profit per unit time $E(TPU(y))$ over the domain of y. Since p is a random variable with the a known density function, the random variable y is continuous by definition a known density fis continuous by definition underunction, hence we have

$$\begin{aligned} E(TPU(y)) = & D(u - v + hy/x) \\ & + D(vhy/\mathrm{x} - \mathrm{c} - \mathrm{d} - \mathrm{K}/\mathrm{y})\, E(1/(1-p)) - hy(1 - \mathrm{E}(p))/2 \end{aligned} \quad (1)$$

Besides, the random variable y is continuous by definition under Salameh and Jaber's (2000) EOQ model, then E($TPU(y)$) is concave and y^* could be obtained by taking the first and the second derivatives of Eq. (1). After some straightforward mathematical computations, it can be demonstrated that there exists a unique value of y^* which maximize Eq. (1) and

$$y^* = \{ [2KD\mathrm{E}(1/(1-p))] / [h(1 - \mathrm{E}(p)) - D(1 - \mathrm{E}(1/(1-p))/x)] \}^{1/2}. \quad (2)$$

Note that $y^* = [2\ K\ D/h]^{1/2}$ if $p = 0$ and the Salameh and Jaber's (2000) EOQ model reduces to traditional EOQ model.

3 Mathematical Model

The present study takes the definitions of notations mentioned above and gives some different thought about the assumptions of random variables and y. Consider a lot of size y delivered instantaneously, it is obviously that the items (or productions) are countable and the random variable y is a positive integer. The assumption of continuous y is unrealistic under Salameh and Jaber's (2000) EOQ model, hence E($TPU(y)$) is not a concave function of y and the optimal order quantity y^* cannot be gotten by taking the first and the second derivatives of it.

Recall that the number of good quality of y units $N(y,p)$, $N(y,p) = y(1-) \geqq p$ Dtimplies that $p \leqq 1 - D/x$, i.e., the demand per unit time D must be less or equal to the number of units which can be screened per unit time x. In the real life, there is no guarantee of that. Since p is a random variable, it does not ensure that the inequality $p \leqq 1 - D/x$ can be always held under all circumstances. The inequality guarantees no shortages for all combinations of (x, D) will be

$$x - y \max_{p \in (a,b)} \{p\} \geq D \quad (3)$$

or

$$x - y\, b \geqq D, \quad (4)$$

where b is the maximum failure probability that could occur in the lot of size y. For example, let $y = 500$ units/lot, $x = 110$ units/day, $D = 100$ units/day, and there are total 20 defective items found in this lot. From the example, it exists a shortage problem if there are 11(or more) defective items found in the first day's screening process even that the failure probability $p = 20/500 = 4\ \%$ satisfies the inequality $p \leqq 1 - D/x$.

It follows assumptions and definitions of notations used in our study.

G the number of good quality items

s unit shortage cost, $s > c$

q number of sampling times in the screening process

r percentage rate in the last small batch (number of items in the last batch/x), $0 < r \leqq 1$

Y_i the number of good quality at ith batch in the screening process, $i = 1, 2, \ldots, q$, $\sum_{i=1}^{q} Y_i = G$

- Let $t = \frac{y}{x} = \left[\frac{y}{x}\right] + \left(\frac{y}{x} - \left[\frac{y}{x}\right]\right) = n + r$, here [] be denoted as the Gaussian symbol, $n = \left[\frac{y}{x}\right]$ is the biggest integer less or equal to y/x, $0 \leqq r < 1$.
- Let q represents the number of small batches inspected in screening process per cycle, hence, $q = \begin{cases} n+1, & if\ r \neq 0 \\ n\ , & if\ r = 0 \end{cases}$.
- In the study, we assume that good items for the ith batch is Yi, $i = 1,2, \ldots, q$, and that the sum of all these values must be equal to the number of good items G, i.e., $\sum_{i=1}^{q} Y_i = G$. In statistics, Y_1, $Y_2,\ldots$, and Y_{q-1} can be regarded as random variables and they are randomly selected from the finite population of size y. Note that the last batch Y_q cannot be treated as a random variable since Y_q can be directly computed from $Y_q = G - \sum_{i=1}^{q-1} Y_i$.
- From the discussions mentioned above, the good quantities Y_1, $Y_2,\ldots$, and Y_{q-1} can be regarded as random variables which come from Hypergeometric distribution. Therefore, $pr\left(Y_1 = y_1 | p\right) = \dfrac{\binom{G}{y_1}\binom{N}{x-y_1}}{\binom{y}{x}}$,

where $y_1 = Max\{0,\ G + x - y\},\ 1,\ 2,\ldots,\ Min(x,\ G)$.

$$pr\left(Y_2 = y_2 | p,\ Y_1 = y_1\right) = \frac{\binom{G-y_1}{y_2}\binom{N-(x-y_1)}{x-y_2}}{\binom{y-x}{x}},$$

where $y_2 = Max\{0,\ G - y_1 + x - (y - x)\},\ 1,2,\ldots,\ Min(x,\ G - y_1)$.

$$pr\left(Y_{q-1} = y_{q-1} | p,\ Y_1 = y_1,\ Y_2 = y_2,\ \ldots,\ Y_{q-2} = y_{q-2}\right)$$
$$= \frac{\binom{G - y_1 - \ldots - y_{q-2}}{y_{q-1}}\binom{N - \left((q-2)x - y_1 - \ldots - y_{q-2}\right)}{x - y_{q-1}}}{\binom{y-(q-2)x}{x}},$$

where $y_{q-1} = Max\{0,\ G - y_1 - \ldots - y_{q-2} + x - [y - (q-2)x]\}$, $1, 2, \ldots, Min(x,\ G - y_1 - \ldots - y_{q-2})$.

We use $q = 2$ as an example to find the optimal policies for the EOQ model. In this example, we have only one random variable y_1 and there are x units at the first inspection and $y-x$ units at the second one. After the first inspection, the inventory level are $y-y_1$ if $y_1 < d$, $y-d$ if $y_1 \geqq d$. Also after the second inspection, the inventory level are $y-y_1-\underline{rd}$ if $y_1 < d$, $y-d-\underline{rd}$ if $y_1 \geqq d$, where $\underline{rd}$ denotes the rounded value of $\underline{rd}$.

Let $TCPUT_1(y_1)$ be the total cost per unit time of shortages at the first inspection and $TCPUT_2(y_1)$ the total cost per unit time of non-shortages at the first inspection. Moreover, we can get that

$$TCPUT_1(Y_1) = \frac{\left\{K + cy + dy + h\left[\frac{1\times(y+y-Y_1)}{2} + \frac{r\times\left(y-Y_1+y-Y_1-\overline{rD}\right)}{2} + \frac{\left(y-Y_1-\overline{rD}-N\right)^2/D}{2}\right] + (D-Y_1)\times s\right\}}{t + \frac{\left(y-Y_1-\overline{rD}-N\right)}{D}} \tag{5}$$

and

$$TCPUT_2(Y_1) = \frac{\left\{K + cy + dy + h\left[\frac{1\times(y+y-D)}{2} + \frac{r\times\left(y-D+y-D-\overline{rD}\right)}{2} + \frac{\left(y-D-\overline{rD}-N\right)^2/D}{2}\right]\right\}}{t + \frac{\left(y-D-\overline{rD}-N\right)}{D}} \tag{6}$$

Furthermore, we consider the situation for $(q-1)$ of random variables. After similar computational procedure, the expected total cost per unit time when p is fixed can be written as:

$$ETCPUT|_p = \sum\sum \cdots \sum f(y_1,\ y_2,\ \ldots,\ y_{q-1}|p) \times \left[TCPUT_i(y_1,\ y_2,\ \ldots,\ y_{q-1}|p)\right], i = 1, \ldots, 2^{q-1}, \tag{7}$$

where $f(y_1,\ y_2,\ \ldots,\ y_{q-1}|p)$ is the joint hypergeometric probability of $(y_1, y_2, \ldots, y_{q-1})$ when p is given, and

$$f(y_1, y_2, \ldots, y_{q-1}|p) = \frac{\binom{G}{y_1}\binom{N}{x-y_1}}{\binom{y}{x}} \times \frac{\binom{G-y_1}{y_2}\binom{N-(x-y_1)}{x-y_2}}{\binom{y-x}{x}} \times \ldots \times \frac{\binom{G-y_1-\ldots-y_{q-2}}{y_{q-1}}\binom{N-((q-2)x-y_1-\ldots-y_{q-2})}{x-y_{q-1}}}{\binom{y-(q-2)x}{x}}$$

$$= \frac{\binom{G}{y_1,\ y_2,\ \ldots,\ y_{q-1}}\binom{N}{x-y_1,\ x-y_2, \ldots,\ x-y_{q-1}}}{\binom{y}{x,\ x, \ldots,\ x}},$$

$$y_i = 0,\ 1, \ldots,\ x \text{ for } i = 1,\ 2,\ \ldots,\ q-1,\ \sum_{i=1}^{q} y_i = G \tag{8}$$

Actually the assumption of fixed p is unrealistic in the real-life. We now discuss the cases when p is a random variable. Assumed that $K, c, D\ldots$ are known, the expected total cost per unit time can be composed by the function of y and p:

$$\begin{aligned} ETCPUT &= \sum\sum \ldots \sum f(y_1,\ y_2,\ \ldots,\ y_{q-1},\ p) \times \left[TCPUT_n(y_1,\ y_2, \ldots,\ y_{q-1}|p)\right] \\ &= \text{g}(y, p), \end{aligned} \tag{9}$$

where $p \sim Uniform\ (\alpha,\ \beta),\ \ \beta > \alpha \geq 0$. Thus we can have

$$E[ETCPUT] = \int_{\alpha}^{\beta} h(p) \cdot ETCPUT \cdot dp = \int_{\alpha}^{\beta} h(p) \cdot g(y,\ p) \cdot dp = ETCPUT(y) \tag{10}$$

Note that we cannot get the integrals directly and may use the method of "Riemann sum" to approach true values of these integrals. Hence,

$$\begin{aligned} ETCPUT(y) &= \int_{\alpha}^{\beta} h(p) \cdot g(y,\ p) \cdot dp \cong \frac{\beta-\alpha}{n} \cdot \sum_{i=1}^{n} h(p_i^*) \cdot g(y,\ p_i^*) \\ &= \frac{\beta-\alpha}{n} \cdot \sum_{i=1}^{n} h(p_i^*) \cdot ETCPUT|_{p_i^*} = \frac{1}{n}\sum_{i=1}^{n} ETCPUT|_{p_i^*} \end{aligned} \tag{11}$$

$i = 1,\ 2,\ \ldots,\ n$, where p_i^* is the ith range average value of equal length.

The objective of this paper is to find the optimal order quantity y^* such that ETCPUT(y^*), the expected total cost per unit time at $y = y^*$, is the minimum over domain of y. Unlike the procedure in Salameh and Jaber's (2000) EOQ model, we

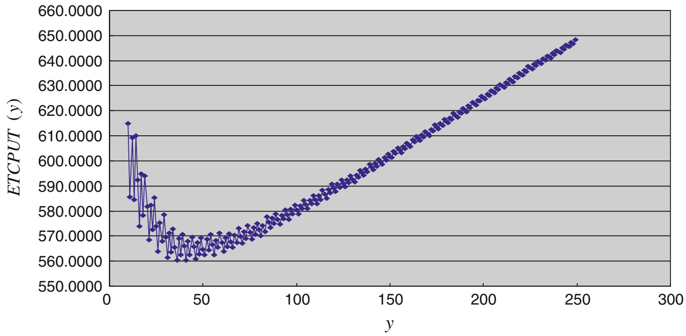


Fig. 1 The expected total cost per unit time

cannot use differentiation to find y^* because y is discrete, a numerical approach method can be utilized to find the optimal order quantity y^* in our study.

4 Numerical Results

The following is a numerical example that applied to our mathematical model to demonstrate the ^{method} that we discussed in Sect. 3. It follows the related parameters: $K = \$50$/cycle, $c = \$25$, $d = \$0.5$, $s = \$30$, $h = \$1$/unit, $D = 20$/unit, and $x = 50$/unit.

Let $p \sim \mathit{Uniform}\ (0,\ 0.04)$, the result are obtained by running Fortune codes for $y = 10, 11, \ldots, 249$ under non-shortage case, we compute the values of ETCPUT|$p(y)$ and summarize the results in Fig. 1. From Fig. 1, a convex pattern is shown and we can get the optimal order quantity $y^* = 41$ and ETCPUT|$p(y^*) = 560.3193$.

5 Conclusions

In this paper, for the EOQ model with imperfect items, we propose the assumptions of y and p to consist with the real-life situations. Based on them, a mathematical discussion is provided to construct an optimal inventory model and to ensure the occurrence of non-shortages discussed for dealing with the possibilities of the shortage problem.

References

Chang HC (2004) An application of fuzzy sets theory to the EOQ model with imperfect quality items. Comput Oper Res 31(12):2079–2092

Chung KJ, Huang YF (2006) Retailer's optimal cycle times in the EOQ model with imperfect quality and a permissible credit period. Qual Quant 40:59–77

Montgomery DC (2001) Introduction to statistical quality control. Wiley, New York

Papachristos S, Konstantaras I (2006) Economic ordering quantity models for items with imperfect quality. Int J Prod Econ 100(1):148–154

Rezaeli J (2005) Economic order quantity model with backorder for imperfect quality items. IEEE Int Eng Manage Conf II 1559191:466–470

Salameh MK, Jaber MY (2000) Economic production quantity model for items with imperfect quality. Int J Prod Econ 64(1):59–64

Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling. Wiley, New York

Stevenson WJ (2004) Operations management. McGraw-Hill, New York

Yu CP, Wee HM, Chen JM (2005) Optimal ordering policy for a deteriorating items with imperfect and partial backordering. J Chinese Inst Indu Eng 22:509–520

Power, Relationship Commitment and Supplier Integration in Taiwan

Jen-Ying Shih and Sheng-Jie Lu

Abstract This research extends power-relationship commitment theory to investigate the impact of power and relationship commitment on supplier integration from manufacturers' perception toward their major suppliers in supply chain context in Taiwan. The power sources include expert power, referent power, legitimate power, reward power and coercive power, which can be categorized as non-mediated power and mediated power. Two types of the relationship commitment are studied, including normative relationship commitment and instrumental relationship commitment. The integration between manufacturers and suppliers (supplier integration) is measured by information integration and strategic integration. Based on a survey using data on 193 manufacturers in Taiwan, results indicate that coercive power has a positive influence on instrumental relationship commitment; however, reward power has no significant impact on any type of relationship commitment. Expert and referent power have positive impact on normative relationship commitment, while legitimate power has no significant influence on relationship commitment. Both normative and instrumental relationship commitment have positive impact on supplier integration and the former has a stronger influence than the latter. The findings can help companies enhance their supply chain integration by developing appropriate relationships with their suppliers.

Keywords Supply chain · Power · Relationship commitment · Supplier integration

J.-Y. Shih (✉)
Graduate Institute of Global Business and Strategy, National Taiwan Normal University, 162, He-ping East Road, Section 1, Taipei 10610, Taiwan, Republic of China
e-mail: jyshih@ntnu.edu.tw

S.-J. Lu
Department of Business Administration, Chang Gung University, 259, Wen-Hwa 1st Road, Taoyuang 333, Taiwan, Republic of China
e-mail: myronlu@pchome.com.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_111,

1 Introduction

The increasing global competition has enhanced awareness of the importance of supply chain management in global businesses (Flint et al. 2008). Nowadays, the focus of supply chain management is not only on cost reduction but it also extends to business agility so as to meet the requirements of challenging business environments (Lee 2004), which shifts the emphasis of supply chain integration to quick and effective response to the volatile environments. Supply chain integration involves information sharing, planning, coordinating and controlling materials, parts and finished goods at the strategic, tactical and operational levels (Stevens 1989). It has been found to be important in enhancing material flow, product development, delivery speed, dependability and flexibility (Carter and Narasimhan 1996; Boyer and Lewis 2002; Flynn and Flynn 2004). Thus, supply chain integration is also an important factor in enabling supply chain management.

Past research regarding marketing channel had investigated power influences issue through the power-relationship commitment theory (Brown et al. 1995). Power plays an important role in the supply chain, and different bases of power have contrasting influences on relationship commitment to supply chain partnership. Effects of power influences on relationship commitment to supply chain partnership and subsequent effects of this partnership upon supply chain performance expose the potential of power as a tool to promote integration of the supply chain. Thus, both the power holder and the power target must be able to recognize the presence of power, and then reconcile supply chain management for power influences. Maloni and Benton (2000) examined supply chain management from the power influences perspective by extending the power-relationship commitment theory established in marketing channel literature to a supply chain context.

Zhao et al. (2008) applied the power-relationship commitment theory to study its impact on customer integration in supply chain context from the viewpoint of a manufacturer toward its main customer by investigating the relationships among perceived customer power, manufacturers' commitment to maintain customer relationship and customer integration in China. Thus, the power-relationship commitment theory was linked with supply chain integration. In addition, because high power distance and collectivism are two important characteristics of China's national culture, their work demonstrated a different pattern of power-relationship commitment in Chinese manufacturers.

However, their study only investigated the impact of power-relationship commitment on customer integration, which lacks the investigation regarding if a manufacturer's perceived power-relationship commitment toward its main supplier has influence on supplier integration. Supplier integration is also an important component in supply chain integration. Therefore, this research extends power-relationship commitment theory to investigate the impact of power and relationship commitment on supplier integration from manufacturers' perception toward their major suppliers in supply chain context in Taiwan. The purpose of this research is to investigate the impact of the exercise of supplier power on a manufacturer's relationship commitment and to investigate how a manufacturer's relationship commitment to its supplier affects supplier integration. Thus, we propose and empirically test a model that represents the relationships among supplier power, relationship commitment and supplier integration in supply chain context.

2 Theoretical Background

Brwon et al. (1995) argued that the sellers' use of different source of power may bring different retailers' relationship commitment to the channel relationship in their marketing channel study. This argument motivated supply chain research to investigate if the power-relationship commitment structure is an enabler of supply chain integration (Zhao et al. 2008). Following this viewpoint, to investigate the impact of perceived suppliers' power usage on manufacturers' commitment to the manufacturer-supplier relationship, the conceptual definition of power in this research is the ability of a supplier to influence the decisions of a manufacturer in a supplier chain. Because French and Raven (1959) classified power into five sources, which have been applied in a lot of empirical research regarding power issue (Brown et al. 1995), this research used the five-source power structure to represent power usage.

The five sources of power include expert power, referent power, legitimate power, reward power and coercive power, which can be mapped to non-mediated power and mediated power in terms of Brown et al. (1995). The definition of the five-source power is provided in Table 1, which is adapted from Zhao et al. (2008) and Maloni and Benton (2000). Non-mediated power indicates that the manufacturer decides by itself whether and how its decision is affected by the power source but not forced by the power source. Mediated power reveals that the power source uses their power to influence the decision of power target to meet the expectation of power source. Therefore, expert power, referent power and legitimate power are considered as non-mediated power. Reward power and coercive power are regarded as mediated power.

The conceptual definition of relationship commitment is the willingness of a party (manufacturer) to maintain a relationship through the investment of financial, physical, or relationship-based resources in the relationship (Morgan and Hunt 1994). In this research, it is an attitude or willingness of a manufacturer to develop and maintain a stable, long-lasting relationship. Past research classified relationship commitment as "normative relationship commitment" and "instrumental relationship commitment". The definition of relationship commitment is shown in Table 2, which is adapted from Zhao et al. (2008) and Morgan and Hunt (1994).

Based on the argument provided by Brown et al. (1995), instrumental relationship commitment is based on evaluation of costs and benefits in developing relationship; therefore, we expected that reward and coercive power would be positively related to it; however, overly exercise of the two mediated power may damage normative relationship commitment. In contrast with the use of mediated

Table 1 Power sources

Power source	Conceptual definition	Operational definition (Scale items)
Reward power	Supplier has the ability to mediate rewards to manufacturer	A. If we do not do what as our major supplier asks, we will not receive very good treatment from it B. We feel that, by going along with our major supplier, we will be favored by it on some other occasions C. By going along with our major supplier's requests, we have avoided some of the problems other customers face D. Our major supplier often rewards us, in order to get our company to go along with its wishes
Coercive power	Supplier has the ability to mediate punishment to manufacturer and manufacturer is thus forced to satisfy the requirement of supplier.	A. Our major supplier's personnel will somehow get back at us if they discover that we did not do as they asked B. Our major supplier often hints that it will take certain actions that will reduce our profits if we do not go along with its requests C. Our major supplier might withdraw certain needed services from us if we do not go along with its requests D. If our company does not agree to its suggestions, our major supplier could make things more difficult for us
Expert power	Supplier has knowledge, expertise or skills desired by the manufacturer so that the manufacturer is willing to meet the expectation of the supplier	A. Our major supplier's business expertise makes it likely to suggest the proper thing to do B. The people in our major supplier's organization know what they are doing C. We usually get good advice from our major supplier D. Our major supplier has specially trained people who really know what has to be done

(continued)

Table 1 (continued)

Power source	Conceptual definition	Operational definition (Scale items)
Referent power	Manufacturer values identification with the supplier	A. We really admire the way our major supplier runs its business, so we try to follow its lead B. We generally want to operate our company very similar to the way we think our major supplier would C. Our company does what our major supplier wants because we have very similar feelings about the way a business should be run D. Because our company is proud to be affiliated with our major supplier, we often do what it asks
Legitimate power	Manufacturers believe their suppliers retain natural right to influence their decisions	A. It is our duty to do as our major supplier requests B. We have an obligation to do what our major supplier wants, even though it isn't a part of the contract C. Since it is the supplier, we accept our major supplier's recommendations D. Our major supplier has the right to expect us to go along with its requests

Table 2 Relationship commitment typology

Power source	Conceptual definition	Operational definition (scale items)
Normative relationship commitment	Manufacturer maintain a long- term relationship based on mutual commitment (e.g., trust) and sharing	A. We feel that our major supplier views us as an important "team member," rather than just another customer B. We are proud to tell others that we are a customer for our major supplier C. Our attachment to our major supplier is primarily based on the similarity between its values and ours D. The reason we prefer our major supplier to others is because of what it stands for, its values E. During the past year, our company's values and those of our major supplier have become more similar F. What our major supplier stands for is important to our company
Instrumental relationship commitment	Manufacturer is willing to be influenced by supplier on the expectation of receiving favorable reactions from supplier	A. Unless we are rewarded for it in some way, we see no reason to expend extra effort on behalf of our major supplier B. How hard we work for our major supplier is directly linked to how much we are rewarded by it

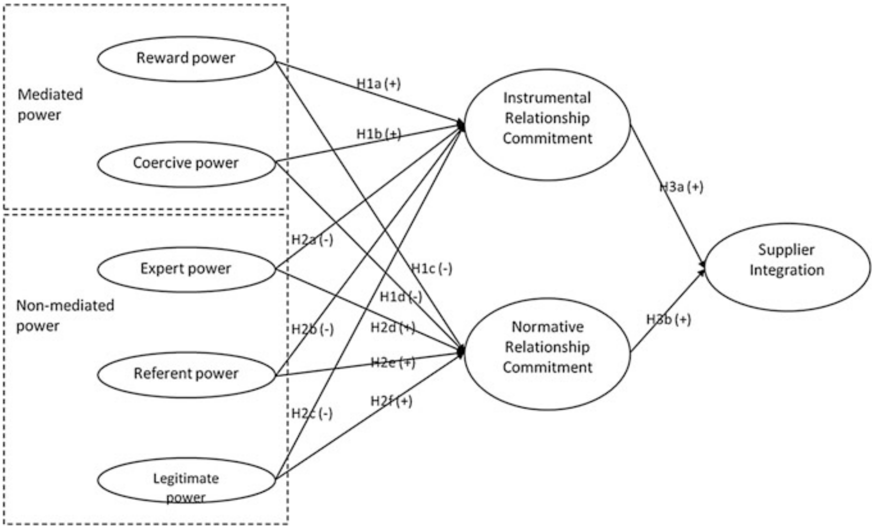


Fig. 1 Conceptual model

power, the use of non-mediated power may enhance positive attitudes toward partner relationship which, in turn, enhance normative relationship commitment. Therefore, expert, referent and legitimate power may demonstrate positive relationships with normative relationship commitment; however, the use of non-mediated power may lower instrumental relationship commitment. The reason is that the more power holder uses non-mediated power to influence channel members (power target), the more it focuses upon long-term relationship, which is a kind of intrinsic factor, therefore, extrinsic factors such as rewards and punishments become less important. Accordingly, the hypotheses of this research are demonstrated in a conceptual model shown in Fig. 1.

Zhao et al. (2008) propose that both types of relationship commitment are positively related with supply chain integration based on traction cost theory and social exchange theory. Because supply chain integration is created by cooperative, mutually beneficial partnerships with supply chain members, relationship commitment thus plays a very important role in supply chain integration. In this research, we examine influence of two types of relationship commitment on supplier integration.

3 Research Methodology

This research used purposive sampling approach to select subject companies from a sampling frame, which is composed of several directories provided by "China Productivity Center", "Metal Industries Research and Development Center", "Small and Medium Enterprise Administration, Ministry of Economic Affairs", and "Industrial Development Bureau, Ministry of Economic Affairs". A total of 511 possible valid participants were contacted through survey mailings. The follow-up calls yielded a total of 222 respondents. Twenty-nine of the responses were deemed unusable due to incompleteness, missing data, or excessive response of "no opinion". The cleansing yielded a sample of 193 responses with a response rate of 37.77 %.

Manufacturers' responses to the survey questions (parts of them are shown in Tables 1 and 2; survey items of supplier integration construct are available upon request.) indicated the extent of their agreement with instrument items. Each question sought responses based on a Likert scale from 1 (strongly disagree) to 7 (strongly agree). A strict process for instrument development was employed to develop and validate the survey instrument, modeled on previous empirical literatures (Chen and Paulraj 2004; Garver and Mentzer 1999; Min and Mentzer 2004). The content validity for the survey instrument was refined through literature review, in-depth interview conducted with experts and researchers and iterative pilot testing prior to data collection. All of the instrument items for related constructs were developed from an extensive review of the academic and practitioner literatures to measure the research variables.

Given the multiple dependence relationships in this research, structural equation modeling (SEM) is a suitable statistical tool to evaluate the conceptual model (Fig. 1). SEM measures multiple relationships between independent and dependent variables, extending the concept of a single dependence-based regression equation to accommodate multiple dependence relationship simultaneously in an aggregate model. We used LISREL software to estimate the causal relationships among the constructs in our research model, which is able to concurrently test all of the proposed research hypotheses.

We performed a series of analyses to test construct validity and reliability after data collection. Confirmatory factor analysis (CFA) was conducted to justify the factor structure. Construct reliability was established through analysis of composite reliability and average variance extracted. The validity of the constructs showed that the instrument items correlate with what they were intended to measure and do not correlate with other constructs.

4 Results

The SEM result is provided in Fig. 2. Reward power is not significantly related to either type of relationship commitment, while coercive power has a positive impact on instrumental relationship commitment, but has no impact on normative relationship commitment, indicating that only use of coercive power may enhance manufacturer's instrumental relationship commitment.

The path coefficients in Fig. 2 reveal that supplier's expert, referent and legitimate power have no significant impact on instrumental relationship

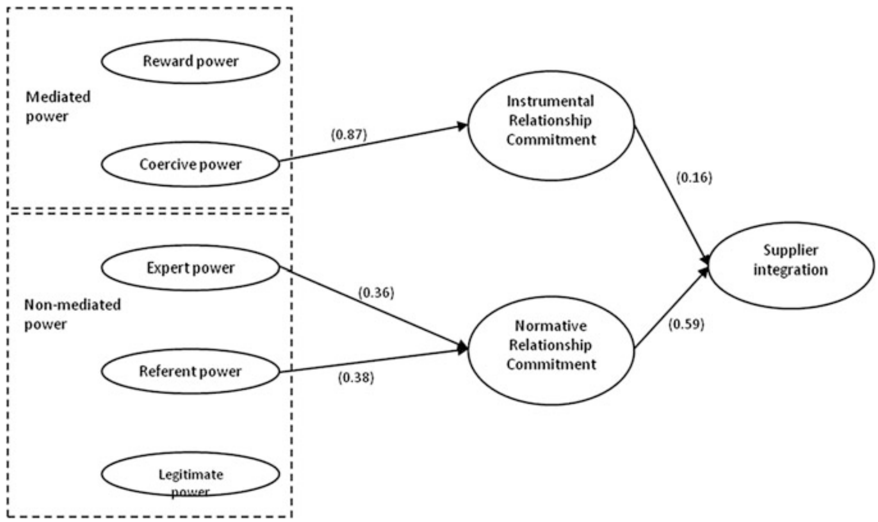


Fig. 2 Structural equation model

commitment. However, expert and referent power have positive impact on normative relationship commitment, but legitimate power has no impact on it. The influences of expert and referent power on normative relationship commitment indicate that supplier's use of these two non-mediated power may enhance manufacturer's normative relationship commitment.

Both normative and instrumental relationship commitment have positive impact on supplier integration and the former has a stronger influence than the latter. The findings can help companies enhance their supply chain integration by developing appropriate relationships with their suppliers.

References

Boyer KK, Lewis MW (2002) Competitive priorities: investigating the need for trade-offs in operations strategy. Prod Oper Manage 11(1):9–20

Brown JR, Lusch RF, Nicholson CY (1995) Power and relationship commitment: their impact on marketing channel member performance. J Retail 71(4):363–392

Carter JR, Narasimhan R (1996) Is purchasing really strategic? J Supply Chain Manage 32(1):20–28

Chen IJ, Paulraj A (2004) Understanding supply chain management: critical research and a theoretical framework. Int J Prod Res 42(1):131–163

Flint DJ, Larsson E, Gammelgaard B (2008) Exploring processes for customer value insights, supply chain learning and innovation: an international study. J Bus Logistics 29(1):257–281

Flynn BB, Flynn EJ (2004) An exploratory study of the nature of cumulative capabilities. J Oper Manage 22(5):439–458

French RP, Raven BH (1959) The bases of social power. In: Cartwright D (ed) Studies in social power. University of Michigan Press, Ann Arbor, pp 155–164

Garver M, Mentzer JT (1999) Logistics research methods: employing structural equation modeling to test for construct validity. J Bus Logistics 20(1):33–58

Lee HL (2004) The triple-a supply chain. Harvard Bus Rev 82(10):102–113

Maloni M, Benton WC (2000) Power influences in the supply chain. J Bus Logistics 21(1):49–73

Min S, Mentzer JT (2004) Developing and measuring supply chain management concepts. J Bus Logistics 25(1):63–99

Morgan RM, Hunt SD (1994) The commitment-trust theory of relationship marketing. J Mark 58(3):20–38

Stevens GC (1989) Integrating the supply chain. Int J Phys Distrib Logistics Manage 19(8):3–8

Zhao X, Huo B, Flynn BB, Yeung J (2008) The impact of power and relationship commitment on the integration between manufacturers and customers in a supply chain. J Oper Manage 26:368–388

A Search Mechanism for Geographic Information Processing System

Hsine-Jen Tsai, Chiang-Sheng Lee and Les Miller

Abstract Geographic data is becoming a critical part of mobile applications. Public and private sectors agencies create and make geographic data available to the public. Applications can make request to download maps to help the user navigate her/his surroundings or geographic data may be downloaded for use in the applications. The complexity and richness of geographic data create specific problems in heterogeneous data integration. To deal with this type of data integration, a spatial mediator embedded in a large distributed mobile environment (GeoGrid) has been proposed in earlier work. The present work looks at a search mechanism used in the spatial mediator that utilizes an algorithm to support the search of the data sources in response to application's request for maps. The algorithm dynamically evaluates uncovered region of the bounding box of the request in an attempt to search for a minimal set of data sources.

Keywords Information processing · Data integration · Geographic data · Mediator

H.-J. Tsai (✉)
Department of Information Management, Fu-Jen Catholic University, New Taipei, Taiwan, Republic of China
e-mail: tsai.fju@gmail.com

C.-S. Lee
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: cslee@mail.ntust.edu.tw

L. Miller
Department of Computer Science, Iowa State University, Ames, USA
e-mail: lmiller@cs.iastate.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_112,

1 Introduction

Every local system designer tends to develop the database that can meet his/her organization's specific needs. It results in a great deal of diversity in a multiple heterogeneous data sources environment. In this environment, a variety of sources and applications use different data models, representations and interfaces. System designers need to develop integrated systems that allow users to access and manage information from multiple heterogeneous data sources. One reason for such need has been that environments for data access have changed from centralized data systems into multiple, distributed data sources. This need becomes even more critical in the mobile computing applications. In the mobile grid, geographic data plays an especially important role. A mobile computer in the mobile grid can either be a user or a creator of geographic data. Mobile applications can make use of downloaded maps to help the user navigate her/his surroundings or geographic data may be downloaded for use in the application. To support this view of geographic data use in the mobile grid, we see the need for an infrastructure embedded in the grid that supplies the tools necessary to locate the appropriate geographic data, has the capacity to modify the data to fit the application and the device it is being used on, and to direct the movement of the data to and from the field. One of the key capabilities of such an infrastructure is to locate data sources that can generate maps which can cover the region of the user's request.

Data quality is an important issue in the geographic data integration. It is easier to maintain a better data quality when fewer data sources are involved in the integration process. A reasonable goal of a geographic data integration system is to locate as minimal number of data sources needed as possible. This paper proposes a dynamic process that attempts to create maps from minimal number of data sources. Specifically, we present an algorithm that tends to find the minimum number of maps to cover the bounding box of a request.

In the next section we briefly look at the related work. Section 3 briefly looks at the GeoGrid model. Section 4 introduces the spatial mediator and the search algorithm. Finally, Sect. 5 provides some concluding remarks.

2 Related Work

The complexity and richness of geographic data create specific problems in heterogeneous data integration. Geographic data is very diverse and dynamic. The geospatial information may be unstructured or semi-structured, and usually there is no regular schema to describe them. As the amount of geographic data grows, the problem of interoperability between multiple geographic data sources becomes the critical issue in the developing distributed geographic systems. Many approaches have been proposed to provide solutions to this problem. The concept of a spatial mediator has gained increasing interest in projects dealing with distributed geographic data (Zaslavsky et al. 2004; Park and Ram 2004). A mediator is build to provide a uniform interface to a number of heterogeneous data sources. Given a user query, the mediator decomposes it into multiple local sub-queries and sent them to the appropriate data sources, merges the partial results and reports the final answer to the user. There is an increasing demand for geospatial information services to support interoperation of massive repositories of heterogeneous geospatial data on Internet. VirGIS is a mediation platform that utilizes an ontology and provides an integrated view of geographic data (Essid et al. 2006). The architecture of a mediator is developed to enable a user to query spatial data from a collection of distributed heterogeneous data sources. They use GML (Geography Markup Language) [OpenGIS] in their implementation to facilitate data integration.

Data quality and metadata are crucial for the development of geographic information Systems. A group of researchers have developed spatial mediation system that focus on spatial quality issues. Lassoued et al. (2007) proposes a quality-driven mediation approach that allows a community of users to share a set of autonomous, heterogeneous and distributed geospatial data sources with different quality information. A common vision of the data that is defined by means of a global schema and a metadata schema is shared by users. The QGM (Quality-driven Geospatial Mediator) supports efficient and accurate integration of geospatial data from a large number of sources (Thakkar et al. 2007). It features an ability to automatically estimate the quality of data provided by a source by using the information from another source of known quality. QGM represents the quality information in a declarative data integration framework, and exploit the quality of data to provide more accurate answers for user queries.

The work done in this paper expands on the work described in (Tsai 2011) that proposes a spatial mediator embedded in a large distributed mobile environment (GeoGrid) (Miller et al. 2007; Tsai et al. 2006). The spatial mediator takes a user request from a field application and uses the request to select the appropriate data sources, constructs subqueries for the selected data sources, defines the process of combining the results from the subqueries, and develops an integration script that controls the integration process in order to respond to the request.

3 GeoGrid Model

To represent the relationship between the components in GeoGrid, it is helpful to visualize GeoGrid as a directed graph G(N,E). N is a set of nodes with some processing power focused on supporting the GeoGrid infrastructure. The edges in the edge set E represent the communication links that tie the components of GeoGrid together. Figure 1 provides a simple illustration of the GeoGrid infrastructure (Miller and Nusser 2002).

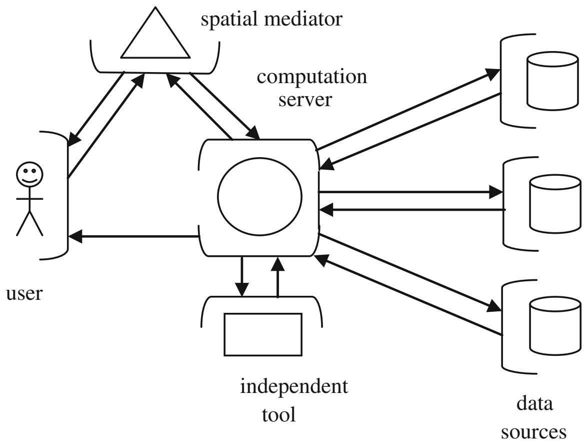


Fig. 1 A simple GeoGrid graph showing the nodes and the data flow for a mediated data request

The process of using the infrastructure starts with a user application in the field sending a request to the spatial mediator. The spatial mediator in turn uses the request to locate the data sources (via LIVs) needed to generate the requested spatial object and form the integration script that defines integration tools. The integration script is passed to the computation server where it is used to manage the process of obtaining the data and creating the spatial object(s). The resulting spatial object (e.g., a map) is then passed back to the user's application.

3.1 Data Sources

The basic structure of a data source is given in Fig. 2. The local interface view (LIV) (Yen and Miller 1995) is designed to export data from the data source into the GeoGrid environment. The number and type of LIVs is a local decision dependent on how the local information manager wants to share the available data within GeoGrid.

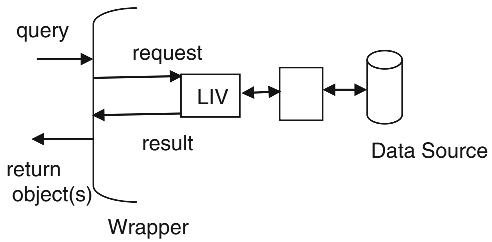


Fig. 2 Data source node layout and request/data flow for retrieval

4 Spatial Mediator

Data is evaluated by the spatial mediator as a set of spatial objects defined through local interface views (LIVs). While spatial objects can take on many forms, the focus here is on spatial objects that define maps. Each data source contributes one or more LIVs, where each LIV can be used to generate a map.

The mediation process starts with the spatial mediator determining the LIVs that are capable of responding to all or part of the incoming request. To do this, the spatial mediator makes use of the LIV registration data. A Facts database is used to identify LIVs that satisfy keywords, theme, or property requirements in the request. Location requirements can take either symbolic (e.g., a city name) or point/bounding box values.

Two lists of LIVs are created to allow the mediator to partition the LIVs into those that cover the requested map area and those that overlap part of the requested map area. The motivation for the two lists is to allow our algorithms to first examine the quality of any complete cover LIVs (if they exist) and only go to the process of generating grouping when they are required. To find the needed LIVs the mediator starts by examining the complete cover LIVs. When no covering LIVs can fulfill the request, the mediator switches to the list of partial covering LIVs. To locate LIVs, the mediator utilizes a search algorithm to locate needed LIVs. The search algorithm continues until either the collection of uncovered bounding boxes is empty or the requested map area is totally covered and the current map grouping is returned.

A grouping is recursively defined as consisting of a tool type name and a list of objects such that each object is either an LIV or a grouping. Once an acceptable map grouping has been generated, it needs to be converted to a syntax recognizable script to the computation server. The tool types must be replaced with actual tool names available in the computation server. Other information related to located LIVs such as the address of the data source site (e.g., IP address, url), and the layout of the spatial object(s) generated by the data source are also included. We call the resulting script the integration script. As mentioned in Sect. 3, the integration script is used to manage the process of obtaining the data and creating the spatial object(s). The resulting spatial object (e.g., a map) is then passed back to the user's application.

This paper highlights a search algorithm used by the mediator that tends to find the minimum number of LIVs to cover the bounding box of a request. The algorithm maintains a list of LIVs whose bounding boxes overlap part of the bounding box of the request which is referred as PartialCoverageList The search algorithm is described in the following section.

4.1 The Search Algorithm

The following algorithm tends to find the minimum number of LIVs to cover the bounding box of the incoming request. A bounding box is an area defined by two longitudes and two latitudes and specified by the set of coordinates which represents the left-bottom and right-top of the bounding box. The left-bottom point is the minimum longitude and minimum latitude. The right-top point is specified by the maximum longitude and maximum latitude of the bounding box. Given a set of LIVs that partially overlap the request bounding box and a list of LIVs whose bounding boxes overlap part of the request bounding box, the algorithm starts the search by attempting to cover from the left-top corner of the request bounding box to the right-bottom corner of the bounding box.

Before introducing the algorithm, some symbols are defined as follows.

1. Let P be the set of corner points of the region that has not be covered by the located LIVs. Initial values for P is the set of four corner points of the request bounding box. For example, P = $\{x_1 = (a_1, b_1), x_2 = (a_2, b_1), x_3 = (a_1, b_2), x_4 = (a_2, b_2)\}$, where x_1 and x_4 are the left-top and right-bottom corner points of the request bounding box respectively. That is, a_1 is the minimum longitude and b_1 is the maximum latitude of the bounding box, a_2 and b_2 are the maximum longitude and minimum latitude respectively (see Fig. 3).
2. Let $S_i = (s_{i1}, s_{i2}, s_{i3}, s_{i4})$ be the set of four longitude/latitude coordinates of the bounding box with (s_{i1}, s_{i2}) for the left-top corner point and (s_{i3}, s_{i4}) for the right-bottom corner point.

The algorithm is described as follows.

Step 1. Determine the left most point with maximum latitude ℓ_2 and the right-bottom point $r = (r_1, r_2)$ from the point set P. Set k = 0 at beginning.
Step 2. Find all LIVs from the PartialCoverageList that covers the point $\ell = (\ell_1, \ell_2)$ and define this set to be $S = \{S_1, S_2, \ldots, S_N\}$.
Step 3. Determine the map S_j by finding the largest inside area below the latitude ℓ_2, that is,

$S_j = \max_{i \in S}\{(\min\{s_{i3}, r_1\} - \ell_1) * (\min\{s_{i4}, r_2\} - \ell_2)\}$If there are more than one LIV with the same area, then any one of them is chosen.

The reason to compute the area below the latitude ℓ_2 is to reduce the overlapping area.

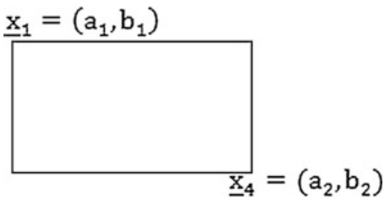


Fig. 3 A request bounding box with (a_1, b_1) and (a_2, b_2)

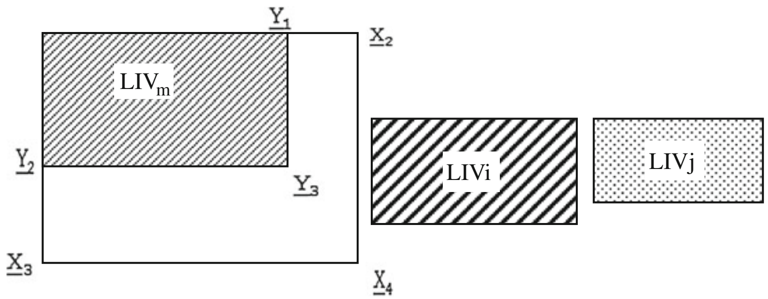


Fig. 4 Covered status of the request bounding box after algorithm finds a LIV_m

Step 4. Set k = k+1 and examine the following two cases.
(a) Delete the corner point from P if the point is covered by the above LIV, and
(b) Add the new corner points to P if they are generated by the new LIV.

If the set P becomes empty after Step 4, then the algorithm stops. Otherwise, it goes to Step 1.

The following example illustrates the search algorithm.

If the bounding box of the request is specified by (a_1, b_1) and (a_2, b_2), then the initial values are set as follows: $P = \{x_1 = (a_1, b_1), x_2 = (a_2, b_1), x_3 = (a_1, b_2), x_4 = (a_2, b_2)\}$, $\ell = (\ell_1, \ell_2) = (a_1, b_1)$, $r = (r_1, r_2) = (a_2, b_2)$ and $k = 0$.

Figure 4 shows the covering status of the request bounding box after algorithm finds a LIV (i.e. LIV_m) that cover the left-top corner of the request bounding box which is shaded under the diagonal line. Set P has new value which is $\{Y_1, Y_2, Y_3, X_2, X_3, X_4\}$. The algorithm then locates two LIVs that cover point Y_2. The algorithm selects LIVi over LIVj since the area of LIVi is greater than the area of LIVj. Since P is not empty, the algorithm continues until P becomes empty.

5 Conclusions

The GeoGrid structure for supporting the use of geographic data within a mobile computing environment has been designed and prototyped. GeoGrid makes use of a set of intelligent components, highlighted by a spatial mediator for providing data source selection, appropriate query construction for the chosen data sources and creation of the necessary geographic data manipulation operations to integrate the results of the queries if more than one data source is needed. In particular, a search algorithm that tends to find minimum number of maps to cover the bounding box of request from the user in GeoGrid is proposed.

References

Essid M, Colonna F, Boucelma O (2006) Querying mediated geographic data sources. Adv Database Technol 3896:1176–1181

Lassoued Y, Essid M, Boucelma O, Quafafou M (2007) Quality-driven mediation for geographic data. In: Proceedings of QDB, pp 27–38

Miller L, Nusser S (2002) Supporting geospatial data in the field. In: Proceedings of the 11th GITA conference on geographic information systems for oil and gas, pp 139–151

Miller L, Ming H, Tsai H, Wemhoff B, Nusser S (2007) Supporting geographic data in the mobil computing environment. In: Proceedings of parallel and distributed computing systems (PDCS-2007), ISCA 20th international conference Sept, Las Vegas, Nevada, pp 24–26

Park J, Ram S (2004) Information systems interoperability: What lies beneath? ACM Trans Inf Syst (TOIS) 22(4):595–632

Thakkar S, Knoblock C, Ambite J (2007) Quality-driven geospatial data integration. Paper presented at the 15th international symposium on advances in geographic information systems, ACM GIS, pp 44–49

Tsai H (2011) A spatial mediator model for integrating heterogeneous spatial data. Iowa State University, Dissertation

Tsai H, Miller L, Ming H, Wemhoffm B, Nusser S (2006) Combining spatial data from multiple data sources. In: Proceedings of the ISCA 19th international conference on computer applications in industry and engineering, pp 89–94

Yen C, Miller L (1995) An extensible view system for multidatabase integration and interoperation. Integ Comput Aided Eng 2:97–123

Zaslavsky H, Tran J, Martone M, Gupta A (2004) Integrating brain data spatially: spatial data infrastructure and atlas environment for online federation and analysis of brain images. Biological data management workshop (BIDM 2004) in conjunction with 15th international workshop on database and expert systems applications (DEXA'04), Zaragosa, Spain, Aug/Sept 2004, pp 389–393

Maximum Acceptable Weight Limit on Carrying a Food Tray

Ren-Liu Jang

Abstract This study was to simulate two ways to carry a food tray, waist-level carry and shoulder-high carry, to determine their maximum acceptable weight of load (MAWL) and to suggest a proper weight for banquet servers or workers in restaurants. Twenty college students were participated in this study. The MAWL on shoulder-high carry was 3.32 ± 0.47 kg for male and 2.78 ± 0.35 kg for female, respectively. The MAWL on waist-level carry were 2.57 ± 0.26 kg for male and 2.21 ± 0.35 kg for female. There were significantly differences between gender and carry methods. On average, the MAWL on waist-level carry was 22 % less than that on shoulder-high carry. The MAWL of female on waist-level carry was 14 % less than that for male while the MAWL of female on shoulder-high carry was 16 % less than that for male. The results suggested banquet servers or workers in restaurants should consider the proper way to deliver the food when it gets heavy.

Keywords MAWL · Food tray

1 Introduction

Banquet servers were responsible for good interactions with guests such as serving guests in a friendly and efficient manner. Meanwhile, they were expected to be attentive to the guest needs and make them feel welcome and comfortable. During the banquet, servers needed to maintain proper dining experience, deliver and remove courses, fulfill customer needs, replenish utensils and glasses. As results, servers normally walked for long periods of time, possibly extended distances in a banquet service. In food service, there were two basic hold positions to correctly

R.-L. Jang (✉)
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei, Taiwan, Republic of China
e-mail: renliuj@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_113,

carry a food tray: the waist-level carry and the shoulder-high carry. The waist-level carry put the food tray's weight in the dominant hand with a fully extended wrist. The shoulder-high carry was more difficult to perform because the food tray's weight was put on one hand and the other serving as a stabilizer. Both ways involved shoulder abduction, internal rotation, and external rotation with supination motions of the dominant hand.

Wrist posture, repetition, tendon force and wrist acceleration are the four major risk factors to cumulative trauma disorders (CTDs) and carpal tunnel syndrome (CTS) (Alexander and Pulat 1995; Armstrong 1983; Williams and Westmorland 1994). Symptoms of CTS included numbness, tingling, loss of strength or flexibility, and pain.

Carpal tunnel syndrome is a cumulative trauma disorder that develops over time when hands and wrists perform repetitive movements. For example, workers moving their hands and wrists repeatedly and/or forcefully in their tasks may lead to CTDs (Marras and Schoenmarklin 1993). The flexion/extension acceleration of wrist can establish relative high risk levels of CTDs for hand-intensive, highly repetitive jobs (Schoenmarklin et al. 1994; Silverstein et al. 1986). In the meat packing industry, the jobs that require repetitious, hand-intensive work were found to have higher incidence of CTDs (Marklin and Monroe 1998).

Snook et al. (1995) used psychophysical methods to determine maximum acceptable forces for various types and frequencies of repetitive wrist motion. In the study repetition rates of 2, 5, 10, 15 and 20 motions per minute were set to each flexion and extension task. Maximum acceptable torques was determined for the various motions, grips, and repetition rates without dramatic changes in wrist strength, tactile sensitivity, or number of symptoms.

2 Methods

Considering banquet servers carrying a food tray as a hand-intensive work, this study was to investigate the work and simulate two ways to carry a food tray, the waist-level carry and the shoulder-high carry (Fig. 1), and to determine their maximum acceptable weight of load and suggest a proper weight for workers in restaurants. Maximum acceptable weight limit is determined by the workers, as the highest acceptable workload, which can be performed comfortably based on their perceived efforts.

This psychophysical approach was assumed that people could integrate and combine all stresses into their subjective evaluation of perceived stress. This method in assessing a carrying-tray task required subjects to adjust the weight of a load to the maximum amount they can perform under a certain condition for a time period without feeling strained or becoming unusually tired, overheated, weakened or out of breath.

During the experiment, participants were instructed to follow the psychophysical method to determine the MAWL and make adjustment. After the MAWL

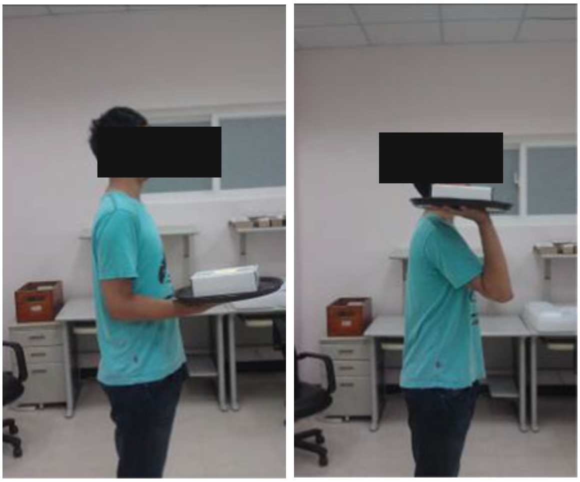


Fig. 1 Waist-level carry and shoulder-high carry

was determined, the participant was required to carry that weight and walk to a table 13.5 m away (Fig. 2). After the walk, if he disagrees on the chosen weight as the MAWL, the participant can make adjustment again until another MAWL was determined.

Twenty college students were participated in this study. Ten female students' average age ranged from 21 to 28 years, with an average of 22.5. Height ranged from 152 to 170 cm, with an average of 161.2. Weight ranged from 48 to 65 kg, with an average of 54.7. Ten male students' average age ranged from 21 to 24 years, with an average of 21.9. Height ranged from 160 to 183 cm, with an average of 174.6. Weight ranged from 55 to 88 kg, with an average of 66.2.

Fig. 2 Walking in the waist-level carry and the shoulder-high carry

3 Results

The MAWL on shoulder-high carry was 3.32 ± 0.47 kg for male and 2.78 ± 0.35 kg for female, respectively. The MAWL on waist-level carry were 2.57 ± 0.26 kg for male and 2.21 ± 0.35 kg for female. There were significantly differences between gender and carry methods using the analysis of ANOVA. On average, the MAWL on waist-level carry was 22 % less than that on shoulder-high carry. The MAWL of female on waist-level carry was 14 % of less than that for male while the MAWL of female on shoulder-high carry was 16 % of less than that for male.

4 Conclusions

This study was to simulate two ways to carry a food tray, the waist-level carry and the shoulder-high carry, and to determine their maximum acceptable weight of load. The results suggested workers in restaurants should consider the proper way to deliver the food when it gets heavy. To prevent high muscle force, the following practices were suggested:

1. Use shoulder-high carry to deliver heavier food tray.
2. Carry fewer plates in the tray at a time.
3. Make two trips or ask other severs to help with large orders.
4. Reduce travel with trays by using tray carrying carts.

References

Alexander DC, Pulat BM (1995) Industrial ergonomics: a practitioner's guide. Industrial Engineering and Management, Norcross

Armstrong TJ (1983) An ergonomics guide to carpal tunnel syndrome. American Industrial Hygiene Association, Fairfax

Marklin RW, Monroe JF (1998) Quantitative biomechanical analysis of wrist motion in bone-trimming jobs in the meat packing industry. Ergonomics 41(2):227–237 (Feb 1998)

Marras WS, Schoenmarklin RW (1993) Wrist motions in industry. Ergonomics 36(4):341–351 (Apr 1993)

Schoenmarklin RW, Marras WS, Leurgans SE (1994) Industrial wrist motions and incidence of hand/wrist cumulative trauma disorders. Ergonomics 37(9):1449–1459 (Sept 1994)

Silverstein BA, Fine LJ, Armstrong TJ (1986) Hand wrist cumulative trauma disorders in industry. Br J Ind Med 43(11):779–784 (Apr 1986)

Snook SH, Vaillancourt DR, Ciriello VM, Webster BS (1995) Psychophysical studies of repetitive wrist flexion and extension. Ergonomics 38(7):1488–1507 (Jul 1995)

Williams R, Westmorland M (1994) Occupational cumulative trauma disorders of the upper extremity. Am J Occup Ther 48(5):411–420 (May 1994)

Fatigue Life and Reliability Analysis of Electronic Packages Under Thermal Cycling and Moisture Conditions

Yao Hsu, Wen-Fang Wu and Chih-Min Hsu

Abstract Many previous researches on electronic packages focused on assessment of package lives under a single state of stress such as vibration, thermal cycling, drop impact, temperature and humidity. The present study considers both effects of thermal cycling and moisture on the fatigue life of electronic packages. The influence of moisture on thermal fatigue life of a package is investigated in particular. A Monte Carlo simulation algorithm is employed to make the result of finite element simulation close to reality. Samples of variables consisting of different package sizes and material parameters from their populations are generated and incorporated into the finite element analysis. The result of a numerical example indicates the thermal-fatigue failure mechanism of the electronic packages is not affected very much by the moisture. However, the mean time to failure of the package does decrease from 1,540 cycles to 1,200 cycles when moisture is taken into consideration.

Keywords Electronic packages · Fatigue life · Moisture diffusion · Reliability

Y. Hsu (✉)
Department of Business and Entrepreneurial Management, Kainan University, No. 1, Kainan Road, Luchu, Taoyuan 33857, Taiwan, Republic of China
e-mail: yhsu@mail.knu.edu.tw

W.-F. Wu
Department of Mechanical Engineering and Graduate Institute of Industrial Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan, Republic of China
e-mail: wfwu@ntu.edu.tw

C.-M. Hsu
Department of Mechanical Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan, Republic of China
e-mail: r99522525@ntu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_114,

1 Introduction

The reliability of electronic packages has become an important issue because it would directly determine their life expectancy. Because of the differences in the coefficient of thermal expansion amongst the materials constituting an electronic package, the package would suffer fatigue damage due to thermal stress when it is under thermal cycling loading. Many researches have been conducted on the responses and reliability of electronic packages under thermal cycling conditions (Li and Yeung 2001; Cheng et al. 2005; Kim et al. 2002; Lau and Lee 2002). When considering the moisture condition, a few studies have focused on how moisture affects the stress/strain fields and the failure mechanics in use of numerical simulation (Yi and Sze 1998; Kim et al. 2007). In the literature review, works concerning the fatigue life of electronic packages under both of thermal cycling and moisture conditions have been rarely seen. In addition, many works discussing about parameter uncertainties and how they affect the life of electronic package have been published (Evans et al. 2000; Wu and Barker 2010). Though many articles have discussed the uncertainties coming from geometry or material property, geometric and material uncertainties were usually considered separately. In summary, the purpose of this paper is to analyze the fatigue life and reliability of electronic packages when they are subjected to thermal cyclic and moisture loadings while considering the uncertainties of both geometry and material properties.

2 Finite Element Analysis

In Finite Element Analysis (FEA), the following assumptions were made. (1) The materials of the package are isotropic and the stress and strain relations for each material are identical under tension and compression. (2) There are no stresses for components in the model at the initial state of 25 °C, and residual stresses during the packaging process are disregarded. (3) The displacements of component in the direction of the model's symmetrical plane are zero. (4) All contact planes of the model are in perfect contacts. (5) The temperature and moisture are the same both inside and outside of the model at the same time instance, and situation that temperature changes with space is not taken into consideration.

The model structure considered in this paper is a wafer-level chip-scale package having a size of $9 \times 9 \times 0.508\ mm^3$, connected underneath to a 10×10 lead-free ball grid array of Sn-3.9Ag-0.6Cu and a $12 \times 12 \times 1.55\ mm^3$ PC board made of FR-4 epoxy glass. The diameter and the height of the solder ball are 0.3 mm and 0.44 mm, respectively, with an interval of 0.85 mm between centers of two solder balls. The model structure is shown in Fig. 1.

The material properties are shown in Table 1. All materials were assumed to be linearly elastic except for the lead-free solder ball. The following Garofalo-

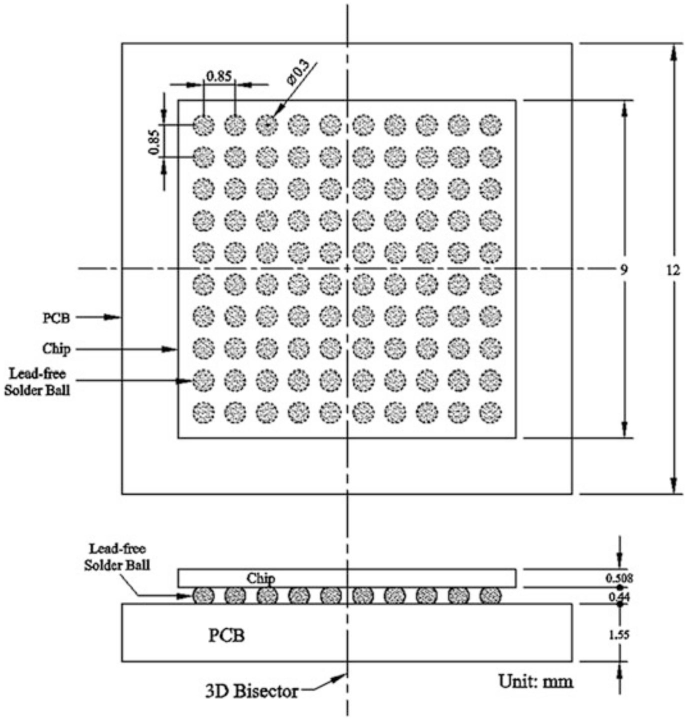


Fig. 1 Geometry and dimensions of the electronic package

Arrhenius creep equation was adopted for the eutectic Sn-3.9Ag-0.6Cu lead-free solder ball

$$\frac{d\varepsilon}{dt} = C_1[\sinh(C_2\sigma)]^{C_3}\exp\left(-\frac{C_4}{T}\right) \tag{1}$$

in which C_1 to C_4 are material constants and their values are shown in Table 2.

Because of symmetry of the packaging structure, for simplicity and time saving, only one-half of the whole package was modeled with appropriate boundary conditions setting. On the cut surface, displacements in x, y and z directions were constrained to prevent the structure from rigid-body motion. All the rest of the surfaces without setting boundary conditions were assumed to free surfaces.

Table 1 Material properties (Jong et al. 2006)

Material	Young's modulus (MPa)	Poison's ratio	CTE (ppm/K)
Chip	131,000	0.3	28
Solder ball	49,000	0.35	21.3
PCB	27,000	0.39	18

Table 2 Creep coefficients of lead-free solder (Lau and Dauksher 2005)

Coefficients	C_1 (1/s)	C_2 (1/MPa)	C_3	C_4 (K)
Value	500,000	0.01	5	5,802

Test condition G in JESD 22-A 104C of the JEDEC STANDARD was adopted for the thermal cyclic simulation on electronic packages for the reliability evaluation. It was performed at temperatures ranging from −40 to 125 °C and the reference temperature is 25 °C. Time for ramp up, dwell, ramp down and dwell loading is 900, 600, 900, 600 s, respectively, and therefore, one complete thermal cycle test is 3,000 s in total.

Regarding the moisture loading, this paper followed IPC/JEDEC Moisture Sensitivity Levels in JEDEC standard specification that requires the package to be put in the environment of 85 °C and relative humidity (RH) of 85 % for 168 h. Conditions of no moisture on the inside of the package and 85 % RH on the package's outer surfaces at initial stage were assumed. The parameters of D and C_{sat} needed in the simulation are tabulated in Table 3. It is noted that effect of thermal expansion was not considered herein during calculation when the structure is subjected to moisture loading.

3 Case Study

Finite element simulation was performed for two phases in the present study. In the first phase (Phase I), simulation was carried out under the condition that only thermal cyclic loading was applied to the model structure. In the second phase (Phase II), moisture diffusion simulation was carried out first, the simulation was subsequently performed under thermal cyclic loading as that made in Phase I.

The accumulated creep strain contour of the electronic package at the end of the simulation of Phase I case is illustrated in Fig. 2. Its maximum value is 0.0612 and it is located in the outmost solder ball as shown in Fig. 2. As for simulation of phase II case, the simulation results such as strain field distribution are nearly the same as those in Phase I case except the maximum value of the accumulated creep strain changes to 0.0786. It could be suggested that the moisture contributed little to the mechanical behaviors of electronic packages subjected to thermal cyclic loading. In addition, the fatigue lives of the package can be obtained from the

Table 3 Parameters for moisture diffusion equation (Cussler 2009)

Material	D (m^2/s)	C_{sat} (kg/m^3)
Chip	1×10^{-14}	1
Solder ball	1×10^{-14}	1
PCB	8.56×10^{-13}	38.4

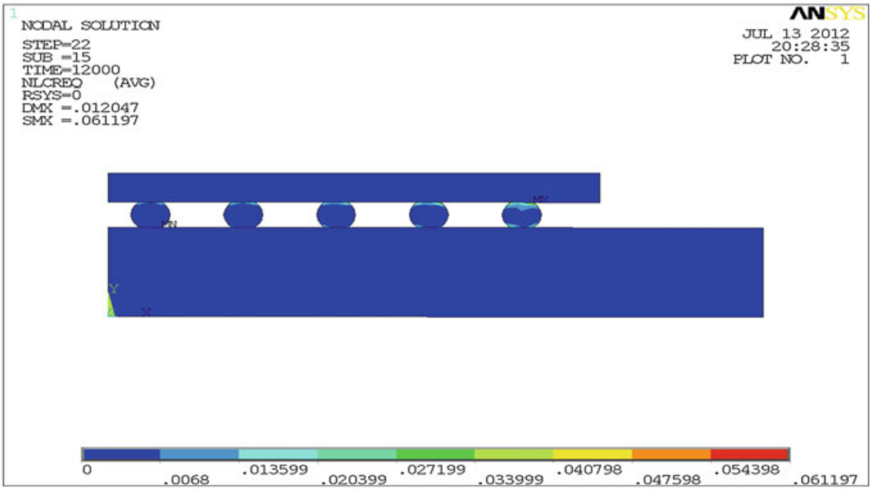


Fig. 2 Contour of accumulated creep strain of the package structure

simulations with the help of calculated creep strain and the prediction rule expressed as follows;

$$N_f = (C'\varepsilon_{acc})^{-1} \quad (2)$$

where N_f is the number of cycles to failure, C' is the material constant and ε_{acc} is the accumulated creep strain per cycle (Syed 2004).

3.1 Uncertainty Consideration

In the present study, nine geometric parameters and material properties of the package, namely radius of the solder ball, heights of the chip and PCB, Young's moduli of the solder ball, chip and PCB, coefficients of thermal expansion of the solder ball, chip and PCB were chosen as design parameters used for considering uncertainties. All of these nine random variables were assumed to be distributed normally and each one has a mean (nominal) value and a coefficient of variation (c.o.v.) of 3 %. Their mean values and corresponding standard deviations are tabulated in Table 4. A Monte Carlo simulation was made along with the FEA to analyze the strain/stress fields of electronic packages when design parameters have randomness. A random sample of size 40 of the uncertainty parameters was generated, and then forty outcomes of the maximum accumulated creep strain were obtained from running FEA. After substituting these strains into Eq. (2), forty fatigue lives of the electronic package were obtained.

Table 4 Statistical characteristics of geometric parameter and material property

Design parameter	Mean value	Standard deviation
Solder ball radius (mm)	0.15	0.0045
Chip height (mm)	0.508	0.01524
PCB height (mm)	1.55	0.0465
Young's modulus of the solder ball (MPa)	49,000	1,470
Young's modulus of the chip (MPa)	131,000	3,390
Young's modulus of the PCB (MPa)	27,000	810
Coefficient of thermal expansion of the solder ball (ppm/K)	21.3	0.639
Coefficient of thermal expansion of the chip (ppm/K)	2.8	0.084
Coefficient of thermal expansion of the PCB (ppm/K)	18	0.54

3.2 Fatigue Life and Reliability Analysis

Predicated fatigue lives can be further analyzed in statistical way. In this research, the fatigue lives in Phase I and II cases were plotted in normal, lognormal and Weibull probability papers, respectively. Chi square tests were used to determine the best goodness-of-fit. The parameters of these three probability distributions can be estimated by least-squared regression or curve fitting techniques. In this study, the Chi square test statistics of normal, lognormal and Weibull distributions are all more than the critical value at the significant level of 0.01, which means fatigue life data cannot be appropriately fitted by any of three empirical distributions. However, the Weibull distribution fits the fatigue life data best. This study then adopted the mixed Weibull distribution for a try to fit the data and eventually has a good fitness (Rinne 2009). Once the probability density function of the fatigue life is determined, the corresponding reliability function can be obtained and is shown in Fig. 3. The mean time to failure (MTTF) of the electronic package subjected to thermal cyclic loading studied in this paper is about 1,540 cycles whereas it is

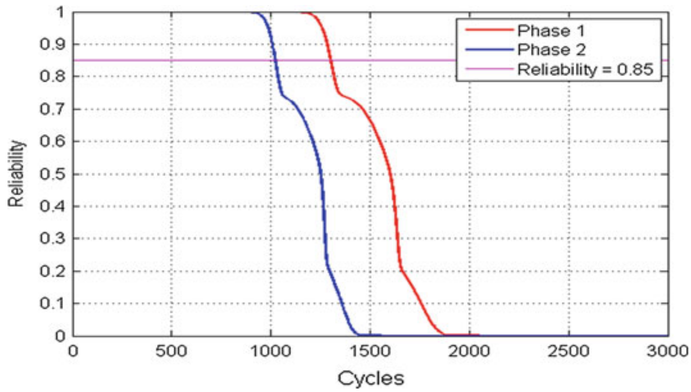


Fig. 3 Comparison of reliability curves of electronic packages

1,200 cycles when more extra moisture loading adds to the package. It can be indicated that moisture does have a negative impact on the thermal fatigue life of packages even if it doesn't seem to affect much the thermal failure mechanism and mechanical behaviors as stated in the preceding paragraph. Furthermore, when reliability of 0.85 was considered, the corresponding fatigue lives are nearly 1,300 and 1,021 cycles for Phase I and Phase cases, respectively.

4 Conclusions

This study intended to investigate how the moisture and thermal cyclic loadings affect the thermal fatigue life and reliability of electronic packages. To be closer to reality, finite element simulation was performed with a Monte Carlo simulation to consider uncertainties of geometry and materials of electronic packages. This analyzing approach proposed in this paper enables to produce the random-distributed fatigue lives of electronic packages and therefore, reliability can be analyzed quantitatively. Under assumptions made in the present paper, several conclusions can be drawn as follows:

1. No matter Phase I or Phase II cases, the numerical results show that the maximum accumulated creep strain occurs in the location of the interfaces between the outmost solder balls and materials connected to them. It is consistent with those results mentioned by other researchers.
2. There are no obvious differences found on the mechanical behaviors of electronic packages in Phase I and II cases. It could be suggested that moisture doesn't have much influence on the thermal fatigue failure mechanism of a package.
3. To the wafer-level chip-scale package considered in this study, the thermal mean time to failure of the package drops about 22 % when the moisture is taken into account. Moreover, the reliability is 0.85 at the thermal cycles of 1,300 when not considering the moisture, whereas for the same reliability, the thermal cycle shortens to 1,021 cycles when considering the moisture. It could be concluded that moisture accelerates the thermal failure of electronic packages to the extent.

Acknowledgments This work is supported by the National Science Council of Taiwan under Grant No. NSC 100-2221-E-002-052. The authors appreciate very much the financial support.

References

Cheng HC, Yu CY, Chen WH (2005) An effective thermal-mechanical modeling methodology for large-scale area array typed packages. Comput Model Eng Sci 7:1–17

Cussler EL (2009) Diffusion: mass transfer in fluid systems. Cambridge University Press, New York

Evans JW, Evans JY, Ghaffarian R, Mawer A, Lee KT, Shin CH (2000) Simulation of fatigue distributions for ball grid arrays by the Monte Carlo method. Microelectron Reliab 40:1147–1155

Jong WR, Chen SC, Tsai C, Chiu CC, Chang HT (2006) The geometrical effects of bumps on the fatigue life of flip-chip packages by Taguchi method. J Reinf Plast Compos 25:99–114

Kim DH, Elenius P, Barrett S (2002) Solder joint reliability and characteristics of deformation and crack growth of Sn-Ag-Cu versus eutectic Sn-Pb on a WLP in a thermal cycling test. IEEE Trans Electron Packag Manuf 25:84–90

Kim KS, Imanishi T, Suganuma K, Ueshima M, Kato R (2007) Properties of low temperature Sn–Ag–Bi–In solder systems. Microelectron Reliab 47:1113–1119

Lau JH, Lee SW (2002) Modeling and analysis of 96.5Sn-3.5Ag lead-free solder joints of wafer level chip scale package on buildup microvia printed circuit board. IEEE Trans Electron Packag Manuf 25:51–58

Lau J, Dauksher W (2005) Effects of ramp-time on the thermal-fatigue life of snagcu lead-free solder joints. In: Proceedings of the 55th IEEE electronic components and technology conference 2005

Li L, Yeung BH (2001) Wafer level and flip chip design through solder prediction models and validation. IEEE Trans Compon Packag Technol 24:650–654

Rinne H (2009) The Weibull distribution: a handbook. CRC Press, Boca Raton

Syed A (2004) Accumulated creep strain and energy density based thermal fatigue life prediction models for SnAgCu solder joints. Electron Componen Technol Conf 1:737–746

Wu ML, Barker D (2010) Rapid assessment of BGA life under vibration and bending, and influence of input parameter uncertainties. Microelectron Reliab 50:140–148

Yi S, Sze KY (1998) Finite element analysis of moisture distribution and hygrothermal stresses in TSOP IC packages. Finite Elem Anal Des 30:65–79

Clustering-Locating-Routing Algorithm for Vehicle Routing Problem: An Application in Medical Equipment Maintenance

Kanokwan Supakdee, Natthapong Nanthasamroeng and Rapeepan Pitakaso

Abstract This research is aimed to solve a vehicle routing problem for medical equipment maintenance of 316 health promoting hospitals in Ubon Ratchathani which conducted by maintenance department of Ubon Ratchathani Provincial Health Office by using clustering-locating-routing technique (CLR). We compared two different methods for clustering. The first method applied the sweep algorithm (SW-CLR) for clustering the health promoting hospital to 4 clusters and each cluster includes 79 hospitals. The second method used district boundary (DB-CLR) for clustering the hospital to 25 clusters. After that, load distance technique was used to determine a location of maintenance center in each cluster. Finally, saving algorithm was applied to solve the vehicle routing problem in each cluster. Both SW-CLR and DB-CLR can reduce transportation cost effectively compared with traditional route. The SW-CLR reduced overall annually maintenance cost 52.57 % and DB-CLR reduced cost 37.18 %.

Keywords Clustering-locating-routing · Vehicle routing problem · Medical equipment maintenance · Sweep algorithm · Saving algorithm

K. Supakdee (✉) · R. Pitakaso
Department of Industrial Engineering, Faculty of Engineering, Ubon Ratchathani University, Ubon Ratchathani, Thailand
e-mail: ksupakdee@hotmail.com

R. Pitakaso
e-mail: enrapapi@mail2.ubu.ac.th

N. Nanthasamroeng
Graduate School of Engineering Technology, Faculty of Industrial Technology, Ubon Ratchathani Rajabhat University, Ubon Ratchathani, Thailand
e-mail: nats@ubru.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_115,

1 Introduction

Nowadays, transportation cost was increased due to scarcity of fossil fuel. Therefore, logistics played an important role in both private and public sectors. If the firm could manage logistics activities effectively, they would have the competitive advantage among their rivalry.

Ubon Ratchathani Provincial Health Office (URPHO) had an objective to develop a standard for public health administration in the province. One of their activities was to take care and repair of medical equipments in 316 health promotion hospitals. Maintenance staffs had to travel with random routing from URPHO office to the hospitals. From information gathered in 2012, total distance of 150 routes was 22,945.20 km and cost 481,574.95 Thai-baht (THB).

This research is aimed to solve a vehicle routing problem for medical equipment maintenance of 316 health promoting hospitals in Ubon Ratchathani which conducted by maintenance department of Ubon Ratchathani Provincial Health Office by using clustering-locating-routing technique (CLR). We compared two different methods for clustering. The first method applied the sweep algorithm (SW-CLR) for clustering. The second method used district boundary (DB-CLR) for clustering the hospital.

2 Literature Review

2.1 Vehicle Routing Problem

In classical Vehicle Routing Problem (VRP), the customers are known in advance. Moreover, the driving time between the customers and the service times at each customer are used to be known. The classical VRP can be defined as follow: Let G = (V, A) be a graph where V = {1 … n} is a set of vertices representing *cities with the depot* located at vertex 1, and *A* is the set of arcs. With every arc (i, j) $i \neq j$ is associated a non-negative distance matrix $C = (c_{ij})$. In some contexts, c_{ij} can be interpreted as a *travel cost* or as a *travel time*. When *C* is symmetrical, it is often convenient to replace A by a set *E* of undirected edges. In addition, assume there are *m* available vehicles based at the depot, where $m_L < m < m_U$. When $m_L = m_U$, *m* is said to be fixed. When $m_L = 1$ and $m_U = n - 1$, *m* is said to be free. When m is not fixed, it often makes sense to associate a fixed cost f on the use of a vehicle. The VRP consists of designing a set of least-cost vehicle routes in such a way that:

1. each city in V{1} is visited exactly once by exactly one vehicle;
2. all vehicle routes start and end at the depot;
3. some side constraints are satisfied.

The formulation of the VRP can be presented as follow.

Let x_{ij} be an integer variable which may take value {0, 1}, ∀{i, j} ∈ E\{{0, j}: j ∈ V} and value {0, 1, 2}, ∀{0, j} ∈ E, j ∈ V. Note that $x_{0j} = 2$ when a route including the single customer j is selected in the solution.

The VRP can be formulated as the following integer program:

$$\text{Minimise} \quad \sum_{i \neq j} d_{ij} X_{ij} \tag{1}$$

Subject to:

$$\sum_{j} x_{ij} = 1, \quad \forall \mathrm{i} \in \mathrm{V}, \tag{2}$$

$$\sum\nolimits_{i} x_{ij} = 1, \quad \forall \mathrm{j} \in \mathrm{V}, \tag{3}$$

$$\sum_{i} x_{ij} \geq |S| - v(S), \{S : S \subseteq V \setminus \{1\}, |S| \geq 2\}, \tag{4}$$

$$\mathrm{x_{ij}} \in \{0, 1\}, \forall \{\mathrm{i},\ \mathrm{j}\} \in E;\ \mathrm{i} \neq \mathrm{j} \tag{5}$$

In this formulation, (1), (2), (3) and (5) define a modified assignment problem (i.e., assignments on the main diagonal are prohibited). Constraints (4) are sub-tour elimination constraints: *v(S)* is an appropriate lower bound on the number of vehicles required to visit all vertices of *S* in the optimal solution.

2.2 Sweep Algorithm

The sweep algorithm is a method for clustering customers into groups so that customers in the same group are geographically close together and can be served by the same vehicle. The sweep algorithm uses the following steps.

1. Locate the depot as the center of the two-dimensional plane.
2. Compute the polar coordinates of each customer with respect to the depot.
3. Start sweeping all customers by increasing polar angle.
4. Assign each customer encompassed by the sweep to the current cluster.
5. Stop the sweep when adding the next customer would violate the maximum vehicle capacity.
6. Create a new cluster by resuming the sweep where the last one left off.
7. Repeat Steps 4–6, until all customers have been included in a cluster.

2.3 Saving Algorithm

In the method of Clarke and Wright (1964), saving of combining two customers *i* and *j* into one route is calculated as:

$$\mathrm{S_{ij}} = \mathrm{d_{oj}} + \mathrm{d_{jo}} - \mathrm{d_{ij}} \tag{6}$$

where d_{ij} denotes travel cost from customer *i* to *j*. Customer ‘‘0’’ stands for the depot.

3 Mathematical Modeling

A mathematical model was formulated from the vehicle routing problem model. The objective function was focus on the capacitated vehicle routing problem (CVRP) which was calculate from health promoting hospitals, time for maintenance, labor cost, fuel consumption, maintenance costs and distance. The objective of CVRP is to minimize the traveling cost. The capacitated vehicle routing problem can be modeled as a mixed integer programming as follows:

$$\text{Minimize} \quad \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{K=1}^{K} C_{ij}X_{ij}^{k} \tag{7}$$

$$\text{Subject to} \quad \sum_{i=0}^{N}\sum_{j=0}^{N} X_{ij}^{K} d_i \le Q^k \quad 1 \le k \le K, \tag{8}$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} X_{ij}^{K}\left(c_{ij} + S_i\right) \le T^k \quad 1 \le k \le K, \tag{9}$$

$$\sum_{j=1}^{N} X_{ijk} = \sum_{j=1}^{N} X_{ijk} \le 1 \quad for\, i = 0 \tag{10}$$

$$\text{and} \quad k \in \{1, \ldots, k\},$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} X_{ij}^{K} \le K \quad for\, i = 0, \tag{11}$$

where $\mathrm{C_{ij}}$ is the cost incurred on customer i to customer j, K the number of vehicles, N the number of customers, the $\mathrm{S_i}$ the service time at customer i, Q_k the loading capacity of vehicle *k*, T_k the maximal traveling (route) distance of vehicle *k*, d_i the demand at customer i, $X_{ij}^{K} \in 0$ and 1 $(i \ne j;\; i, j \in 0, 1, \ldots, N)$. Equation (6) is the objective function of the problem. Equation (7) is the constraint of loading capacity, where $X_{ij}^{K} = 1$ if vehicle k travels from customer i to customer j directly, and 0 otherwise. Equation (8) is the constraint of maximum traveling distance. Equation (9) makes sure every route starts and ends at the delivery depot. Equation (10) specifies that there are maximum K routes going out of the delivery depot.

4 Test Problem

The test instance used in this research was formulated form a real case study of 316 health promoting hospitals into 25 districts in Ubon Ratchathani.

5 Clustering-Locating-Routing Technique

The test instance used in this research was formulated form a real case study of 316 health promoting hospitals in Ubon Ratchathani.

5.1 Sweep Algorithm Clustering-Locating-Routing Technique

Figure 1.

5.1.1 Data

The data used in this research, including the time for maintenance, labor cost, fuel consumption, maintenance costs and distance.

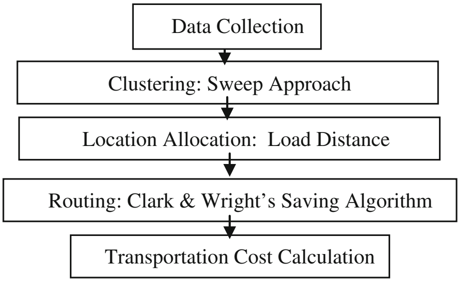


Fig. 1 SW-CLR procedure

5.1.2 Sweep Algorithm

The clustering the health promoting hospital to 4 clusters and each cluster includes 79 hospitals was shown in Fig. 2.

5.1.3 Choosing the Right Location to Find a Way with the Load-Distance Technique

Cluster 1 New location is Ban Khonsanhealth promoting hospital
Cluster 2 New location is Donjikhealth promoting hospital
Cluster 3 New location is Maiphattanahealth promoting hospital
Cluster 4 New location is Ban Kham health promoting hospital

5.1.4 Saving Value

Saving value was calculated by using Eq. (6). Some of calculation results were shown in Table 1.

5.1.5 Routing of Saving Algorithm

Route to health promoting hospital, all health cluster (Table 2), a total distance of 7,514.7 km is the fourth cluster (Table 3)

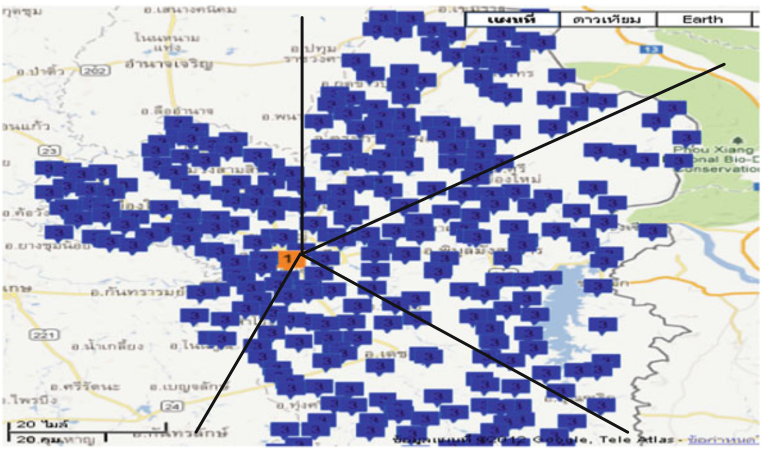


Fig. 2 Ubon Ratchathani Provincial Health Office by using clustering

Table 1 Example of saving value

	d_{0i}	d_{j0}	d_{ij}	Saving value
S1,2	18.1	47.6	42.6	23.1
S1,3	18.1	38.4	20.6	35.9
S1,4	18.1	26.6	8.9	35.8

Table 2 Example of route to health promoting hospital

Route	Sequence	Total distance (km)
1	0-24-32-9-41-0	77.8
2	0-6-10-47-79-0	75.4
3	0-36-42-11-50-0	84.1

Table 3 Total cost of fourth cluster

Cluster	Number of tours	Distance (km)	Total cost (THB)
1	18	1,620.5	51,252.55
2	20	2,237.8	59,548.47
3	21	1,976.2	60,376.44
4	20	1,680.2	56,302.12
Total	79	7,514.7	227,479.58

5.1.6 Transportation Cost

It can be calculated as Eq. (12) below

$$\text{Transportation cost} = [(C_f + C_m)d] + [(C_l r)] + [(C_h(r - 1)] \tag{12}$$

5.2 District Boundary Clustering-Locating-Routing Technique

District boundary clustering-locating-routing technique (DB-CLR) procedure was similar to SW-CLR procedure except the clustering method. In DB-CLR, district boundary was use to cluster health promoting hospital to 25 clusters. Each cluster contained different number of hospital as shown in Table 4 (Fig. 3).

5.3 Comparison Result

The comparison between SW-CLR and DB-CLR was shown in Table 5. From the result, SW-CLR contributed the lower total cost than DB-CLR algorithm 15.58 %

Table 4 Clustering result for with district boundary

No.	Province	Number of hospital	No.	Province	Number of hospital
1	Mueang	17	14	Na Tan	7
2	Don Mot Daeng	4	15	Khemarat	11
3	Lao SueaKok	7	16	DetUdom	26
4	Tan Sum	8	17	Buntharik	17
5	Phibun Mangsahan	20	18	Na Chaluai	10
6	Sirindhorn	8	19	Nam Yuen	13
7	Khong Chiam	11	20	Muang Sam Sip	24
8	Warin Chamrap	19	21	KhueangNai	31
9	Sawang Wirawong	7	22	Nam Khun	7
10	Trakan Phuet Phon	29	23	Thung Si Udom	7
11	Si Mueang Mai	17	24	Na Yia	6
12	Pho Sai	11	25	Samrong	13
13	Kut Khaopun	9			

Fig. 3 DB-CLR procedure

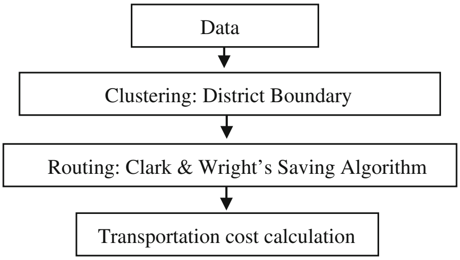


Table 5 Comparison between SW-CLR and DB-CLR

	Traditional	SW-CLR	DB-CLR
Total cost (THB)	481,574.95	227,479.58	298,497.85
Decrease (%)	–	52.76	37.18

6 Conclusions

We compared two different methods for clustering. The first method applied the sweep algorithm (SW-CLR) for clustering the health promoting hospital to 4 clusters and each cluster includes 79 hospitals. The second method used district boundary (DB-CLR) for clustering the hospital to 25 clusters. After that, load distance technique was used to determine a location of maintenance center in each cluster. Finally, saving algorithm was applied to solve the vehicle routing problem in each cluster. Both SW-CLR and DB-CLR can reduce transportation cost effectively compared with traditional route. The SW-CLR reduced overall annually maintenance cost 249,774.84 bath 52.57 % and DB-CLR reduced cost 176,652.44 bath 37.18 %

Reference

Clarke G, Wright JW (1964) Scheduling of vehicles from a central depot to a number of delivery points. Oper Res 12:568–581

Whole-Body Vibration Exposure in Urban Motorcycle Riders

Hsieh-Ching Chen and Yi-Tsong Pan

Abstract Twenty-two male and twenty-three female motorcycle riders performed ninety test runs on six 20-km paved urban routes. Root mean square of acceleration, 8-hour estimated vibration dose value ($VDV_{(8)}$), and 8-hour estimated daily static compression dose (S_{ed}) were determined in accordance with ISO 2631-1 (1997) and ISO 2631-5 (2004) standards. The analytical results indicated that over 90 % of the motorcycle riders revealed $VDV_{(8)}$ exceeding the upper boundary of health guidance caution zone (17 m/s$^{1.75}$) recommended by ISO 2631-1 or S_{ed} exceeding the value associated with a high probability of adverse health effects (0.8 MPa) according to ISO 2631-5. Over 50 % of the motorcycle riders exceeded exposure limits for *VDV* and S_e within 3 h. Significantly greater exposure levels were observed in male participants than in female participants for $VDV_{(8)}$ ($p < 0.05$) and S_{ed} ($p < 0.005$). The health impacts of WBV exposure in motorcycle riders should be carefully addressed with reference to ISO standards.

Keywords ISO 2631 standards · Motorbike · Health risk

1 Introduction

Commonly reported health effects caused by whole-body vibration (WBV) exposure include discomfort, musculoskeletal problems, muscular fatigue, reduced stability, and altered vestibular function (Seidel 1993; Wasserman et al. 1997;

H.-C. Chen (✉)
Department of Industrial Engineering and Management, Taipei University of Technology, No. 1, Sec. 3, Zhongxiao E. Road, Taipei 10608, Taiwan, Republic of China
e-mail: imhcchen@ntut.edu.tw

Y.-T. Pan
Institute of Occupational Safety and Health, Council of Labor Affairs, Executive Yuan, No. 99, Lane 407, Hengke Road, Xizhi, New Taipei 22143, Taiwan, Republic of China
e-mail: yitsong@mail.iosh.gov.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_116,

Bongers et al. 1988; Griffin 1998). Several studies have indicated that long-term WBV exposure is associated with early spinal degeneration (Frymoyer et al. 1984), low back pain, and herniated lumbar disc (Bovenzi and Zadini 1992; Boshuizen et al. 1992).

Motorcycles are a common transportation mode in Asia. An estimated 33 million motorcycles are used in mainland China, 18 million in Vietnam, 13.8 million in Taiwan, 13 million in Japan, 5.8 million in Malaysia, 2.7 million in Korea, and 1.8 million in the Philippines (IRF 2006). Most motorcycles in Taiwan can be categorized as scooters (i.e., no clutch, seated riding position) or motorbikes (equipped with clutch, straddled riding position). These motorcycles generally have 125 cc engines or smaller, are ridden on shoulders or in reserved lanes, and are convenient for accessing driving lanes. Although motorcycles are typically used only for short-distance transport, they are the main transportation mode for workers such as postal workers, delivery workers, and urban couriers. Consequently, these occupations are likely associated with high WBV exposure.

Health problems associated with WBV exposure in motorcycle riders are often overlooked despite the potentially large size of the population. Chen et al. (2009) reported high WBV exposure in twelve male motorcycle riders traveled on a 20.6 km rural–urban paved road according to ISO 2631-1 (1997) and ISO 2631-5 (2004) standards. However, the generalizability of the experimental results in that study is limited since they analyzed only male subjects riding on one specific route.

This study measured the WBV exposure of motorcycle riders while riding on urban routes with standard paved surfaces. The vibration exposure in motorcycle riders was compared with the upper boundary of health guidance caution zone (HGCZ) recommended by ISO 2631-1 (1997) $\left(\overline{VDV}\right)$ and with the limit value associated with a high probability of adverse health effects according to ISO 2631-5 (2004) $\left(\overline{S_{ed}}\right)$.

2 Method

2.1 Participants and Vehicles

This study analyzed 45 university students (23 male and 22 female) who volunteered to participate in motorcycle riding tests. All subjects rode their own motorcycles, and all had at least 2 years of motorcycle riding experience.

Table 1 presents the detailed characteristics of the participants and their vehicles. The male participants were significantly taller and heavier than the female participants ($p < 0.001$, t test) were. Males were also significantly older (3.2 years) in age, and had more years of riding experience as well as more years of vehicle ownership (3.6 and 1.9 years, respectively) ($p < 0.001$, t-test) than the female participants did. The number of male participants who rode 125 cc motorcycles (90.9 %) was significantly higher than the number of female participants who rode 125 cc motorcycles (30.4 %) ($p < 0.001$, Mann-Whitney).

Table 1 Characteristics of the participants and motorcycle (N = 45)

Participant					Motorcycle			
Gender	Age (year)	Height (cm)	Weight (kg)	Experience (year)	Engine size(cc)	Wheel size(in)	Years (year)	Manufacturer (n)
Male (n = 22)	24.5 (2.6)	172.9 (6.8)	72.5 (14.9)	6.7 (2.8)	125 * 20 100 * 2	10	5.7 (2.1)	Yamaha (5) Sanyang (11) Kymco (6)
Female (n = 23)	21.3 (2.5)	160.2 (3.8)	52.8 (8.0)	3.1 (2.4)	125 * 7 100 * 16	10	3.8 (3.0)	Yamaha (4) Sanyang (11) Kymco (8)
Gender diff. *p*-value	<0.001 (t-test)	<0.001 (t-test)	<0.001 (t-test)	<0.001 (t-test)	<0.001 (Mann-Whitney test)	–	0.001 (t-test)	–

2.2 Equipment and Field-Testing Procedure

A triaxial ICP seat pad accelerometer (model 356B40, Larson Davis Inc., USA) was employed to measure vibrations transmitted to the seated human body as a whole through the supporting surface of the buttock. Seat pad outputs were connected to a 3-channel amplifier (model 480B21, PCB Piezotronics Inc., USA). The outputs of the amplified signals were recorded on a portable data logger which acquires three analog signals each at a rate of 5 k samples/s. The logger can continually store collected data on a 2 GB compact flash (CF) memory card up to 2 h.

A GPS device was used to provide geographical information as participants rode on an assigned route. Vocal messages from the GPS were transmitted to participants via earphones. The view of a motorcycle rider was recorded by a portable media recorder and a minicamera. The recorded video was synchronized with the logged acceleration data using a remote transmitter, which sent radio frequency signals at the beginning and end of the riding task.

The test runs were performed on six 20-km paved urban routes. All routes started from a cafe located in downtown Taichung City and followed various main roads of Taichung City before returning to the cafe. The standard testing procedure for the riding test was explained, and detailed instructions were given to all participants before the test. Each motorcycle rider performed two different riding tasks on randomly assigned routes. Each motorcycle rider wore a helmet with a mini-camera taped on its frontal side and carried a portable media recorder in a case with a shoulder strap (Fig. 1). Each rider also wore a backpack containing the signal amplifier, the data logger, and a rechargeable battery set. The backpack weighed approximately 1.5 kg. The GPS device was affixed with a suction cup and tape to the control panel of test motorcycle.

No speed limits were imposed on participants. However, the subjects were instructed to comply with urban speed limits. Each participant was asked to remain seated throughout the riding task. To avoid harmful shocks, the riders were instructed to either avoid or to slowly drive over any potholes, manhole covers, humps, or uneven road surfaces. Each task required 50–60 min. The duration of each task was measured from the time the participant exited the cafe parking lot to the time that the participant returned.

2.3 Data Analysis

'Viewlog' software programmed with LabVIEW 7.0 (National Instruments, USA) was applied to download the logged data from the CF card, and to combine the data with the taped video. 'Viewlog' consists of calibration, vibration analysis, script interpretation and batch processing modules to facilitate analysis and processing of data in bulk. The vibration analysis module, developed under a research contract of Taiwan IOSH (2007), evaluates WBV exposure for both ISO 2631-1

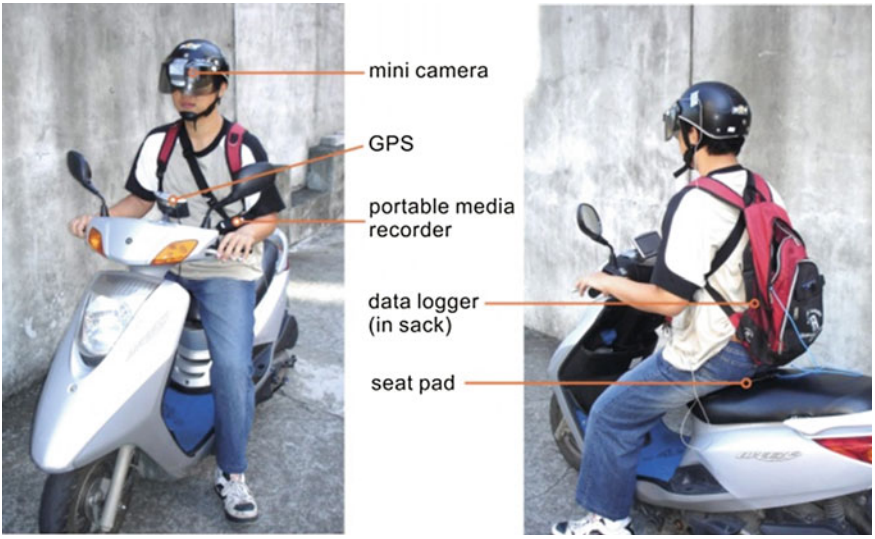


Fig. 1 Experimental apparatus

(1997) and ISO 2631-5 (2004). The module was specifically designed to perform batch computing and export the results to a user-defined MS Excel template. The Excel report employed an embedded macro program to calculate the estimated 8-h *RMS*, *VDV* and S_e. Detailed data processing and artifact removal procedures were documented in previous study (Chen et al. 2009).

The statistical analysis was performed with SPSS 10 for Windows. Gender differences in participant and motorcycle characteristics were assessed by independent *t*-test for all scale variables and by Mann-Whitney test for the nominal variable (engine size). According to both Pearson and Spearman rho correlations, participant age, body height and weight, riding experience, and vehicle years were all significantly correlated (r range, 0.401–0.952, $p < 0.01$). Therefore, only riding experience was applied as an independent variable in ANOVA analyzes. The differences among all measurements obtained in the motorcycle ride tests were compared by univariate ANOVA using gender, route, and engine size as fixed factors and riding experience and measurement period as covariates. A *p* value less than 0.05 was considered statistically significant.

3 Results

Male participants completed the test much faster than female participants did (male = 50.2 ± 6.6 min, female = 56.9 ± 11.1 min) ($p < 0.05$, Table 2). However, the measurement period was not significantly affected by route and engine size.

Table 2 Mean ± SD [range] of RMS, $VDV_{(8)}$, S_{ed}, and riding period

Gender	Engine size(cc)	N	(1997)		(2004)	
			RMS§ (m/s^2)	$VDV_{(8)}$* ($m/s^{1.75}$)	S_{ed}** (MPa)	Riding period* (s)
Male	125	40	0.81 ± 0.13 [0.56 − 1.11]	23.49 ± 4.20 [16.16 − 34.57]	1.17 ± 0.41 [0.68 − 2.49]	3062 ± 418 [2,280 − 4,050]
	100	4	0.88 ± 0.03 [0.85 − 0.91]	24.35 ± 1.46 [23.57 − 26.38]	1.51 ± 0.21 [1.23 − 1.75]	2,903 ± 250 [2,640 − 3,240]
Female	125	14	0.72 ± 0.08 [0.59 − 0.90]	19.57 ± 2.78 [16.50 − 26.79]	0.88 ± 0.20 [0.65 − 1.26]	3,403 ± 551 [2,280 − 4,260]
	100	32	0.80 ± 0.11 [0.56 − 1.02]	22.05 ± 3.04 [16.84 − 28.37]	1.08 ± 0.36 [0.64 − 2.61]	3,419 ± 721 [2,580 − 5,370]

*$p < 0.05$,**$p < 0.005$; significant gender difference (ANOVA)
$p < 0.05$, significant engine size effect (ANOVA)
§ $p < 0.01$, significant riding period effect (ANOVA)

The analytical results indicated that acceleration in the *z*-axis generated the most severe total *RMS* and *VDV* levels. Therefore, *RMS* and *VDV* vibration parameters in this study were determined by frequency-weighted acceleration in the z dominant axis. Significant gender differences were observed in $VDV_{(8)}$ ($p < 0.05$) and S_{ed} ($p < 0.005$, Table 2). Nevertheless, only *RMS* revealed a significant association with measurement period ($p < 0.01$) and engine size ($p < 0.05$). Route and riding experience revealed no associations with vibration parameters. In all 20-km trials, vibration exposures exceeded the lower boundary of HGCZ recommended by ISO 2631-1 (1997) or the value associated with a low probability of adverse health effects according to ISO 2631-5 (2004); 32 and 2 % trials exceeded $\overline{S_{ed}}$ and $\overline{VDV}$ (upper boundary), respectively (Fig. 2). In approximately 97 % of the trials, the 8-h predicted vibration exposures exceeded either $\overline{VDV}$ or $\overline{S_{ed}}$, and in 83 % trials, they exceeded both (Fig. 2). Statistical results revealed both linear and nonlinear (power) regression lines through the conjunction of the two caution zones and 8-h predicted regression lines revealed a tendency toward increased *VDV*.

For most motorcycle riders, daily motorcycle use is typically for short periods. Therefore, allowable durations (T_a) for *RMS*, *VDV,* and S_e to reach corresponding values of $\overline{RMS}$, $\overline{VDV}$, and $\overline{S_{ed}}$ were computed for each riding task. Figure 3 shows the cumulative probability of T_a to reach $\overline{RMS}$, $\overline{VDV}$ and $\overline{S_{ed}}$. Analytical results of S_e and *VDV* showed that 50 % exposures were limited to about 2 and 3 h, respectively. Nevertheless, T_a to reach $\overline{RMS}$ was significantly longer than that to reach $\overline{VDV}$ and $\overline{S_{ed}}$. For 1-h daily exposure, 35 and 9 % motorcycle riders were restricted according to ISO 2631-5 and ISO 2631-1 standards, respectively (Fig. 3). Besides the difference between the two ISO standards, T_a also revealed significant gender differences. Fifty percent of male participants but only 25 % of female participants revealed T_a less than 1.2 h according to S_e. Similarly, 50 % of male participants had T_a less than 2.3 h according to *VDV*, but less than 35 % female participants had T_a less than 2.3 h.

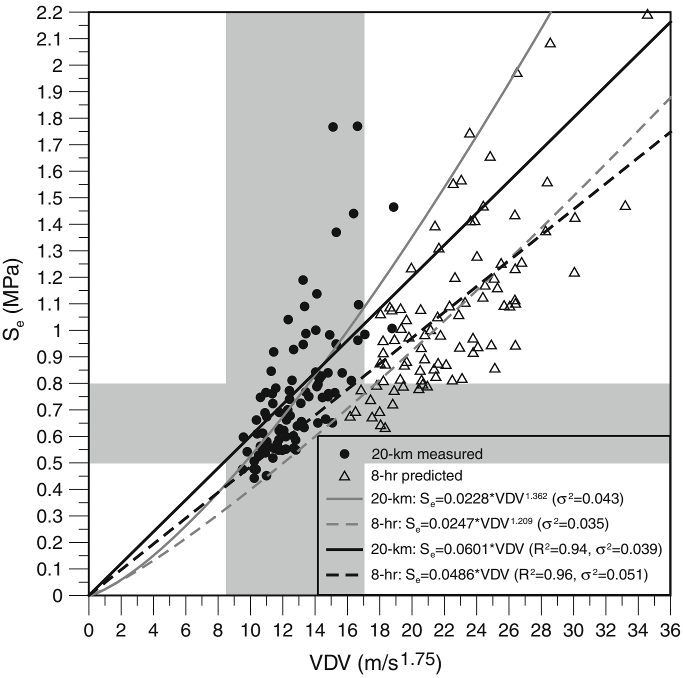


Fig. 2 *VDV-S_e* scatter plot of all tasks, with the caution zones (*grey bands*) of ISO 2631-1 and ISO 2631-5 (*solid symbol* 20-km measured, *hollow symbol* 8-h predicted)

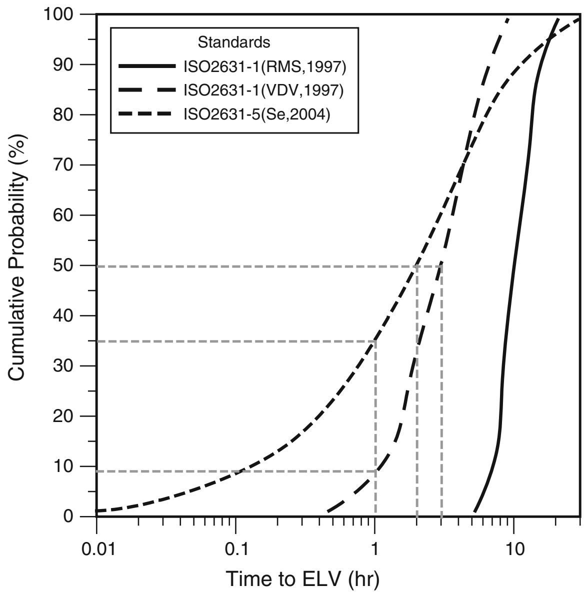


Fig. 3 Cumulative probability distribution of allowable duration (T_a) to reach limit values of $\overline{VDV}$ and $\overline{S_{ed}}$ according to ISO 2631-1 (1997) and ISO 2631-5 (2004) standards

4 Discussion

This study suggests that, after prolonged traveling on typical paved roads, vibration exposure may be greater in motorcycle riders than in 4-wheel vehicle drivers. Previous studies report WBV exposure of 0.17–0.55 m/s^2 *RMS* among urban taxi drivers in Taiwan (Chen et al. 2003) and 0.34–0.56 m/s^2 *RMS* among highway transport truck drivers (Cann et al. 2004). In this research, significantly increased WBV exposure (ranged 0.56–1.11 m/s^2 *RMS*) was observed in urban motorcycle riders. To compare WBV exposure of motorcycle riders in this study with that of industrial vehicle drivers of previous studies, experimental measurements were extrapolated to predict 8-h exposure of *VDV* and S_e. Rehn et al. (2005) indicated that $VDV_{(8)}$ in operators of forwarder vehicles were in the 2.92–18.9 $m/s^{1.75}$ range, and in all tested operators, T_a reached $\overline{VDV}$ for longer than 8 h. Eger et al. (2008) estimated the 8-h WBV exposure in seven operators of load-haul-dump mining vehicle after 7 h operation and 1 h resting and found that $VDV_{(8)}$ was 12.38–24.67 $m/s^{1.75}$, and S_{ed} was 0.21–0.59 MPa. The $VDV_{(8)}$ (range 16.16–34.57 $m/s^{1.75}$) and S_{ed} (range 0.64–2.49 MPa) obtained from motorcycle rides exceeded above mentioned vehicles and many other passenger and industrial vehicles reported by Paddan and Griffin (2002).

Chen et al. (2009) reported that, after 8 h of exposure, over 90 % of all motorcycle rides would produce $VDV_{(8)}$ (mean 23.1 $m/s^{1.75}$) and S_{ed} (mean 1.15 MPa) values over the corresponding $\overline{VDV}$ and $\overline{S_{ed}}$, which indicates a high probability of adverse health effects. The current study revealed a similar conclusion for motorcycle riding in urban areas. Notably, the use of fundamental *RMS* evaluation (ISO 2631-1 1997) probably underestimates the health risks of multiple shocks, especially after prolonged exposure. Therefore, certain Asian countries that top use WBV guidelines solely based on frequency-weighted accelerations and *RMS* index may overlook the potential health risks caused by WBV exposure in motorcycle riders.

The conclusion drawn in this study may not be applicable to all motorcycle riding conditions. The experimental setup was limited to the use of young subjects (<30 years) and main roads of Taichung city. The possible effects of age on speed and personal riding characteristics as well as the effects of road condition on vehicle vibration may limit the ability to generalize the experimental results to other riding cases. Additionally, the testing conditions were limited to single riders and the most common motorcycle engine sizes (100 and 125 cc) in Taiwan. Heavier loads can also affect riding speed, acceleration, and vibration characteristic of the system. Therefore, the WBV results for heavy-duty motorbikes or motorcycles ridden with a passenger or additional weight may differ from those reported here.

The experimental results of this study indicate the need for caution in occupations in which motorcycles are the major transportation mode (e.g., postal workers, police officers, delivery workers, and some urban couriers). Further research in the dose–response relationship of these workers should also be explored further to confirm the findings of this study.

Acknowledgments The authors wish to thank the Institute of Occupational Safety and Health for financially supporting this research study (IOSH97-H317).

References

Bongers PM, Boshuizen HC, Hulshof TJ, Koemeester AP (1988) Back disorders in crane operators exposed to whole-body vibration. Int Arch Occup Env Health 60:129–137

Boshuizen HC, Bongers PM, Hulshof CT (1992) Self-reported back pain in fork-lift truck and freight-container tractor drivers exposed to whole-body vibration. Spine 17:59–65

Bovenzi M, Zadini A (1992) Self-reported low back symptoms in urban bus drivers exposed to whole-body vibration. Spine 17:1048–1059

Cann AP, Salmoni AW, Eger TR (2004) Predictors of whole-body vibration exposure experienced by highway transport truck operators. Ergonomics 47:1432–1453

Chen JC, Chang WR, Shih TS, Chen CJ, Chang WP et al (2003) Predictors of whole-body vibration levels among urban taxi drivers. Ergonomics 46:1075–1090

Chen HC, Chen WC, Liu YP, Chen CY, Pan YT (2009) Whole-body vibration exposure experienced by motorcycle riders—An evaluation according to ISO 2631-1 and ISO 2631-5 standards. Int J Ind Ergon 39:708–718

Eger T, Stevenson J, Boileau P-É, Salmoni A, Vib RG (2008) Predictions of health risks associated with the operation of load-haul-dump mining vehicles: Part 1—Analysis of whole-body vibration exposure using ISO 2631-1 and ISO 2631-5 standards. Int J Ind Ergon 38:726–738

Frymoyer JW, Newberg A, Pope MH, Wilder DG, Clements J, MacPherson B (1984) Spine radiographs in patients with low-back pain. An epidemiology study in men. J Bone Joint Surgery Am Vol 66:1048–1055

Griffin MJ (1998) General hazards: vibration. Encyclopedia of occupational health and safety (International Labour Organization Geneva), 50.2–50.15

International Organization for Standardization (1997) ISO2631-1 Mechanical vibration and shock–evaluation of human exposure to whole-body vibration. Part 1: general requirements. ISO, Geneva

International Organization for Standardization (2004) ISO2631-5 Mechanical vibration and shock–evaluation of human exposure to whole-body vibration. Part 5: method for evaluation of vibration containing multiple shocks. ISO, Geneva

IRF (2006) World road statistics 2006—data 1999 to 2004 International Road Federation (IRF), Geneva, Switzerland

Paddan GS, Griffin MJ (2002) Effect of seating on exposures to shole-body vibration in vehicles. J Sound Vibr 253:215–241

Rehn B, Lundström R, Nilsson L, Liljelind I, Jörvholm B (2005) Variation in exposure to whole-body vibration for operators of forwarder vehicles—aspects on measurement strategies and prevention. Int J Ind Ergon 35:831–842

Seidel H (1993) Selected health risks caused by long-term whole-body vibration. Am J Ind Med 23:589–604

Taiwan IOSH (2007) Development of software and field testing tools for assessing whole-body vibration with shocks. Taiwan Institute of Occupational Safety and Health (IOSH), Council of Labor Affairs, Taiwan. Contract Report No. IOSH 96-H318 (in Chinese)

Wasserman DE, Wilder DG, Pope MH, Magnusson M, Aleksiev AR, Wasserman JF (1997) Whole-body vibration exposure and occupational work-hardening. J Occup Env Med 39:403–407

Analysis of Sales Strategy with Lead-Time Sensitive Demand

Chi-Yang Tsai, Wei-Fan Chu and Cheng-Yu Tu

Abstract Nowadays, more and more customers order products through non-conventional direct sales channel. Instead of purchasing from retail stores, customers place orders directly with the manufacturer and wait for a period of lead-time for the ordered items to be delivered. With limited production capacity, it is possible that the manufacturer is unable to deliver all the orders in regular delivery time if too many orders are placed in a period of time. The delivery lead-time may become longer than expected and that can have an impact on future demand. This study assumes customer demand is sensitive to the length of lead-time. That is, demand decreases as the actual delivery lead-time in the previous period becomes longer. Mathematical models are constructed for the considered multiple-period problem. Numerical experiments and sensitivity analysis are conducted to examine how lead-time sensitive demand affects system behaviors. It is observed that the system behaviors heavily depend on the size of initial demand. It is also found that when initial demand is greater than the fixed capacity, the cumulated profit of the manufacturer may increase in the beginning. However, it will decline in the long run.

Keywords Lead-time sensitive demand · Direct sales channel · Pricing

C.-Y. Tsai (✉) · W.-F. Chu · C.-Y. Tu
Department of Industrial Engineering and Management, Yuan Ze University,
135 Yuan-Tung Rd, Chung-Li, Tao Yuan, Taiwan
e-mail: iecytsai@saturn.yzu.edu.tw

W.-F. Chu
e-mail: s995414@mail.yzu.edu.tw

C.-Y. Tu
e-mail: s1005422@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_117,

1 Introduction

The market of direct sales has been growing significantly in the past years. Instead of purchasing from retail stores, more and more customers purchase products directly from manufacturers. Usually, the sales price of a product purchased from the direct sales channel is lower due to the reduced costs by bypassing the retailer. It is a motivation for customers to select direct sales channel. Therefore, it is common that pricing strategies are applied in direct sales channel system to increase demand. In addition, one major difference between the direct sales channel and the traditional retail sales channel is that it takes a period of lead time to deliver the ordered product to the customer. With finite production capacity, the manufacturer can be overwhelmed by excessive demand and fails to deliver within the promised lead time. As the delivery lead time lengthens, customers are discouraged and future demand may drop.

This study attempts to develop a mathematical model for the direct sales channel system with lead-time-sensitive and price-sensitive demand. The model is used to analyze the behaviors of the system and explore the use of pricing strategy to maximize profits.

In a direct sales channel, manufacturers sell products directly to customers through the internet, their owned stores or mail order (Kotler and Armstrong 1994). Lead time is the time it takes from when customers confirm their order through the internet until customers receive the ordered products (Hua et al. 2010). Reducing delivery lead time may reduce the resistance of customers to direct purchase (Balasubramanian 1998). Liao and Shyu (1991) proposed an inventory model where lead time is considered as a decision variable. Ben-Daya and Raouf (1994) extended their model and considered both lead time and order quantity as decision variables with shortages prohibited. Ouyang et al. (1996) further extended their model to allow shortages. Hua et al. (2010) constructed a dual-channel (direct and retail) system and identified the optimal price and lead time that maximize profit.

The rest of the paper is organized as follows. Section 2 describes the considered direct sales channel system and the constructed mathematical model. A base instance is presented. Section 3 provides the conducted numerical experiment. The last section concludes the paper.

2 Problem Description and Model

This study considers a direct channel system in a multi-period setting. The system contains a manufacturer who produces a single product. It takes orders directly from customers and delivers order to customers. The production capacity per period of the manufacturer is assumed to be finite and fixed. If demand of a period cannot be satisfied in the same period, it is backordered. The available total amount of the product the manufacturer can supply in a period is the production capacity. If the available quantity is enough to cover the backordered quantity and the demand of that period, the length of time to deliver is one period. For demand that is backordered, the delivery lead time becomes longer.

It is assumed that demand is sensitive to the actual length of the delivery lead time. To be more precise, the amount of demand in a period is set to be a function of the actual length of the lead time for demand in the previous period. If the actual lead time is longer than the promised length of one period, demand in the next period declines.

2.1 Model

The following notation will be used.

a	Primary demand
α	Demand sensitivity to lead time
b	Demand sensitivity to price
k	Backorder cost per unit per period
Q	Production capacity per period, in units
u	Production cost per unit
D_i	Demand in period i
L_i	Lead time in period i
O_i	Backorders in period i
q_i	Production quantity in period i
P	Sales price per unit

Demand from customers is assumed to be sensitive to the sales price and the lead time. It is expressed as

$$D_i = D_0 - \alpha D_0 \left(1 - \frac{1}{L_{i-1}}\right), \tag{1}$$

where $D_0 = a–bP$ is the base demand. The demand in period i decreases as the lead time in the previous period increases.

The production quantity in period i can be written as $q_i = \min\{Q, D_i + O_{i-1}\}$. Backorders in period i is $O_i = D_i + O_{i-1}–q_i$, where $O_0 = 0$. The actual length of the lead time in period i is determined as

$$L_i = 1 + \frac{O_i}{Q}. \tag{2}$$

The basic lead time is one period. The second term on the right hand side of the equation represents the expected length of time to fill the current backorders. The actual lead time is equal to the basic lead time when there are no backorders. It becomes longer with larger backorder quantity. It is assumed that $L_0 = 1$.

Costs that occur in each period include production cost and backorder cost. Revenue comes from taking orders from customers. Profit per period then can be written as $\pi_i = PD_i – (uq_i + kO_i)$. If the system operates n periods, total profit is

$$\pi_n^T = \sum_{i=1}^{n} \pi_i - uO_n, \tag{3}$$

where the last term is the production cost of the backorders at the end of period n.

When the base demand, D_0, is not greater than the production capacity per period, Q, the delivery lead time in period 1 is one period. Thus, the demand in the next period will be equal to the base demand. It then can easily be seen that demand per period will remain at the base demand. Therefore, the following analysis will focus on the case when the base demand is greater than the production capacity per period ($D_0 \geq Q$).

2.2 Base Instance

A base instance is presented to demonstrate the behavior of the system. The parameter setting of the base instance is shown in Table 1. Figure 1 compares the demand per period at the two sales prices, 500 and 480.

When the sales price is 500, the base demand is equal to the production capacity. There are no backorders and lead time is always at one period. Thus,

Table 1 Parameter setting of base instance

Parameters	Value
a	105,000
b	200
α	0.3
Q	5,000
k	10
u	380

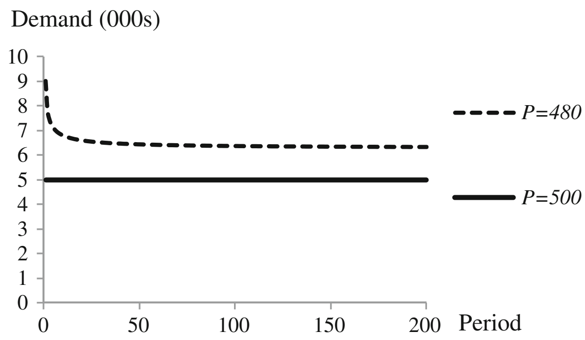


Fig. 1 Comparison of demand per period

demand period remains at the same level. With a sales price of 480, the base demand is 9,000, which is higher than the production capacity. Since backorders occur, lea time becomes longer. As a result, demand per period drops but remains above the production capacity.

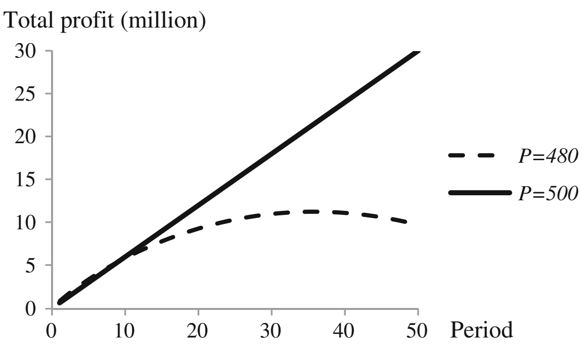
Figure 2 illustrates the comparison of the total profits at the two sales prices. As can be seen, the total profit increases linearly when the sales price is 500. It is because demand per period is steady at 5,000 at this sales price and there are no backorders. When the sales price is 480, the total profit goes up in the first place as well, even at a higher increment rate. The increment slows down gradually, though, until the total profit reaches a highest level. It then starts dropping afterwards and keeps dropping at an accelerated speed. Demand is boosted by a lower sales price. However, since demand per period becomes greater than the production capacity per period, backorders occur and accumulate. The total profit is rising at a faster speed in the beginning due to the revenue generated by the boosted demand. The delivery lead time is then prolonged due to the growing backorders. The demand per period decreases and so does the revenue per period. Furthermore, the total profit is eaten away gradually by the growing backorder cost and eventually may become negative.

The trend indicates that it is possible to create greater profit by lower the sales price and attract more demand. However, there is a risk with this strategy when the production capacity is limited. The delivery lead time can be prolonged due to the overwhelming demand and the backorders become too much of a burden for the system to bear.

3 Numerical Experiment

Numerical experiment is conducted to further explore the behaviors of the system constructed in the previous section. First, sales price setting strategy with the consideration of profit maximization is discussed. Next, sensitivity analysis on the various parameters is carried out.

Fig. 2 Comparison of total demand



3.1 Pricing Strategy Analysis

Analysis is performed on how the sales price affects the system. The parameter setting of the base instance is used and the sales price is set at 500, 480, 460, 440 and 420, respectively. Table 2 shows the comparison.

When the sales price is set at 480, the highest total profit is 11,268.498. It is reached after 36 periods. The total profit starts falling afterwards and reaches zero when the system operates for 74 periods. The fall continues after that and the total profit becomes negative. As shown, the highest total profit increases as the sales becomes closer to the base price, which is 500. The best number of periods and the break-even number of periods are greater as well.

Table 3 compares the total profit in each period under various sales prices in more detail. Values in bold face are the greatest total profit in the same period. During period 1 to period 4, the total profit is the greatest with the sales price of 460. It is the greatest with the sales price of 480 from period 5 to period 9 and with the sales price of 500 after period 10. It implies that the best sales price setting depends on how long the system is intended to run. If the system is intended to run for only a short duration of time, a lower sales price should be set in order to quickly attract more demand. If it is planned to run the system for longer duration, a higher sales price is preferred.

3.2 Sensitivity Analysis

Sensitivity analysis is conducted to further explore the behaviors of the system. The value of one parameter is changed while all the other parameter values are fixed as in the basic instance except the sales price which is set at 480. The sales

Table 2 Comparison under various sales prices

Sales price	Highest total profit	Best number of periods	Break-even number of periods
480	11,268,498	36	74
460	5,599,691	15	30
440	3,192,569	9	17
420	1,464,201	5	10

Table 3 Total profits in each period under various sales prices

Sales price	Period											
	1	2	3	4	5	6	7	8	9	10	11	12
500	60	120	180	240	300	360	420	480	540	600	660	720
480	86	157	222	283	341	396	448	497	544	589	632	673
460	96	167	230	285	335	379	418	453	482	507	526	541
440	90	150	199	239	271	294	310	318	319	312	298	277
420	68	105	130	144	146	138	120	91	52	3	−55	−124

Table 4 Parameter setting in sensitivity analysis

Parameter	Value				
α	0	0.3	0.5	0.7	0.9
b	10	50	100	150	20
k	0	10	20	30	
u	300	340	380	320	

Table 5 Results of sensitivity analysis

Parameter	Highest total profit	Best number of periods	Break-even number of periods
$\alpha \uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
$b \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$
$k \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$
$u \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$

price is set at this level such that the base demand is greater than the production capacity. Table 4 lists the parameter setting in the sensitivity analysis. The results are summarized in Table 5.

When demand sensitivity to lead time increases, the highest total profit, the best number of periods and the break-even number of periods all increase as well. It is because the base demand is higher than the production capacity. Backorders accumulate and thus lead time becomes longer. With greater demand sensitivity to lead time, demand per period drops more quickly to the level where the manufacturer can better manage with its limited production capacity. On the other hand, demand per period is reduced in a slower pace if customers are not very sensitive to lead time. The fast-accumulating backorders quickly erodes the profit. The total profit starts declining earlier and quickly reaches zero. Demand sensitivity to price has the opposite effect on the system. As it increases, the base demand grows and the highest total profit, best number of periods and break-even number of periods all drop. The backorder cost per unit per period and the production cost per unit have inference on the system in the same fashion. All the three indexes go down as they rise.

4 Conclusions

This study considers a multi-period direct sales channel system. A single manufacturer produces a single product with finite production capacity. Demand for a single product is price sensitive and lead time sensitive. A mathematical model is constructed for the system and numerical experiment is conducted for the purpose of analyzing its behaviors. It is found that if the base demand does not surpass the production capacity, demand per period is stable as the delivery lead time maintains at the promised level and thus profit per period is constant. When the base demand is greater than the production capacity, total profit may grow more quickly in the beginning. However, the increment slows down gradually and eventually the total profit starts declining. It is suggested that if the system is intended to operate for a long duration of time, the sales price should be set such that the base demand matches the production capacity. On the other hand, if the planned operating duration is short, e.g. the sold product has a short life cycle, a lower sales price can be set to quickly attract more demand and boost profit in a short term.

The setting of the relationship between the demand per period and the lead time length is primitive and simple. A setting that better grasps the nature of the demand sensitivity to lead time can be developed and applied to the proposed model in future research work.

References

Balasubramanian S (1998) Mail versus mall: a strategic analysis of competition between direct marketers and conventional retailers. Mark Sci 17:181–195

Ben-Daya M, Raouf A (1994) Inventory models involving lead time as decision variable. J Oper Res Soc 45:579–582

Hua GW, Wang SY, Cheng TCE (2010) Price and lead time decisions in dual-channel supply chains. Eur J Oper Res 295:113–126

Kotler P, Armstrong G (1994) Principles of marketing. Prentice Hall, New Jersey

Liao CJ, Shyu CH (1991) An analytical determination of lead time with normal demand. Int J Oper Prod Manag 11:72–78

Ouyang LY, Yeh NC, Wu KS (1996) Mixture inventory model with backorders and lost sales for variable lead time. J Oper Res Soc 47:829–832

Order and Pricing Decisions with Return and Buyback Policies

Chi-Yang Tsai, Pei-Yu Pai and Qiao-Kai Huang

Abstract This paper considers application of return and buyback policies in a supply chain system. The system contains a manufacturer and a retailer. The manufacturer produces and sells a single product to the retailer and promise to buy back all the remaining units from the retailer at the end of the selling season. The retailer orders from the manufacturer before the season and applies a return policy to its customers with full refund. Customer demand is assumed to be sensitive to the retail price. Before the beginning of the selling season, the manufacturer offers the wholesale price and the buyback to the retailer. The retailer then determines the order quantity and the retailer price. Two types of control are investigated. Under decentralized sequentially decision making, both the manufacturer and the retailer make their decisions to maximize their own profit. Under centralized control, all the decisions are jointly made to maximize the profit of the whole system. Mathematical models under the two types of control are constructed and optimal order and pricing decisions are derived. The optimal decisions and the resulting profits are compared. We show that centralized control always generates higher overall profit.

Keywords Return policy · Buyback policy · Supply chain · Price-sensitive demand

---

C.-Y. Tsai (✉) · P.-Y. Pai · Q.-K. Huang
Department of Industrial Engineering and Management, Yuan Ze University,
135 Yuan-Tung Road, Chung-Li, Tao Yuan, Taiwan
e-mail: iecytsai@saturn.yzu.edu.tw

P.-Y. Pai
e-mail: s1005407@mail.yzu.edu.tw

Q.-K. Huang
e-mail: s1015411@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_118,

1 Introduction

People's everyday life is linked to supply chains. A supply chain is a system and network of organizations, people, technology, activities, information and resources that participate in the production, product or service delivery, and product sale from the supplier to the retailer and from the retailer to the customer. In a supply chain system, there is management or control of materials, information, and finances as they move in a process from suppliers to customers.

In a supply chain system, customers may feel unsatisfied with the product they purchase from retailers for a variety of reasons. For example, the product is not suitable for them, not meeting their expectations or tastes, such as its color, shape, function, size in the case of T-shirts. Because of these conditions, customer's willingness to purchase the product may decline. In order to increase customer's willingness to purchase the product, the retailer may adopt customer product return policy. Under this policy, customers can return their purchased product to the retailer and get full or partial refund. To deal with the returned product, the manufacturer may adopt the buyback policy where the retailer can "sell back" the product returned by customers and unsold products (unsold inventories) to the manufacturer. The manufacturer buys back those products with a pre-agreed buyback price. Product buyback often occurs in the special seasons such as Christmas and Thanksgiving.

Cooper and Ellram (1993) stated that a supply chain consists of all parties involved in fulfilling a customer request, directly or indirectly. Hines et al. (1998) pointed out that supply chain strategies require a system view of the linkages in the chain that work together efficiently to create customer satisfaction at the end point of delivery to the consumer. Toktay et al. (2000) stated that customer return rates ranged from 5 to 9 % of sales for most retailers. Vlachos and Dekker (2003) considered a newsvendor-style problem with returned products to be resold only in the single period. Chen and Bell (2009) showed that given a wholesale price, an increasing customer return will reduce retailer's profit dramatically. Davis et al. (1995) stated that part of the motivation for retailers to offer a liberal returns policy is the fact that the retailer can share the cost of customer product returns with the supplier/manufacturer through a buyback policy. Kandel (1996) showed that the manufacturers and the retailers use a buyback policy to deal with demand information asymmetry. Tsai and Peng (2013) considered a single-period supply chain system where the manufacturer applies a buyback policy and the retailer accepts product returns from customers. The optimal pricing and order policy under decentralized was derived.

The rest of the paper is organized as follows. Section 2 describes the considered supply chain system and the mathematical model. The optimal pricing and order policies under decentralized and centralized controls are derived in Sect. 3. A numerical example is displayed in Sect. 4. The last section concludes the paper.

2 Problem Description and Model

This research follows the work of Tsai and Peng (2013) and discusses about the decision making in single-period supply chain system. The system contains a manufacturer and a retailer. The manufacturer adopts a buyback policy and the retailer applies a product return policy. At the beginning of the sales period, the manufacturer sets the wholesale price of its product and the buyback price. The retailer then places an order with the manufacturer and set the retail price. The manufacturer produces the quantity ordered by the retailer and delivers. During the period, customers purchase the product from the retailer. After purchasing the product, if customers feel unsatisfied with the product, they can return it to the retailer. The retailer will accept the returned product unconditionally and give full refund to the customer for the product returned. After the sales period ends, if there are units remaining at the retailer, including unsold units and units returned from customer, the retailer will repackage those units and sell them back to the manufacturer. The manufacturer buys back those units at the promised buyback price. After buying back those inventories, the manufacturer will sell all of them at the salvage price. The described supply chain system and its operations are shown in Fig. 1.

The following notation will be used.

P_r Retail price per unit
P_w Wholesale price per unit
P_b Buyback price per unit set
Q_r Quantity ordered by the retailer to the manufacturer
C_u Production cost per unit for the manufacturer
C_h Handling cost per unit by the retailer for handling sold back units to the manufacturer
P_s Salvage price per unit for the manufacturer
α Customer product return rate, $0 \leq \alpha \leq 1$
D_r Customer demand, products demand by the customer
a Primary demand
b Price sensitivity

It is assumed that the salvage price per unit is less than the production cost per unit, or the manufacturer would benefit simply by producing and selling at the salvage price. There is no limit on how many products the retailer can order. If the order quantity is greater than or equal to the customer demand, the selling volume is the customer demand; if the customer demand is greater than or equal to the order quantity, the selling volume is the order quantity.

It is assumed customer demand is retail-price sensitive. The customer demand is expressed as

$$D_r = a - bP_r. \tag{1}$$

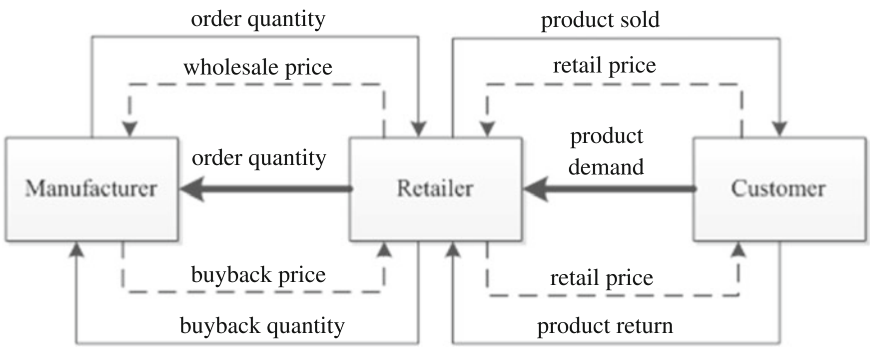


Fig. 1 Supply chain model framework

The costs incurred at the manufacturer include production cost from producing the quantity ordered by the retailer and cost of buying back all the remaining units from the retailer at the end of the period. The total cost of the manufacturer can be expressed as

$$TC_M = \begin{cases} Q_r C_u + P_b(Q_r - (1-\alpha)D_r) & \text{if } Q_r \geq D_r, \\ Q_r(C_u - \alpha P_b) & \text{otherwise.} \end{cases} \tag{2}$$

The manufacturer's revenue comes from the payment from the retailer for the ordered quantity and the salvage of the buyback units. It can be written as

$$TR_M = \begin{cases} Q_r P_w + P_s(Q_r - (1-\alpha)D_r) & \text{if } Q_r \geq D_r, \\ Q_r(P_w - \alpha P_s) & \text{otherwise.} \end{cases} \tag{3}$$

Equation (4) calculates the total cost of the retailer which includes payment to the manufacturer for the ordered quantity, cost of handling returned product and full refund to customers. The retailer's revenue contains the sales to customers and the buyback from the manufacturer. It can be expressed as Eq. 5.

$$TC_R = \begin{cases} Q_r P_w + \alpha D_r(P_r + C_h) & \text{if } Q_r \geq D_r, \\ Q_r(P_w + \alpha(P_r + C_h)) & \text{otherwise.} \end{cases} \tag{4}$$

$$TR_R = \begin{cases} Q_r P_r + P_b(Q_r - (1-\alpha)D_r) & \text{if } Q_r \geq D_r, \\ Q_r(P_r - \alpha P_b) & \text{otherwise.} \end{cases} \tag{5}$$

The respective profits of the manufacturer and the retailer are the difference between their own total revenue and total cost.

3 Optimal Control Policies

In this section, the optimal pricing and order policies are developed. Two types of control are considered. Under decentralized control (Tsai and Peng 2013), the manufacturer firstly sets the wholesale price and the buyback price. The retailer then determines the retail price and the order quantity. The two parties make their decisions to maximize their own profits. This paper further derives the optimal pricing and order policy for the system under centralized. That is, the decisions are made to maximize the profit of the system.

3.1 Optimal Decisions Under Decentralized Control

Under decentralized control, the retailer determines the retail price and the order quantity based on the wholesale price and the buyback price offered by the manufacturer, as well as customer demand that is sensitive to the retail price, and the product return rate. It is assumed that the manufacturer has full information of the entire supply chain system and it knows how the retailer makes decisions. It is a sequential decision making process where the manufacturer needs to makes its decisions first and the retailer makes its own decisions based on the manufacturer's offer. Therefore, the manufacturer needs to anticipate the retailer's move and incorporated it into its own decision making.

Given the wholesale price, buyback price and retailer price, the retailer would order a quantity that matches the demand if the following condition (marked as condition 1) holds. Otherwise, it would not order from the manufacturer as no profit would be gained.

$$P_r - P_w + \alpha(P_b - P_r - C_h) > 0 \tag{6}$$

In the case where this condition holds, the optimal retail price for the retailer can be obtained, as Eq. 7.

$$P_r = \frac{a}{2b} + \frac{P_w - \alpha(P_b - C_h)}{2(1-\alpha)} \tag{7}$$

Knowing how the retailer would make its decisions, it can be shown that the optimal wholesale price and buyback price for the manufacturer need to satisfy the following equation. Apparently, the manufacturer has to set the wholesale price and the buyback price such that condition 1 holds in order for the retailer to place an order.

$$P_w - \alpha P_b = \frac{1}{2}\left[\frac{a(1-\alpha)}{b} + C_u - \alpha(P_s + C_h)\right] \tag{8}$$

3.2 Optimal Decision Under Centralized Control

Under centralized control, all the decisions are jointly determined with the single objective of maximizing total profit of the whole supply chain system. It can be derived that the optimal order quantity is the demand if the following condition (marked as condition 2) holds, and zero otherwise.

$$(1-\alpha)P_r + \alpha(P_s - C_h) - C_u > 0 \tag{9}$$

When condition 2 holds, the optimal retail price can be written as Eq. 10. As can be seen, it does not involve the wholesale price and the buyback price. These two prices are the transfer prices in the supply chain system who transfer profit between the manufacturer and the retailer within the system. They determine how the total profit of the system distributes between the manufacturer and the retailer but do not affect the total profit of the system.

$$P_r = \frac{a}{2b} + \frac{C_u - \alpha(P_s - C_h)}{2(1-\alpha)} \tag{10}$$

It can be shown mathematically that under decentralized control, the optimal profit of the manufacturer is greater than that of the retailer. Furthermore, the optimal retail price under centralized control is always lower than that under decentralized control. It implies that the optimal order quantity under centralized control is greater than that under decentralized control. In addition, the optimal total profit of the system under centralized control is greater than that under decentralized control.

4 Numerical Example

A numerical example is created for the purpose of illustration. Table 1 shows the parameter setting of this example. Table 2 lists the optimal decisions, the resulting profit of the two parties and the system under centralized control and decentralized control. The example is designed such that condition 2 holds. Under decentralized control, the wholesale price and the buyback price are set at 14.375 and 12, respectively. The two prices are set such that Eq. 8 and condition 1 hold. Under

Table 1 Parameter setting of numerical example

Parameters	Value
a	500
b	20
α	0.05
P_s	3
C_u	4
C_h	1

Table 2 Optimal decisions and profits

Value	Decentralized control	Centralized control	Centralized control
Wholesale price	14.375	14.375	13.000
Buyback price	12.000	12.000	12.000
Optimal retail price	19.78	14.55	14.55
Optimal order quantity	104.47	208.95	208.95
Retailer's profit	518.45	0.00	287.30
Manufacturer's profit	1036.90	2073.80	1786.50
System's profit	1555.35	2073.80	2073.80

centralized control, two sets of the wholesale price and the buyback price, (14.375, 12) and (13, 12), are applied.

It can be seen clearly that under centralized control the optimal retail price, the optimal order quantity and the optimal profit of the system are the same regardless what wholesale price and buyback price are used. The two prices do not affect the optimal order quantity, the optimal retail price and the optimal system's profit. They only determine how the profit of the system is distributed between the manufacturer and the retailer.

When comparing the results under the two types of control, it can be found that the optimal order quantity and the optimal retail price under decentralized control are both lower than those under centralized control. Under decentralized control, the retailer tends to set a higher retail price in order to protect its own profit. It leads to a lower level of customer demand and thus a lower order quantity. In addition, centralized control generates higher system's profit compared to that under decentralized control.

5 Conclusions

This study considers a single-period supply chain system with a manufacturer and a retailer. The retailer accepts product return from customers with full refund. The manufacturer promises to buy back all the remaining units from the retailer at the end of the period. Customer demand is assumed to be retail-price sensitive. At the beginning of the period, the wholesale price, buyback price, retail price and quantity ordered by the retailer are to be determined. Assuming under centralized control, the optimal pricing and order policy are developed with the objective of maximizing the profit of the system. The condition on whether an order should be placed with the manufacturer is also derived. The results are compared to the optimal policy under decentralized control (Tsai and Peng 2013). It is shown that under centralized control, the wholesale price and the buyback price serve as transfer prices that do not affect the profit of the system and thus the optimal retail price and order quantity. The two prices only control how the system's profit is allocated to the manufacturer and the retailer. In addition, it can be mathematically proven that centralized control always generates higher profit of the system when compared to decentralized control. A numerical example is presented to further illustrate the result.

As it is shown the optimal overall profit of the system is never achieved with decentralized control. The issue of supply chain coordination rises for systems under decentralized control. The design of contracts that coordinate the system and are accepted by both the manufacturer and the retailer would be an interesting extension of this research.

References

Chen J, Bell PC (2009) The impact of customer returns on pricing and order decisions. Eur J Oper Res 195:280–295

Cooper MC, Ellram LM (1993) Characteristics of supply chain management and the implications for purchasing and logistics strategy. Int J Logist Manag 4:13–24

Davis S, Gerstner E, Hagerty M (1995) Money back guarantees in retailing matching products to consumer tastes. J Retailing 71:7–22

Hines P, Rich N, Bicheno J, Brunt D, Taylor D, Butterworth C, Sullivan J (1998) Value stream management. Int J Logist Manag 9:25–42

Kandel E (1996) The right to return. J Law Econ 39:329–356

Toktay LB, Wein LM, Zenios SA (2000) Inventory management of remanufacturable products. Manag Sci 46:1412–1426

Tsai CY, Peng PH (2013) Sequential decision making in a supply chain with customer return and buyback policies. Paper presented at the 3rd international forum and conference on logistics and supply chain management, Bali, Indonesia, pp 27–29

Vlachos D, Dekker R (2003) Return handling options and order quantities for single period products. Eur J Oper Res 151:38–52

Investigation of Safety Compliance and Safety Participation as Well as Cultural Influences Using Selenginsk Pulp and Cardboard Mill in Russia as an Example

Ekaterina Nomokonova, Shu-Chiang Lin and Guanhuah Chen

Abstract The aim of this study was to assess the effectiveness of the job demands–resources (JD–R) model in explaining the relationship of job demands and resources with safety outcomes (i.e., workplace injuries and near-misses). We collected self-reported data from 203 pulp and paper production workers from Pulp and Cardboard Mill which is located in Russia during the period 2000–2010. The results of a structural equation analysis indicated that job demands (psychological and physical demands) and job resources (decision latitude, supervisor support and coworker support) could affect safety performance and safety compliance, and thus influence the occurrence of injuries and near-misses and whether the cultural influences play a significant role in both safety compliance and safety participation.

Keywords Safety participation · Safety compliance · Job demands · Job resources · Cultural influences

E. Nomokonova (✉) · S.-C. Lin
Department of Industrial Management, National Taiwan University of Science and Technology, 43 Keelung Road, Sect. 4, Taipei 106, Taiwan, Republic of China
e-mail: nkaterina.s@gmail.com

S.-C. Lin
e-mail: slin@mail.ntust.edu.tw

G. Chen
Foundation of Taiwan Industry Service, Industrial Safety Division, No. 41, Alley 39, Ln. 198, Siwei Road, Taipei, Taiwan, Republic of China
e-mail: bill@ftis.org.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_119,

1 Introduction

Russia has predominantly a huge Pulp and Paper Industry. The Russian paper industry is the second largest in the world. The Pulp and paper industry graph in Russia has continued to show an upward trend since 1999.

According to RAO (Russian Association of Pulp and Paper Mills and Institutions) Bumprom, Russia's Pulp and Paper Industry has increased its paper production by 5.4 % (about 3.9 million tons) and the production of cardboard, which also includes production of container board by 7 % (about 2.9 million tons) since 2004.

As there are a lot of mills in this industry, on this research we will analyze one factory only and then compare it with Pulp and Cardboard Mill in Taiwan, which is one of the top three pulp factories among the world for potential cultural difference, in order to see if there are any cultural influence for safety performance and safety compliance.

2 Background Information

Selenginsk pulp and cardboard mill was created in 1973. In 1992, in accordance with privatization program of state and municipal enterprises of Republic of Buryatia. JSC "Selenginsk PCM" is a diverse enterprise, but its main activity makes it related to the pulp and paper industry. Since 1990 the Company operates the world's only system of a closed water cycle which enables to exclude discharge of industrial wastewater plant.

The company organized integrated conversion of pulp into the final product, that is, a cardboard container. Selenginsk Mill is a city-forming enterprise that provides more than 2.1 thousand of Selenginsk' population with jobs and, therefore, is a major source of replenishment of the local budget via fees and taxes. The territory of the mill is more than 400 ha and its annual containerboard production averages approximately 100,000 tone, sacks and paper bags production around 6 million and corrugated production around 60 million square meters.

Pulp and paper manufacturing can also be very hazardous due to massive weights and falling, rolling, and/or sliding pulpwood loads. Workers may be struck or crushed by loads or suffer lacerations from the misuse of equipment, particularly when machines are used improperly or without proper safeguards. Other causes of multiple deaths included electrocution, hydrogen sulphide and other toxic gas inhalation, massive thermal/chemical burns and one case of heat exhaustion. The number of serious accidents associated with paper machines has been reported to decrease with the installation of newer equipment in some countries. In the converting sector, repetitive and monotonous work, and the use of mechanized equipment with higher speeds and forces, has become more common.

Although no sector-specific data are available, it is expected that this sector will experience greater rates of over-exertion injuries associated with repetitive work.

Today, many industries and indeed regulatory agencies still focus completely on common safety performance measures such as lost time injury frequency rate and number of lost days in an effort to measure safety performance. Unfortunately, such indicators just measure failure to control and give no indication of risk management effort, which may take time to come to fruition. A lot of researches have been done in order to investigate safety performance or safety-related components for the last quarter century.

In more recent years, there has been a trend toward conceptualizing safety performance as multi-dimensional in the occupational safety research literature. For example, Griffin and Neal (2000) have conceptualized two types of employee safety performance: safety compliance and safety participation. Safety compliance corresponds to task performance and includes such behaviors as adhering to safety regulations, wearing protective equipment, and reporting safety-related incidents. Safety participation is parallel to contextual performance and focuses on voluntary behaviors that make the workplace safe beyond prescribed safety precautions, including taking the initiative to conduct safety audits and helping co-workers who are working under risky conditions. There are three safety–specific determinants such as job demands, job control and social support.

3 Hypotheses

The objective of this study is to investigate how these three characteristics simultaneously influence the work performance on the example of Selenginsk Pulp and Cardboard Mill in Russia, and whether the cultural influences play a significant role in both safety compliance and safety participation. In the present study, the job demands–resources (JD–R) framework (Bakker et al. 2003a) is used to explore how job demands and resources affect safety outcomes, specifically near-misses and injuries, thus we have made three hypotheses, as stated below, for further investigations into our objective.

Hypothesis 1 Job resources are positively correlated with safety compliance.

Although the Job demands resources (JD–R) model does not propose relationship between job demands and engagement, there have been inconsistent and unexpected results. In the area of occupational safety, however, challenge demands may actually constrain employees' progress toward workplace safety as stress can compel individuals to focus narrowly on only a few specific aspects of the work environment or objectives (Hofmann and Stetzer 1996; Weick 1990). For instance, under increased performance pressure or time constraints, employees might utilize more "short cut" work methods, perceiving there is not always enough time to follow safety procedures and resulting in a higher frequency of unsafe behaviors (Hofmann and Stetzer 1996). A recent meta-analysis found that hindrance demands such as risks and hazards, physical demands, and complexity were negatively associated with safety compliance (Nahrgang et al. 2011). Taken together, we expect that both challenge demands and hindrance demands will be negatively related to safety compliance.

Hypothesis 2 Job demands are negatively correlated with safety compliance.

In general, the JD–R model proposes that a state of exhaustion leads to increased absenteeism as a result of illness and decreased in-role performance (Bakker et al. 2003b, 2005). Burnt-out employees are more likely to commit mistakes and injure themselves, because of a depletion of their mental and physical energy (Nahrgang et al. 2011). Thus, we expect that emotional exhaustion will be positively associated with near-misses and injuries in the workplace.

Hypothesis 3 Safety compliance is positively correlated with safety outcomes (safety performance).

Existing studies support the dual psychological processes proposed by the JD–R model; related data suggest that job demands and resources can predict important organizational outcomes by such dual pathways. In the literature on occupational safety, a direct correlation between job demands/resources and safety outcomes has been found; situational constraints, time pressures and work overload have all shown positive relationships with injuries and near-misses (Goldenhar et al. 2003; Jiang et al. 2010; Nahrgang et al. 2011; Snyder et al. 2008). Conversely, supportive environments and job autonomy have shown negative associations with injuries and near-misses (Barling et al. 2003; Goldenhar et al. 2003; Jiang et al. 2010; Nahrgang et al. 2011).

4 Methods

A survey was administered to pulp and paper workers from Selenginsk Pulp and Cardboard Mill in Russia. The core job responsibility of these workers is to ensure effective execution and completion of the pulp and paper production plan by working as a crew. Specifically, their job duties are to inspect and resolve equipment failure, to operate and maintain all kinds of equipment (e.g., starting or shutting paper machine line), to adjust or replace mechanical components according to workflow, to handle emergency, and so on. During work hours, these workers might be subject to various risks, such as harsh physical environments, being injured by machines, being struck by objects, falling from a high place, fire, and chemical corrosion.

The present study examined 203 reports of occupational accidents and fatalities in the industry from 2000 to 2010, as recorded in the occupational accidents database of the Selenginsk Pulp and Cardboard Mill. The major factors affecting pulp and cardboard accidents were: most people who got injuries are men (74 %), at the age from 26 to 30 (18 %), accident type (fall down, trapping by shifts and influence by moving objects), unsafe acts mostly failure to use safeguard measures and warnings. This percentage of male respondents may seem usual for pulp and paper workers. One explanation is that male workers had a lower response rate than female workers.

5 Proposed Measurements

5.1 Job Demands

In the present study, job demands were defined as physical demands (4 items) and psychological demands (7 items), using the Job Content Questionnaire (JCQ); Karasek et al. (1998). Two factors supported the use of this measure. First, physical exposure (e.g., working with heavy equipment) is the most frequent stressor experienced by pulp and paper production workers. Second, the psychological demands subscale includes mental and cognitive workloads and time constraints, which have demonstrated positive relationships with injuries and near-misses (Goldenhar et al. 2003; Jiang et al. 2010; Nahrgang et al. 2011; Snyder et al. 2008).

5.2 Job Resources

According to the literature, supportive environments and job autonomy have both shown negative associations with injuries and near-misses (Barling et al. 2003; Goldenhar et al. 2003; Jiang et al. 2010; Nahrgang et al. 2011). Thus, in the current study, job resources were measured by decision latitude (9 items), supervisory support (5 items) and coworker support (6 items), according to the JCQ. As a variable often used to describe control on the job (i.e., autonomy; Westman 1992), decision latitude was divided into the two theoretically distinct, although often highly correlated, sub dimensions of skill discretion and decision authority (Karasek et al. 1998).

All items from the JCQ were rated by the respondents using a 4-point scale: strongly disagree (1), disagree (2), agree (3), and strongly agree (4).

5.3 Safety Compliance

A 3-item scale by Neal and Griffin was adopted to assess safety compliance in terms of core safety activities that should be carried out by employees to maintain workplace safety. All items were rated on a 5-point scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree).

5.4 Safety Outcomes

Self-reported injuries and near-misses were used to assess safety outcomes. Specifically, injuries were indicated by a summation of the employees' responses regarding whether any major body parts had been injured during the past year, including the head, neck, eyes, shoulders, arms, wrists, hands, upper back, lower back, legs, ankles, feet and other (Goldenhar et al. 2003; Jiang et al. 2010). Participants were also asked to recall the total number of near-misses (i.e., incidents that could have resulted in an injury, but did not) that they had experienced during the past year (Goldenhar et al. 2003; Jiang et al. 2010).

5.5 Analyses

Maximum likelihood structural equation modeling (SEM) will be used to test our proposed model with Lisrel 8. Based on Anderson and Gerbing's suggestions, a two-step approach to SEM was adopted. First, the factor structure of the variables in this study was tested to confirm that the model specifying the posited structure of the underlying constructs would fit the observed data. Second, the proposed structural model was compared with an alternative model to assess which one better accounted for the co variances observed between the model's exogenous and endogenous constructs.

References

Bakker AB, Demerouti E, de Boer E, Shaufeli WB (2003) Job demands and job resources as predictors of absence duration and frequency. J Vocat Behav 62:341–356

Bakker AB, Demerouti E, Euwema MC (2005) Job resources buffer the impact of job demands on burnout. J Occup Health Psychol 10:170–180

Barling J, Kelloway EK, Iverson RD (2003) High-quality work, job satisfaction, and occupational injuries. J Appl Psychol 88:276283

Goldenhar LM, Williams LJ, Swanson NG (2003) Modelling relationships between job stressors and injury and near-miss outcomes for construction labourers. Work Stress 17:218–240

Griffin MA, Neal A (2000) Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. J Occup Health Psychol 5:347–358

Hofmann DA, Stetzer A (1996) A cross-level investigation of factors influencing unsafe behaviors and accidents. Pers Psychol 49:307–339

Jiang L, Yu G, Li Y, Li F (2010) Perceived colleagues' safety knowledge/behavior and safety performance: safety climate as a moderator in a multilevel study. Accid Anal Prev 42:1468–1476

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B (1998) The job content questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 3:322–355

Nahrgang JD, Morgeson FP, Hofmann DA (2011) Safety at work: a meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. J Appl Psychol 96:71–94

Snyder LA, Krauss AD, Chen PY, Finlinson S, Huang Y (2008) Occupational safety: application of the job demand–control–support model. Accid Anal Prev 40:1713–1723

Weick KE (1990) The vulnerable system: an analysis of the Tenerife air disaster. J Manage 16:571–593

Westman M (1992) Moderating effect of decision latitude on stress–strain relationships does organizational level matter? J Organiz Behav 13:713–722

Identifying Process Status Changes via Integration of Independent Component Analysis and Support Vector Machine

Chuen-Sheng Cheng and Kuo-Ko Huang

Abstract Observations from the in-control process consist of in-control signals and random noise. This paper assumes that the in-control signals switch to different signal types when the process status changes. In these cases, process data monitoring can be formulated as a pattern recognition task. Time series data pattern recognition is critical for statistical process control. Most studies have used raw time series data or extracted features from process measurement data as input vectors for time series data pattern recognition. This study improves identification by focusing on the essential patterns that drive a process. However, these essential patterns are not usually measurable or are corrupted by measurement noise if they are measurable. This paper proposes a novel approach using independent component analysis (ICA) and support vector machine (SVM) for time series data pattern recognition. The proposed method applies ICA to the measurement data to generate independent components (ICs). The ICs include important information contained in the original observations. The ICs then serve as the input vectors for the SVM model to identify the time-series data pattern. Extensive simulation studies indicate that the proposed identifiers perform better than using raw data as inputs.

Keywords Time series data pattern · Independent component analysis · Support vector machine

---

C.-S. Cheng (✉) · K.-K. Huang
Department of Industrial Engineering and Management, Yuan Ze University,
135 Yuan-Tung Road, Chung-Li 32003, Taiwan
e-mail: ieccheng@saturn.yzu.edu.tw

K.-K. Huang
e-mail: m9223016@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_120,

1 Introduction

Statistical process control (SPC) concepts and methods have been successfully implemented in the manufacturing and service industries for decades. A process is considered out of control when a point exceeds the control limits or a series of points exhibit an unnatural pattern. Unnatural pattern analysis is important for SPC because unnatural patterns can reveal potential process quality problems (Western Electric Company 1956). Once unnatural patterns are recognized, narrowing the diagnostic search process scope to a smaller set of possible causes for investigation reduces the troubleshooting time required. Hence, accurate and timely detection and recognition of time series data patterns are important when implementing SPC.

A real manufacturing process often operates in an in-control state over a relatively long period. This study assumes that process status during an in-control state is gamma distributed. The gamma distribution is a typical case for the asymmetric distributions. Borror et al. (1999) used the gamma distribution to study the effect of a skewed distribution on monitoring performance. In addition, the impurities and particle counts of the semiconductor industry are considered as gamma distribution (Levinson 1997). However, certain conditions occasionally occur, resulting in an out-of-control state where much of the process output does not conform to requirements. Capizzi and Masarotto (2012) considered eight nonrandom patterns, including constant, intermittent, geometric, linear, mixture-20, mixture-80, cosine and chirp. Figure 1 shows these out-of-control patterns. These out-of-control patterns shows either intermittent or oscillatory behaviors.

Occasionally, measurement noise corrupts time series data patterns. The time series data pattern identifier is usually unable to accurately recognize the out-of-control time series data patterns caused by this noise. Thus, a powerful time series data pattern identifier is necessary to accurately classify all types of time series data patterns. Several approaches have been proposed for identifying time series data patterns. These include statistical approaches (Cheng and Hubele 1996; Yang and Yang 2005), rule-based system (Cheng 1989; Wang et al. 2009), artificial neural network techniques (Cheng and Cheng 2008; Jiang et al. 2009), and support vector machine (SVM) (Das and Banerjee 2010). For a more detailed discussion of how to identify time series data patterns, please refer to Hachicha and Ghorbel (2012). Most studies have used raw process data or extracted features from process measurement data as input vectors for time series data pattern recognition.

Process-measured data can be considered as linear mixtures of unknown time series data patterns where the coefficient mixing matrix is also unknown. This study improves identification by focusing on the essential patterns that drive a process. However, these essential patterns are not usually measurable or are corrupted by measurement noise if they are measurable. Independent component analysis (ICA) is a novel algorithm that is able to separate independent components (ICs) from complex signals (Hyvärinen 1999; Hyvärinen and Oja 2000). This study develops a novel approach that combines ICA and an SVM for time series data pattern identification. The proposed method applies ICA to the measurement data to generate ICs. The ICs include important information contained in the original observations. The ICs then serve as the input vectors for the SVM model to identify the time series data patterns.

2 Methodology

2.1 Independent Component Analysis

ICA is a very useful technique and suitable for data processing in manufacturing process. ICA can be used to demix the observed time series data blindly and extract the statistically independent components expressed as linear combinations of observed variables. ICA is usually used for revealing latent factors underlying sets of random variables, signals, or measurements. ICA was originally proposed to solve the problem of blind source separation, which involves recovering independent source signals after they have been linearly mixed by an unknown mixing mechanism.

The general model for ICA is that the sources are generated through a linear basis combination, where additive noise can be present. Suppose we have N statistically independent signals, $s_i(t),\ i = 1, 2, \ldots, N$. We assume that the sources themselves cannot be directly observed and that each signal, $s_i(t)$, is a realization of some fixed probability distribution at each time point t. Also, suppose we observe these signals using $s_i(t)$ sensors, then we obtain a set of N observation signals $x_i(t),\ i = 1, 2, \ldots, N$ that are mixtures of the sources. A fundamental aspect of the mixing process is that the sensors must be spatially separated so that each sensor records a different mixture of the sources. With this spatial separation assumption in mind, we can model the mixing process with matrix multiplication as follows:

$$x(t) = \mathbf{A}s(t). \tag{1}$$

where $\mathbf{A}$ is an unknown matrix called the mixing matrix and $x(t)$, $s(t)$ are the two vectors representing the observed signals and source signals respectively. Incidentally, the justification for the description of this signal processing technique as blind is that we have no information on the mixing matrix, or even on the sources themselves. The objective is to recover the original signals, $s_i(t)$, from only the observed vector $x_i(t)$. We obtain estimates for the sources by first obtaining the "unmixing matrix" $\mathbf{W}$, where, $\mathbf{W} = \mathbf{A}^{-1}$. This enables an estimate, $\hat{s}(t)$, of the independent sources to be obtained:

$$\hat{s}(t) = \mathbf{W}x(t). \tag{2}$$

2.2 Support Vector Machine

The SVM is a powerful new machine learning algorithm, which is rooted in statistical learning theory. By constructing a decision surface hyper-plane which yields the maximal margin between position and negative examples, SVM approximately implements the structure risk minimization principle. A classification task usually involves training and testing data that consist of certain data instances. Each training set instance contains one target value (class label) and several attributes (features). The goal of a classifier is to produce a model that predicts the target value of testing set data instances that are only given attributes.

In practical, constructing a separating hyper-plane in the feature space leads to a non-linear decision boundary in the input space. Time-consuming calculation of dot products in a high-dimensional space can be avoided by introducing a kernel function that satisfies $K(\mathbf{x}_i, \mathbf{x}_j) = \phi(\mathbf{x}_i) \cdot \phi(\mathbf{x}_j)$. The kernel function allows all necessary computations to be performed directly in the input space. Many types of kernel functions can be used in SVM, but two types are usually used: the radial basis function (RBF), $K(\mathbf{x}_i, \mathbf{x}_j) = \exp\{-\gamma||\mathbf{x}_i - \mathbf{x}_j||^2\}$, $\gamma > 0$; and the polynomial kernel of degree d, $K(\mathbf{x}_i, \mathbf{x}_j) = (\gamma \mathbf{x}_i \cdot \mathbf{x}_j + r)^d$, $\gamma > 0$. This research uses the RBF kernel function for the SVM classifier because it can analyze data that are non-linear and have multiple dimensions and require fewer parameters to be determined.

3 The Proposed ICA and SVM Scheme

This section presents a novel ICA-SVM scheme to identify the eight out-of-control time series data patterns (shown in Fig. 1) and a gamma distribution, in-control, time series data pattern. The nine time series data patterns are the corresponding multiple target values (class labels) in the SVM. The proposed scheme has two stages: off-line training and on-line testing. Each training set instance contains one target value (class label) and several attributes (features). However, each testing set instance has attributes and no target values because this is generated by the proposed identifier. The training and testing data have the same number of data instances, other than the testing data target values, which are predicted by the identifier.

In the training stage, time-series data are collected during an in-control state. Each data matrix row is normalized individually using the mean (μ_{in}) and standard deviation (σ_{in}) of each row. A normalized data matrix is referred to as $\mathbf{X}_{in}$. Applying the FastICA algorithm to the normalized data produces demixing Matrix $\mathbf{W}$. From (2), the ICs ($\hat{\mathbf{S}}_{in}$) at in-control conditions can be calculated using $\hat{\mathbf{S}}_{in} = \mathbf{W}\mathbf{X}_{in}$. A similar process is used to obtain ICs at out-of-control conditions, but they are normalized using in-control μ_{in} and σ_{in}. The out-of-control data matrix

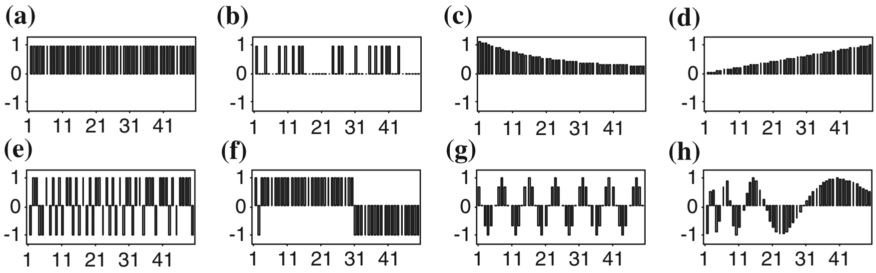


Fig. 1 Eight types of out-of-control patterns. **a** Constant, **b** Intermittent, **c** Geometric, **d** Linear, **e** Mixture-20, **f** Mixture-80, **g** Cosine, **h** Chirp

is referred to as $\mathbf{X}_{out}$. ICs ($\hat{\mathbf{S}}_{out}$) at out-of-control operation conditions are calculated using $\hat{\mathbf{S}}_{out} = \mathbf{W}\mathbf{X}_{out}$.

In order to select the target $\hat{\mathbf{S}}$ which represents the time series pattern, the non-gaussianity of each $\hat{\mathbf{S}}$ is evaluated using the Shapiro–Wilk test of normality. The null hypothesis is that $\hat{\mathbf{S}}$ has a normal distribution with mean and variance estimated from $\hat{\mathbf{S}}$, against the alternative that $\hat{\mathbf{S}}$ is not normally distributed with the estimated mean and variance. The test returns the $p - value$, computed using inverse interpolation into the table of critical values. Small values of $p - value$ cast doubt on the validity of the null hypothesis. The test rejects the null hypothesis at the 5 % significance level.

This study uses an SVM to develop time-series data pattern identifiers. The LIBSVM program (Chang and Lin 2010) in a MATLAB development environment was used to build the SVM model. Selecting an appropriate kernel is the most important SVM design decision because this defines the feature space and mapping function ϕ. Different SVM parameter kernel functions were tested. The RBF kernel was selected as the kernel function because it tends to perform better. The RBF kernel function must only tune kernel parameter γ and penalty factor C. However, there are no general rules for selecting C and γ. SVM parameters are usually selected by experimenting. To determine the two parameters, a grid search with 5-fold cross-validation experiment was used to select parameter settings that yielded the best results. Exponentially increasing C and γ sequences were tested, that is, $C \in \{2^{-5}, 2^{-4}, \ldots, 2^{5}\}$ and $\gamma \in \{2^{-5}, 2^{-4}, \ldots, 2^{5}\}$, respectively. C and γ parameter sets with the highest correct classification rates during cross-validation were selected as the optimal parameter sets. The final SVM model was built using these settings and used to test time-series data pattern identification.

During the testing stage, normalized input data were obtained before the identifier was applied. The normalized data set is referred to as $\mathbf{X}_{new}$. The new ICs ($\hat{\mathbf{S}}_{new}$) were obtained using $\hat{\mathbf{S}}_{new} = \mathbf{W}\mathbf{X}_{new}$. $\hat{\mathbf{S}}_{new}$ was fed into the trained SVM model to identify the IC pattern.

Table 1 Parameters for out-of-control patterns

Pattern type	Equations
Constant	$s(t) = \delta$
Inrermittent	$s(t) = \delta \times u(t)$, where $u(t) \sim \text{Binomial}(1, 0.2)$
Geometric	$s(t) = \delta \times (0.2 + 0.95^t)$
Linear	$s(t) = \delta \times (t/50)$
Mixture-y	$s(t) = \begin{cases} \delta, & t = 0 \\ \delta \times (-1)^{1-u(t)} x(t-1), & t \neq 0 \end{cases}$ where $u(t) \sim \text{Binomial}(1, \frac{y}{100})$
Cosine	$s(t) = \delta \times \cos(2\pi t/8)$
Chirp	$s(t) = \delta \times \cos\left(\frac{2\pi t}{2 + t/5}\right)$

4 Experimental Results

This section uses a simulation to illustrate the efficiency of the proposed scheme. Ideally, example patterns for in- and out-of-control process statuses should be developed from a real process. However, sufficient training instances of out-of-control statuses may not be easily available. Studies have generated training examples based on a predefined mathematical model and Monte Carlo simulations. This study uses an observation window with 52 data points, implying that each sample pattern consists of 52 time-series data (Table 1).

A two-dimensional vector ($\mathbf{x}(t) = [x_1(t),\ x_2(t)]^T$) represents the two process measurement data sets obtained simultaneously from two parallel machines. The two variables in the two-dimensional vector ($\mathbf{s}(t) = [s_1(t),\ s_2(t)]^T$) denotes as the source variables, $s_2(t)$ is gamma distribution and $s_1(t)$ is the process pattern. There are eight out-of-control time series data patterns and gamma distribution (in-control) time series data pattern considered as process patterns in this paper. Observations from gamma distribution are non-negative. The gamma distribution can be denoted as Gam (α, β) with the probability density function given by

$$f(x) = \frac{1}{\alpha^\beta \Gamma(\beta)} x^{\beta-1} \exp(-x/\alpha), \quad x > 0. \tag{3}$$

And the mean and variance given, respectively, by $\mu = \alpha/\beta$ and $\sigma^2 = \alpha/\beta^2$. In this paper, we considered two heavily skewed cases, Gam(0.5,1) and Gam(1,1).

It is assumed that the measured data, $\mathbf{x}(t)$, are linear combinations of unknown source patterns $\mathbf{s}(t)$. The discrete ICA time model is described as

$$\mathbf{x}(t) = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \mathbf{s}(t) + \ v. \tag{4}$$

where $a_{11},\ a_{12},\ a_{21},\ a_{22}$ are unknown mixing constants. Without a generality loss, it is assumed that $\sum_{j=1}^{2} a_{1j} = 1$ and $\sum_{j=1}^{2} a_{2j} = 1$. $a_{11},\ a_{12},\ a_{21},\ a_{22}$ were randomly generated between 0 and 1; therefore, $a_{11} = 0.1736$, $a_{12} = 0.8264$, $a_{21} = 0.5482$, and $a_{22} = 0.4518.v$ following normal distribution with standard deviation $\sigma_v = 0.5$.

The first in-control distribution considered in this paper is Gam(0.5,1). FastICA is first used to estimate demixing matrix $\mathbf{W}$ in the training stage. Then, in the testing stage, FastICA is applied to measurement data from the two parallel machines to estimate the two ICs. Each input instance was composed of 52 data points per observation window, and 36,000 instances were used as SVM input data to build the raw data-based time series data pattern recognition model. To demonstrate the performance of the proposed scheme, FastICA was used to preprocess the same 36,000 instances to obtain ICs that were used to build the IC-based time-series data pattern recognition model.

After applying the grid search method to the raw data-based identifier to tune the SVM parameters, the best parameter sets were $C = 0.5$ and $\gamma = 2^{-7}$. The best set of parameters for the IC-based identifier was $C = 1$ and $\gamma = 2^{-7}$. The average correct classification rates of the raw data-based identifier and IC-based identifier were 86.21 and 83.17 %, respectively. The results prove that the proposed method removes noise while preserving the main time-series data pattern information.

When the parameter α increases, the gamma distribution appears more nearly normal. To further compare the performance of the proposed ICA-SVM scheme to methods under different α values, Gam(1,1) was considered. This study also used the RBF kernel function and grid search strategy to select the best parameter sets. The best parameter sets for the raw data-based identifier and IC-based identifier were $C = 0.5$, $\gamma = 2^{-6}$ and $C = 0.5$, $\gamma = 2^{-6}$, respectively. Without the proposed ICA-SVM, the average correct classification rates of the raw data-based identifier and IC-based identifier were 86.13 and 92.48 %, respectively. The simulation experiments confirm empirically that the IC-based identifier performs better than the raw data-based identifier under Gam(1,1).

5 Conclusion

Effectively and accurately identifying time-series data patterns from an out-of-control process status is a difficult and challenging task. Most previous studies have used raw process measurement data as the input vector for time series data pattern recognition. The process signal is often mixed with unknown noise. A traditional pattern identifier has difficulty excluding noise that affects accurate pattern classification. This paper proposes a novel approach that uses ICA and SVM for time series data pattern recognition. The proposed method applies ICA to the obtained measurement data to generate ICs. The SVM model is then applied to each IC for time series data pattern recognition. This study uses nine time series data pattern groups to evaluate the performance of the proposed scheme.

The simulated experiment results show that the proposed ICA-SVM identifier produces a higher average correct classification rate than the traditional identifier when using the same raw data as inputs. The results show that the proposed scheme effectively and accurately recognizes the nine types of time-series data patterns in either in-control or out-of-control process statuses.

References

Borror CM, Montgomery DC, Runger GC (1999) Robustness of the EWMA control chart to non-normality. J Qual Technol 31:309–316

Capizzi G, Masarotto G (2012) Adaptive generalized likelihood ratio control charts for detecting unknown patterned mean shifts. J Qual Technol 44:281–303

Chang CC, Lin CJ (2010) LIBSVM 3.11: a library for support vector machines. Technical report, Department of Computer Science and Information Engineering, National Taiwan University. http://www.csie.ntu.edu.tw/~cjlin/libsvm/

Cheng CS (1989) Group technology and expert systems concepts applied to statistical process control in small-batch manufacturing. PhD Dissertation, Arizona State University, Tempe, AZ, USA

Cheng HP, Cheng CS (2008) Denoising and feature extraction for control chart pattern recognition in autocorrelated processes. Int J Signal Imaging Syst Eng 1:115–126

Cheng CS, Hubele NF (1996) A pattern recognition algorithm for an x-bar control chart. IIE Trans 29:215–224

Das P, Banerjee I (2010) An hybrid detection system of control chart patterns using cascaded SVM and neural network-based detector. Neural Comput Appl 20:287–296

Hachicha W, Ghorbel A (2012) A survey of control-chart pattern-recognition literature (1991–2010) based on a new conceptual classification scheme. Comput Ind Eng 63:204–222

Hyvärinen A (1999) Fast and robust fixed-point algorithms for independent component analysis. IEEE Trans Neural Networks 10:626–634

Hyvärinen A, Oja E (2000) Independent component analysis: algorithms and applications. Neural Networks 13:411–430

Jiang P, Liu D, Zeng Z (2009) Recognizing control chart patterns with neural network and numerical fitting. J Intell Manuf 20:625–635

Levinson W (1997) Watch out for nonnormal distributions of impurities. Chem Eng Prog 93:70–76

Wang CH, Dong TP, Kuo W (2009) A hybrid approach for identification of concurrent control chart patterns. J Intell Manuf 20:409–419

Western Electric Company (1956) Statistical quality control handbook. Western Electric Company, Indianapolis

Yang JH, Yang MS (2005) A control chart pattern recognition system using a statistical correlation coefficient method. Comput Ind Eng 48:205–221

A Naïve Bayes Based Machine Learning Approach and Application Tools Comparison Based on Telephone Conversations

Shu-Chiang Lin, Murman Dwi Prasetio, Satria Fadil Persada and Reny Nadlifatin

Abstract This paper investigates the application of hybrid Bayesian based semi-automated task analysis machine learning tool, Text Miner. The tool is still in its developing stage. Telephone's dialog conversation between call center agent and customer was used as training and testing dataset to feed in parsing based Text Miner. Preliminary results extracted from Text Miner based on the naïve Bayes approach was further compared to one open sourced machine learning program, tokenizing based Rapid Miner. Fifteen prediction words combinations were compared and the study finds that both tools are capable of processing large dataset with Text Miner performs better than Rapid Miner in predicting the relationship between prediction words and main subtask categories.

Keywords Machine learning · Naive bayes · Text miner · Rapid miner · Parsing · Tokenizing · Task analysis

---

S.-C. Lin (✉) · S. F. Persada · R. Nadlifatin
Department of Industrial Management, National Taiwan University of Science and Technology, 43 Keelung Road, Section 4, Taipei 106, Taiwan, Republic of China
e-mail: slin@mail.ntust.edu.tw

S. F. Persada
e-mail: d10101807@mail.ntust.edu.tw

R. Nadlifatin
e-mail: m10001834@mail.ntust.edu.tw

M. D. Prasetio
Independent Electrical Consultant, Hidrodinamika 4 T-74, Surabaya 60115, Indonesia
e-mail: prasetio_arel.corp@yahoo.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_121,

1 Introduction

Lin and Lehto's study (2009) proposed a Bayesian inference based semi-automated task analysis tool, Text Miner, to better help task analysts predict categories of tasks/subtasks performed by knowledge agents from telephone conversations where agents help customers troubleshoot their problems. The study finds that the task analysis tool is able to learn, identify, and predict subtask categories from telephone conversations. With the profusion of results obtained in previous work, more analyses needed to be done in order to identify the relationship between prediction words and main subtask category. For that reason, this study further examines and compares the performance results from Text Miner with another machine learning tool, an open sourced Rapid Miner. The prediction accuracy to main subtask categories among fifteen combinations of prediction words were carried out by both tools based on naïve Bayes method.

2 Literature Review

2.1 *Task Analysis and Task Modeling*

Methods of collecting, classifying and interpreting data on human performance lie at the very fundamental of ergonomics. Task analysis and task modeling especially play critical roles for interactive system design. Task analysis helps the designers to acquire an user oriented perspective of the activity, thus avoiding function oriented biases during the development process (Kirwan and Ainsworth 1992). Task modeling helps for in depths understanding, communicating, testing and predicting fundamental aspects of the human–machine system.

2.2 *Naive Bayes*

Naive Bayes is one of the most efficient probabilistic algorithms for machine learning (Zhang 2004) without trading much of the effectiveness. The general naïve Bayes rule is illustrated in Eq. (1), where P(B|A) is the probability of the evidence P(A) given that the hypothesis B is true, P(B) is the prior probability of the hypothesis being true prior to obtaining the evidence A.

$$P(B|A) = \frac{P(A|B) * P(B)}{P(A)} \tag{1}$$

The implementation of naïve Bayes in text classification is known as Naïve Bayes Classifier. Many researches use Naive Bayes Classifier as a core classification in their classification method. Mosteller and Wallace (1964, 1984) proposed

Hierarchical Bayes Model for contagious distribution in modern language models. Lin et al. (1999) used Naive Bayes to identify plausible causes for ship collisions in and out five major US ports. Berchiala et al. (2013) used the Naïve Bayes Classifier with selection feature in hospital to identify the severity level of children injury in order to detect the most critical characteristic of the injury that can result to the hospital treatment. Perhaps the most recent success example was Silver (2012)'s Bayesian approach to predict US presidential elections.

3 Model Used and Tool Comparison

3.1 Current Model

Lin and Lehto's (2009) proposed model is shown in Fig. 1. The model consists of 4 phases: data collection, data manipulation, machine learning tool environment, and tools evaluation. In the machine learning phase, the machine learning was used to adapt the situation from knowledge base and classify the data into several subtasks categories. An application of Text Miner was used as a semi-automated task analysis tool to help identify and predict the subtask categories based on naïve Bayes, fuzzy Bayes, and hybrid Bayes.

3.2 Machine Learning Tools Comparison

To represent the use of machine learning, a software called Rapid Miner was chosen as a comparison tool to the proposed Text Miner. Rapid Miner is an open source environment for machine learning and data mining (Mierswa et al. 2006). Similar to Text Miner, Rapid Miner provides most of the necessity functionalities for a project utilizing machine learning tool. The functionalities include data acquisition, data transformation, data selection, attribute selection, attribute transformation, learning or modeling and validation. In our study, we utilized Rapid Miner to create a prediction with the probability of the frequencies combination and subtasks categories based on naïve Bayes. The results were compared to Text Miner's naive Bayes based session. The comparison schema is shown in Fig. 2.

4 Results and Discussions

To predict the relationship between prediction words and main subtasks categories, 71 subtasks categories for a dataset of 5,184 narrative dialog datasets with more than 175.000 words were fed into both Text Miner and Rapid Miner. Two third of

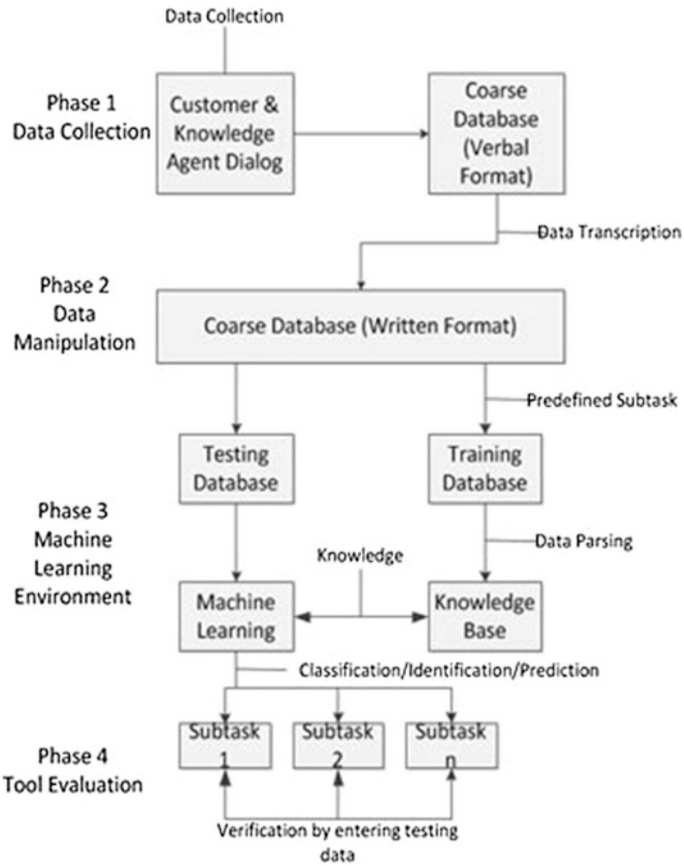


Fig. 1 Lin and Letho's semi-automated task analysis model

dataset was used as training set with the rest one third of dataset was used as testing set. Both Text Miner and Rapid Miner have to go through several phases prior to extract the combination words, as briefly described below.

For Text Miner, the first phase begins with setup initialization where the input texts were inserted in this phase, following with create database phase where the parsed dataset was classified between usable and unusable data to get the morph list. The next phase is learning phase, where Text Miner creates fifteen combination words frequency list. The last phase is cross index, where Text Miner provides the index for the possible word of each category when the combination words are presented.

For Rapid Miner, the first phase is started by tokenizing the characters into words. After the characters are set, the Rapid Miner tool filters the stop word which has similar function with separating usable and unusable words. The third phase is filtering the token which Rapid Miner will categorize the token by the

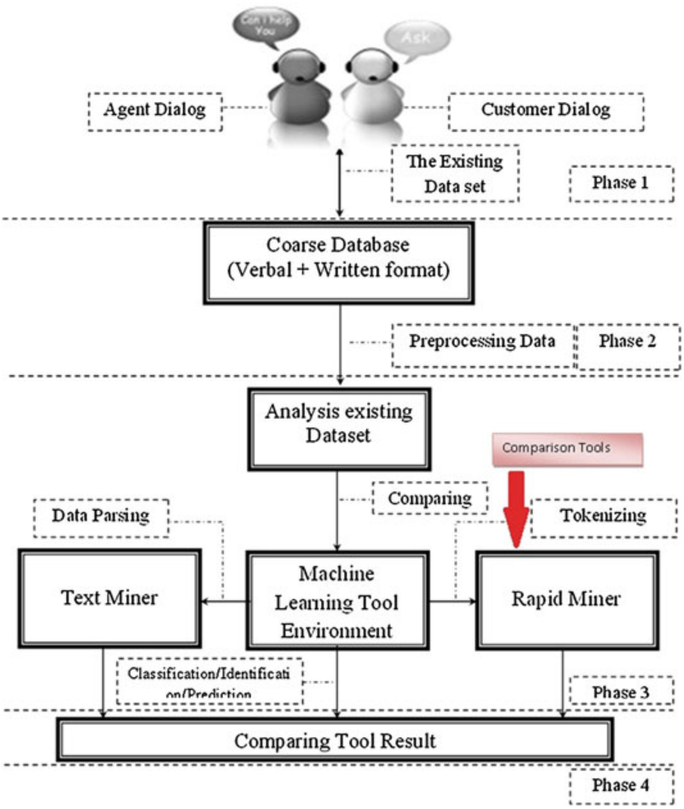


Fig. 2 Machine learning tools comparison based on semi-automated task analysis model

length of the sentences. The last phase is generating the n-gram to identify the sequence of combination words.

Table 1 summarizes the testing results after the combination words processed in both Text Miner and Rapid Miner. As illustrated in Table 1, the results reveal that the average probability of correction prediction in train set for Rapid Miner is 21.23 and 50.31 % for Text Miner, following with the average probability in testing set for Rapid Miner is 17.30 and 36.17 % for Text Miner. Overall, Rapid Miner has average of 19.91 % while for Text Miner, the probability is 45.58 %.

The differences between Text Miner and Rapid Miner in Table 2 were statistically significant, with the t-value equals to 8.18 and the p value equals to 0.007 with the confidence level of 95 %. This result leads to a suggestion that Text Miner statistically performs better than Rapid Miner.

Table 1 Comparison of two machine learning

Task	Value	
	Rapid miner	Text miner
Process the dataset	Tokenizing process	Parsing process
Eliminate stop words	Yes	Yes
Compute frequency	Yes	Yes
Format output	Converted excel	Converted access
Efficient for large database	Yes	Yes
Overall performance	Average prob-all: 19.91 %	Average prob-all: 45.58 %
	Average prob-train: 21.23 %	Average prob-train: 50.31 %
	Average prob-test: 17.30 %	Average prob-test: 36.17 %

Table 2 t-Test analysis result

Tools	N	Mean	StDev	SE mean	T-value	p-value
Text miner	3	44.02	7.20	4.16		
Rapid miner	3	19.48	2.00	1.15	8.18	0.007
Differences	3	22.54	5.20	3.0		

5 Conclusions

Both tools are capable of processing large dataset with parsing based Text Miner performs better than tokenizing based Rapid Miner in predicting the relationship between prediction words and main subtask categories when fifteen prediction words combinations were compared. The finding with Text Miner's robust predicted performance provides an opportunity to explore more of Text Miner's tool performance with different criteria, and the possibility to re-evaluate coarse subtask categories rather than main subtask categories to improve tool's efficiency. A comparison with other machine learning tools can also be considered in future research.

References

Berchialla P, Foltran F et al (2013) Naïve Bayes classifiers with feature selection to predict hospitalization and complications due to objects swallowing and ingestion among European children. Saf Sci 51(1):1–5

Kirwan B, Ainsworth LK (1992) A guide to task analysis. Taylor & Francis, London

Lin S, Lehto MR (2009) A Bayesian based machine learning application to task analysis. In: Wang J (ed) Encyclopedia of data warehousing and mining, classification B, 1-7, 2nd edn

Lin S, Patrikalakis NM, Kite-Powell HL (1999) Physical risk analysis of ship grounding. Navigational technology for the 21st century, 55th annual meeting, Cambridge, MA

Mierswa I, Wurst M, Klinkenberg R et al (2006) YALE: rapid prototyping for complex data mining tasks. In: Proceedings of the 12th ACM SIGKDD international conference on knowledge discovery and data mining (KDD-2006), pp 935–940

Mosteller F, Wallace DL (1964) Inference and disputed authorship: the federalist. Addison-Wesley, Reading

Mosteller F, Wallace DL (1984) Applied Bayesian and classical inference: the case of "The Federalist" papers. Springer, Berlin

Silver N (2012) The signal and the noise: why so many predictions fail-but some don't. Penguin Group US

Zhang H (2004) The optimality of naive Bayes. FLAIRS conference. doi: citeulike-article-id:370404

Evaluating the Development of the Renewable Energy Industry

Hung-Yu Huang, Chung-Shou Liao and Amy J. C. Trappey

Abstract While the world is increasingly concerned with the utilization of fossil energy and carbon emission, renewable energies have been promoted by many governments as alternatives worldwide. Wind power is currently the most mature renewable energy technology. Although Taiwan is located in a region of abundant wind power, this energy industry still faces big challenges in effectively growing the market. This study employs a variation of the hidden Markov model (HMM) to analyze the development of wind power industry in Taiwan, because the renewable energy development is determined by multiple time-series-related factors. The methodology may assist industry in making correct investment decision and provide recommendations to the government for setting suitable green energy policy.

Keywords Renewable energy · Wind power · Hidden Markov model

1 Introduction

Many nations have recognized the need to reduce dependence on traditional energy in order to avoid the associated environmental damage last several years. Governments have emphasized the application of renewable energies. In particular,

H.-Y. Huang (✉) · C.-S. Liao · A. J. C. Trappey
Department of Industrial Engineering and Engineering Management,
National Tsing Hua University, Hsinchu 30013, Taiwan
e-mail: smileking081700@gmail.com

C.-S. Liao
e-mail: csliao@ie.nthu.edu.tw

A. J. C. Trappey
e-mail: trappey@ie.nthu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_122,

wind power is currently the most mature renewable energy technology. In the past decades, some research focused on the assessment of the development of wind power industry. The research of Buen (2006), compares the role of policy instruments in stimulating technological change in Denmark and Norwegian wind industry. Camadan (2011) investigated the status and future of the wind energy industry in Turkey. Zhao et al. (2013) have adopted a strength, weakness, opportunity and threat analysis (SWOT) approach to examine both the internal and external factors that affect the competitiveness of the wind power industry in China. However, with increasing number of influential factors, these analytic approaches have become overly complicated and time consuming.

In order to encourage the public as well as industrial companies to invest in and use renewable energy, a series of measures was adopted by government in Taiwan. However, the huge budget required for the government to carry out this policy adversely affects the promotion of renewable energy. Because industrial investors and policy makers are generally concerned with profit-making opportunities and promotion of renewable energy, our aim is to develop an efficient forecasting approach for developments in the renewable energy industry. To this end, in this study, we employed HMM to assess the development of the wind power industry, due to its strong statistical foundation, computational efficiency, and ability to handle new data robustly and to predict similar patterns efficiently (Hassan and Nath 2005). HMM has been successfully used to forecast oil prices (De Souza e Silva et al. 2010), the Dow Jones Average stock index (Wang 2004) and the leading indicator composite index of real estate (Wu 2009). Because the renewable energy development is determined by multiple time-series-related factors, we use a variation of the HMM, called the hidden Markov model with multiple feature streams (HMM/MFS), to simultaneously consider distinct factors influencing the development trends of renewable energy. This model can be used to assist industrial investors when making cost analysis decisions and provide specific recommendations to the government about sustainable energy policy.

2 Modeling

2.1 Hidden Markov Model with Multiple Feature Streams

HMM (Rabiner 1989) is a doubly embedded stochastic process: the first process is a Markov chain, and the second is an observation process, whose distribution at any given time is fully determined by the current state of the Markov chain. This study considered the development of wind power industry as being determined by a number of factors; therefore, we used a variation of HMM, called the Hidden Markov Model with Multiple Feature Streams (HMM/MFS) (Somervuo 1996).

Figure 1 shows an example of the HMM with two states and multiple (three) feature streams. It simultaneously considers three independent factors $\{V^1, V^2, V^3\}$

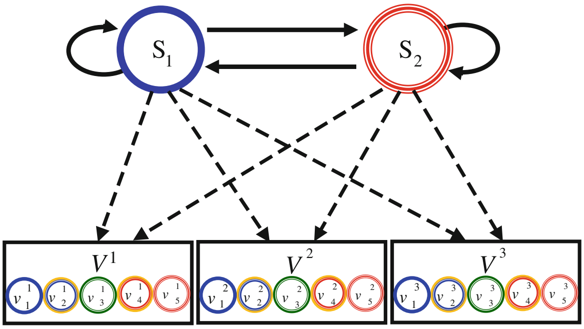


Fig. 1 An illustration of a hidden Markov model with two states and three feature streams

for the development of industry. In HMM, factor vectors represent observation vectors. The set of the factor V^i's factor vectors is $\{v_1^i, v_2^i, v_3^i, v_4^i, v_5^i\}$, where $1 \le i \le 3$. We considered how the observation streams could be fed into HMM: either by concatenating them into a single factor vector or keeping the three factor vectors separate. If vectors with different scales are concatenated into a single factor vector (e.g., CPI and crude oil price), the result would be dominated by the factors with large variance; however, the factors with small variance may play a more important role. This is called scaling problems, which may miss information. If different factor vectors are kept separate, scaling problems can be avoided (Somervuo 1996).

2.2 Dataset

Our forecasting methodology can be used to analyze time-series data. Thus, the data set of interest is the history of the development of wind power. In this study, the installed monthly capacity of wind power (BEMOEA)[1] as the hidden state in the development of this industry. To select related factors as the observations of our model, which potentially fit the states of a development trend, we studied the relevant factors about the wind power industry. From the interviews with the Green Energy and Environment Research Laboratories of ITRI experts, as well as related background and literature, we selected five related factors as the observations of our model; include the steel price index (Finance),[2] the Consumer Price Index (CPI) (BEMOEA), the crude oil price (Mundi index),[3] the export price of

[1] Bureau of Energy of Ministry of Economic Affairs (BEMOEA). Taiwan, ROC. http://www.moeaboe.gov.tw/ (in Chinese).

[2] Finance. http://big5.ifeng.com/gate/big5/app.finance.ifeng.com/data/indu/jgzs.php?symbol=5/ (in Chinese).

[3] Mundi index. http://www.indexmundi.com/ (in English).

coal from Australia (Mundi index) and the electricity price (Taiwan Power Company).[4]

For data transformation, first, HMM has M distinct observation symbols, which represent the physical outputs of the system being modeled. To predict the installed capacity for wind power, it is necessary to assign one symbol for each monthly installed capacity. Therefore, the classes of hidden states and observations in training data were labeled through Wang's approach (Wang 2004) and transformed them into variables with the discrete data as the input of HMM.

We divided the number of hidden states into three states based on the total length of the change rate per period of installed capacity. The three states are similar to the monitoring indicators announced by the Council for Economic Planning and Development (CEPD).[5] The mapping of the change rate into symbols for the HMM, described hereafter. The three states are the three signals of the monitoring indicator. If the change rate per period of installed capacity is less than X, the signal is Blue, between X–Y Green, and more than Y Red, where $Y > X$. The signals of the monitoring indicators are: Blue shows that the development of the wind power industry is slumping; Green represents stability; and Red indicates a boom. Similarly, the data of observations can be transformed into discrete data in a similar manner.

3 Experiments

In this experiment, there were two stages to construct the model: model training and model predicting. Model training (2010/12-2012/10), was to determine the parameters of the HMM model. The parameters were used for the structure inference. Next, model predicting (2012/11-2013/01), was to predict the future installed capacity of wind power

To further validate our method, we employed HMM by the Viterbi algorithm to predict the state of the wind power industry in Taiwan. The next monthly state (November 2012) depended only on the industry state in October 2012. The real state transit was from (Green) to (Green). The predicted result of the HMM with a single factor is shown in Table 1. Consider the observation of the crude oil price. If the state in October 2012 is (Green), there is a 56 % chance that the next state is (Green); this probability value was the highest. And consider the observation of the electricity price. If the state in October 2012 is (Green), there is a 75 % chance that the state of next month is (Red). Result of predicted analyses show that when we consider these observations of crude oil price, coal price and steel price index, these models correctly predicted the industry trend than CPI and electricity price. It shows that these three factors have a higher degree of influence for wind power industry of Taiwan.

[4] Taiwan Power Company. Taiwan, ROC. http://www.taipower.com.tw/ (in Chinese).

[5] Council for Economic Planning and Development (CEPD). The monitoring indicators. Taiwan, ROC. http://www.cepd.gov.tw/m1.aspx?sNo=0000160/ (in Chinese).

Table 1 HMM of wind power industry in Taiwan from 2012/11 to 2013/01

	2012/11 State	2012/12 State	2013/01 State
Single factor			
Crude oil price	G (56 %)	G (69 %)	G (73 %)
Coal price	G (93 %)	G (90 %)	G (81 %)
Steel price index	G (73 %)	G (43 %)	G (41 %)
CPI	G (61 %)	G (64 %)	G (51 %)
Electricity price	R (75 %)	G (55 %)	G (83 %)
Multiple factors	G (100 %)	G (100 %)	G (100 %)
Real state	G	G	G

R Red(Boom), *G* Green(Stability), *B* Blue(Downturn)

On the other hand, the predicted probability of multiple factors was much closer to the real state than single factor. For this case, the probability of correct prediction in HMM/MFS is significantly larger, compared with that in HMM with a single factor.

4 Conclusions

Developing renewable energy has become the focus of national policy due to energy shortages. For government or companies who want to support the renewable energy industry, there are budget and policy concerns for the former and investment capital and income concerns for the latter. Therefore, in this study we have used HMM and HMM/MFS to analyze the developmental movements of the renewable energy industry. According to our experimental result, we concluded that HMM/MFS is an effective forecasting model for predicting the trends of industrial development. Because the Taiwanese renewable energy industry is an emerging industry, data collection has limitations. However, when this problem is overcome, it would be of great interest if the forecasting model could provide more accurate prediction. Finally, it would be worthwhile to apply the proposed methodology to other renewable energy industries for future investigation.

References

Buen J (2006) Danish and Norwegian wind industry: the relationship between policy instruments, innovation and diffusion. Energy Policy 34(18):3887–3897

Camadan E (2011) An assessment on the current status and future of wind energy in Turkish electricity industry. Renew Sustain Energy Rev 15(9):4994–5002

De Souza e Silva EG, Legey LFL, De Souza e Silva EA (2010) Forecasting oil price trends using wavelet and hidden Markov models. Energy Econ 32(6):1507–1519

Hassan MR, Nath B (2005) Stock Market forecasting using hidden markov model: a new approach. In: Proceeding of the 5th international conference on intelligent systems design and applications, pp 8–10

Rabiner LR (1989) A tutorial on hidden markov models and selected applications in speech recognition. Proc IEEE 77(2):257–285

Somervuo P (1996) Speech Recognition Using Context Vectors And Multiple Feature Streams. Dissertation, Helsinki University of Technology

Wang SC (2004) Investment Decision Support with Dynamic Bayesian Networks. Dissertation, National Sun Yat-sen University

Wu YL (2009) Studies on the Predicting Power of Leading Indicator of Taiwan's Real Estate Cycle—Hidden Markov Model Analysis. Dissertation, National Pingtung Institute of Commerce

Zhao ZY, Hong Y, Zuob J, Tian YX, Zillantec G (2013) A critical review of factors affecting the wind power generation industry in China. Renew Sustain Energy Rev 19:499–508

On-Line Quality Inspection System for Automotive Component Manufacturing Process

Chun-Tai Yen, Hung-An Kao, Shih-Ming Wang and Wen-Bin Wang

Abstract The automotive industry in a nation not only forms an economic base, but also plays an important role for safety and convenience in the society. In average, a vehicle is composed of more than thousands components, and the quality of each component is definitely critical. Automotive component manufacturers, as suppliers to automotive manufacturers, are forced to emphasize the quality inspection for their products. Hence, this research proposes an online quality inspection system for vehicle component manufacturing industries. The system is composed of three subsystems, which are real-time machine condition monitoring, supply chain management, and production information management. The transparency of the production process can further be analysed to infer the quality of product on production line. The proposed system is introduced to a Taiwanese vehicle component manufacturing industry for validating its capability to reduce the effort spent on inspection work, the rate of waste, and to improve overall equipment efficiency (OEE).

C.-T. Yen (✉)
Institute of Industrial Engineering, National Taiwan University, Taipei, Taiwan, Republic of China
e-mail: ctyen516@gmail.com

H.-A. Kao
NSF I/UCRC for Intelligent Maintenance Systems, University of Cincinnati, Cincinnati, OH, USA
e-mail: kaohn@mail.uc.edu

S.-M. Wang
Department of Mechanical Engineering,
Chung Yuan Christian University, Chung-Li, Taiwan, Republic of China
e-mail: shihming@cycu.edu.tw

W.-B. Wang
Innovative DigiTech-Enabled Applications and Services Institute, Institute for Information Industry, Taipei, Taiwan, Republic of China
e-mail: wwbjoe@iii.org.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_123,

Keywords Production optimizations · Online quality inspection · CNC machine monitoring · Manufacturing information management

1 Introduction

The automotive industry in a nation not only forms an economic base, but also plays an important role for safety and convenience in the society. In average, a vehicle is composed of more than thousands components, and the quality of each component is definitely critical. Automotive component manufacturers, as suppliers to automotive manufacturers, are forced to emphasize the quality inspection for their products. For instance, a transmission shaft of a vehicle is required to have total inspection and the inspection result should be within $\mu \pm 6\sigma$, where μ is specification value and σ is defined standard deviation. Besides, since the sales performance of automotive industries vary a lot, the needs for automotive component also alternate through seasons. The common requirement of Just-in-time from customers also makes automotive component manufacturers to focus on how to response to customers' orders quickly and precisely.

To aid automotive component manufacturers in solving the above-mentioned needs from customers, this research proposes an online quality inspection system for automotive component manufacturing process. The system is composed of three subsystems, which are real-time machine condition monitoring subsystem, supply chain management subsystem, and production information management subsystem. The transparency of the production process can further be analysed to infer the quality of online product. The proposed system is introduced to a Taiwanese vehicle component manufacturing industry, and validated its capability to reduce the effort spent on inspection work, the rate of waste, and to improve overall equipment efficiency (OEE).

2 Information Communication Technology Based Solution Framework

For automotive component manufacturing process, a system including three subsystems, which are *real-time machine condition monitoring subsystem*, *supply chain management subsystem*, and *production information management subsystem*, is proposed based on information communication technology. The architecture of this system is shown in Fig. 1. First of all, the controller signal and sensory data can be extracted automatically from online process by *real-time machine condition monitoring subsystem*, which can reveal the condition of machine operation, the NC program of the machine, and the corresponding control parameters in real time.

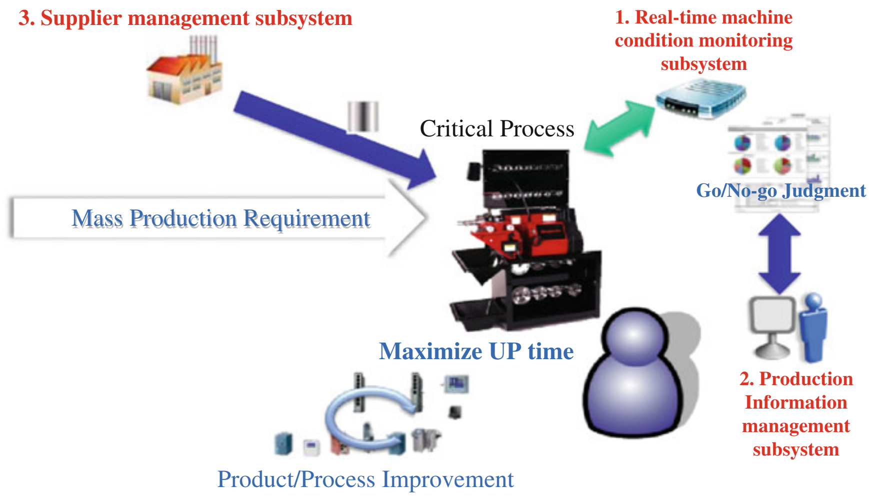


Fig. 1 Architecture of online quality inspection system

Secondly, by analysing these signals, a quality inference engine is utilized to assess the quality and stability of the current process, in order to achieve online quality inspection. The quality information, which is computed by online intelligent inspector, will be mapped with original production recipe (control parameters and production history). The quality information of a product will be stored, sorted, and streamlined according to its work order identification, batch number, and ERP tag by the *production information management subsystem*. Finally, the manufacturing operators can make query and retrieve related information for optimization of the manufacturing process. The *supply chain management subsystem* can support to communicate with suppliers and seamlessly feedback scraps and their impacts for process improvement.

3 Real-Time Machine Condition Monitoring

To acquire the operation condition from machines, architecture for extracting controller signal from CNC systems is designed. A *controller signal extractor* and *real-time monitoring module* are integrated in an industrial PC. Each machine is equipped with a controller and RJ-45 Internet cable is used to connect between controller and the signal extractor through the Ethernet Internet protocol.

The *controller signal extractor* is implemented by C# and .Net Framework and utilize FOCAS library API provided by FANUC controllers. It includes a parameter extractor (connect with controllers and extract parameters), rule configuration module (write rules and trigger points for parameter extraction), command receiver (receive the commands from real-time monitoring module and configure accordingly), and an information sender (transfer extracted signals to real-time monitoring module). The *real-time monitoring module* is developed by Java and web programming library. It includes some basic components like server interface, user authorization, Model-View-Controller application, and central management unit.

Since the sampling frequency of the *controller signal extractor* is high, the communication between the *controller signal extractor* and the *real-time monitoring module* is frequent. To efficiently process the data set and at the same time provide a real-time, stable data extraction performance, an asynchronous transmission mechanism is designed and adopted. Once the *controller signal extractor* extract the signal data, the data set will be sent to a message queue instead of monitoring module directly. The message queue is a high performance buffer space and can be easily customized to receive and store the data. Once the data set is reserved in the message queue, the *real-time monitoring module* will use its Listener to register to the message queue. When there are messages waiting in the message queue, the Listener will be triggered to extract the messages from the queue and parse them. The parsed information will then be sent to *real-time monitoring module* to analyze and become visualized information through user interface.

4 Online Quality Inspection System

In this research, we propose to develop rules for diagnose the quality of production by using real-time signals generated from manufacturing processes. The error estimation and cutting monitoring can be integrated into online process in order to infer the quality information. This method can save the cost spent on inspection, and also avoid the uncertainty of manual inspection. Besides, the integration of error estimation results and production history can let manufacturers examine the relationship among design, operation and control parameters and further improve the production quality.

The signals are extracted from manufacturing process based on *real-time machine condition monitoring module*. The feature values are then analysed and served as input for model training. There are three development steps: (1) Signal processing and feature extraction; (2) Quality inspection rule and threshold establishment; (3) Validation. The experiments are firstly conducted in order to collect the vibration signal, control signal, and corresponding air gage quality inspection data. The data set is then used to analyse the correlation of vibration and cutting accuracy. Based on a history data set, rules and thresholds are defined for online precision diagnosis. After the model is learned from training data set, the system is implemented by the integration of each subsystem, and validated using real production line.

In this research, the vibration signal, which is collected from an accelerometer (X and Z directions) during cutting process, is mainly used to infer the quality information since the sensitivity of vibration signals is suitable for the detection of abnormal cutting process. The amplifier will adjust the acquired signals. Other than vibration signals, NC code information is also collected for understanding of the current operation of the machine. The air gage measurement results are then utilized to correlate the vibration and size distribution of work pieces. After combining these three types of input data, the model for quality inspection can then be learned.

To implement the real-time machine condition monitoring, a ServBox is proposed to be a service-oriented device to enable the functions. ServBox is a service channel that provides synchronized communication between the CNC machine tool and the remote service platform, so called ServAgent, inside a factory. With both ServBox and ServAgent, machinery industry could implement innovative services and machine network via remote cloud computing service to achieve optimal productivity and enhance the partnership with customers. Through ServBox, we can change the traditional model of service communication, and achieve an active and fast two-way communication with service platform.

Nowadays, ServBox can extract more than 4,000 parameters from Fanuc i-series controllers, including 6 main categories: historical information, CNC File data, NC Program, Spindle servo, library handle.

To achieve online quality inspection goals, a platform for increase productivity and collaborative manufacturing with suppliers is implemented. Here, the proposed platform is so called ServAgent. When there are more and more machine tools in a factory, ServAgent can grasp the machine tools' real-time condition, monitoring operation and detecting production quality and performance. In addition, it can connect to machine tools only when needed and avoid data-leakage problem. A win–win situation is created for automotive component manufacturers and their suppliers by integrating the solution and production line based on the mechanism of production management.

ServAgent leverages the machining information extracted from machine tools to unveil the machining data that in the past is concealed in the mysterious manufacturing process. It collects productivity information from production lines and forms a machine service network to help customers manage their production line in real-time and more intelligent, and finally the productivity and utilization can be improved. While the domain-specific knowledge of machining process is accumulating, it can also support customer to find out the weakness in the current manufacturing process, which means the quality of their manufacturing is also increased. Besides, the knowledge collected can used to be an expert or reference and provided to customers. Before the abnormal condition occurs, take the actions to avoid the possible damages and stabilize the production quality level. Finally, customers can manage the overall productivity and efficiency of their equipment in the factory. It offers customers the flexibility and knowledge toward their equipment and factory.

5 Experiments

To validate the feasibility of the proposed system, an experiment is designed and conducted in automotive manufacturing facilities. To find out which signals and features are reliable for quality inspection, a turning machine is used as test-bed and the relationship between signals and turning tool is evaluated. A CMOS camera also records the turning tool wear condition during each experiment in order to quantify tool wear condition.

The experimental process is as follows:

1. Use clay to cover the spindle to avoid the lubricant interfere the accelerometer. The sensor is then connected to an amplifier and DAQ system. Through ServBox, the sensory signal and control signals are then be extracted.
2. Test if the signals from the accelerometers are table and correct.
3. Install a work piece and set the controller.
4. Start the NC program to activate the cutting process.
5. Observe the signals extracted. If the signals are normal and stable then the experiments can be started.
6. Cutting 20 times and 10 times for 2 repetitions each. So, there will be totally 4 set of experimental data.

The results are shown in Fig. 2. Figure 2e is the cutting vibration of cycle 1–10, while Fig. 2f is cycle 11–20. It can be observed that the latter vibration condition is 0.015 g larger than previous one. Compared with Fig. 2c, the wear condition after 20 cutting cycles is 1.5–2 times of the 10-cutting-cycle condition, and after 30 cutting cycles the wear condition is even worse. At the same time, the wear condition at the middle area on the blade expands as cutting cycles pass. The reason is that after the cutting tool wears, the leaning angle of the blade will change, which forces the friction between debris and blade increases. From the results of the experiments, it can be concluded that the cutting vibration can be used to monitor if the turning tool reaches the threshold and can cause unwanted quality. After the training data set is collected, an automatic rule-learning

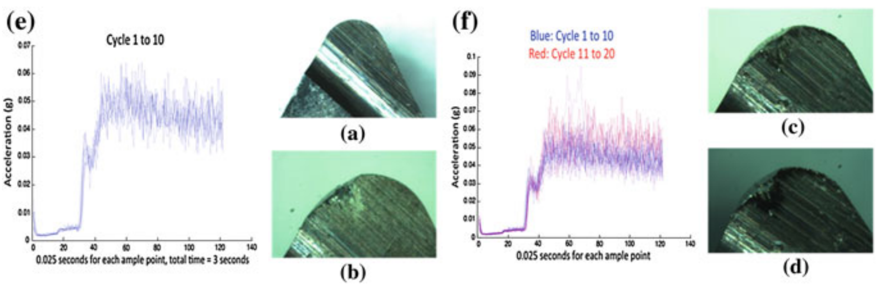


Fig. 2 Cutting vibration signals of cycle times. **a** New tool, **b** After 10 cycles, **c** After 20 cycles, **d** After 30 cycles, **e** Cycle 1 to 10, **f** Cycle 11 to 20

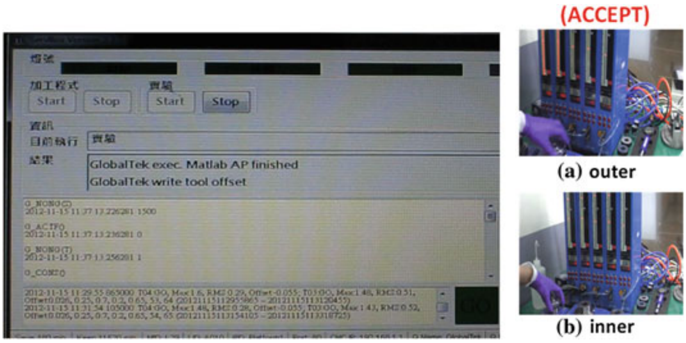


Fig. 3 Result of ‘Go’ case from online quality inspection system

algorithm develops rules and thresholds for quality inspection. The model is then introduced in the system as a core analyzer.

The experiments period is three months and totally 7,286 work pieces are validated. The air gauge measurement results are used as ground truth to evaluate the performance of proposed system. The results shown in Fig. 3 are from the same experiment with qualified work piece. The online quality inspection system can successfully diagnose it is accepted during manufacturing process. That is, the quality information can be detected before metrology stage. On the other hand, Fig. 4 show results from one of the failed products. The system can detect the work piece might have unwanted quality during the process. The process can be adjusted immediately instead of waiting until knowing bad inspection results. The overall experimental result shows no difference between the judgment of the proposed online quality inspection system and the results from the air gage metrology, which proves the feasibility of the system.

Fig. 4 Result of ‘No-Go’ case from online quality inspection system

6 Conclusions

This research proposes an online quality inspection system for automotive component manufacturing process. The system is composed of three subsystems, which are real-time machine condition monitoring subsystem, supply chain management subsystem, and production information management subsystem. The vibration signals are used to evaluate the process and tool condition, and the models are used to diagnose the quality and work piece in real time. After the training data set is collected, an automatic rule-learning algorithm develops rules and thresholds for quality inspection. The overall system is introduced to an automotive component manufacturing process to validate its feasibility. The experimental results from 7,286 work pieces prove its capability of distinguish good and bad quality of work piece during the process. The proposed method can benefits automotive component manufacturers to understand the quality information earlier and improve current process immediately. Eventually, it can optimize the manufacturing process and also the collaboration among manufacturers, suppliers and customers.

Acknowledgments This study is conducted under the “Precision Machine Equipment Characteristic Service Development—Trial Service Operation for Machine Tool Agile Service Center Project” of the Institute for Information Industry which is subsidized by the Ministry of Economy Affairs of the Republic of China.

References

Carrilero MS, Bienvenido R, Sa′nchez JM, A′lvarez M, Gonza′lez A, Marcos M (2000) A SEM and EDS insight into the BUL and BUE differences in the turning processes of AA2024 Al–Cu alloy. Int J Mach Tools Manuf 42:215–220

Dohner JL, Lauffer JP, Hinnerichs TD, Shankar N, Regelbrugge M, Kwan CM, Xu R, Winterbauer B, Bridger K (2004) Mitigation of chatter instabilities in milling by active structural control. J Sound Vib 269(1–2):197–211

Doi M, Masuko M et al (1985) A study on parametric vibration in chuck work. Bull JSME 28(245):2772–2781

Hahn RS (1954) On the theory of regenerative chatter in precision grinding operations. Trans ASME, B 76(1):593–597

Hook CJ, Tobias SA (1963) Finite amplitude instability—a new type of chatter. In: Proceedings of 4th MTDR, pp 97–109

Inamura T, Senda T, Sata T (1977) Computer control chattering in turning operation. Ann CIRP 25(1):181–186

Kao A et al (2011) iFactory cloud service platform based on IMS tools and servo-lution. World Congress on Engineering Asset Management, Cincinnati

Marui E et al (1983) Chatter vibration of lathe tools. Trans ASME, B 105:107–133

Shinobu K, Etsuo M, Masatoshi H, Yamada T (1986) Characteristice of chatter vibration of lathe tools. Mem Fac Eng, Nagoya, 38(2):208–215

Tlusty J, Spacek L (1954) Self-excited vibrations in machine tools. Nakladateistvi CSAV Prague, Czech

Using Six Sigma to Improve Design Quality: A Case of Mechanical Development of the Notebook PC in Wistron

Kun-Shan Lee and Kung-Jeng Wang

Abstract Wistron has transformed from private brand to OEM/ODM after reorganizing in 2003, witnessing phenomena that profits of personal computer and its peripherals decline day by day, and domestic manufacturers had gradually moved to China mainland because unit cost is not competitive, continued to survive with the help of low processing cost and then expanded the production base. Therefore, companies of this case considered to fully carry out Six Sigma program to improve the plan in order to solve their troubles in 2005. The company of the case in 2007/Q2 grew quickly in NB business, but its defective products caused a huge loss to the company. Consequently, a project team was established to consider carrying out preventive measures and design improvement during product R&D. As a whole, the individual case will discuss subjects as follows: (1) The core processes of Six Sigma and the opportunity of using tools shall be understood in order to get the maximum benefit and enhance the capability of solving problems. (2) Performance comparisons before and after Six Sigma design are imported. (3) The process mode and standard design norms of new product R&D are constructed through research of actual cases.

Keywords Six Sigma · Research and Design · DMAIC · Notebook PC

K.-S. Lee (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Da'an District, Taipei City 106, Republic of China
e-mail: andy_lee@wistron.com

K.-J. Wang
School of Management Department Assistant Head, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Da'an District, Taipei City 106, Republic of China
e-mail: kjwang@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_124,

1 Individual Case

Wistron transformed from private brand to OEM/ODM after reorganizing in 2003. It is mainly to assemble products according to product specifications and complete detail design provided by OEM customers, or ODM customers strive for getting orders according to products designed by themselves.

In 2005, Wistron imported Six Sigma project to improve plan and began to consider how to use Six Sigma technology to improve manufacturing quality. The past OEM focuses on improvement and control of product process, whereas, ODM focuses on improvement of design process.

In the 2nd quarter of 2007, a customer complained to Jeff (leader of league), secretary of the NB business division via telephone about quality control. The extra charges for defective products become increasingly high, so the company suffered from a big loss (the more the goods are shipped, the higher the loss will be).

1.1 Company Develops Highly but Falls into Reworking Trouble

In 2007/Q4, the NB business grew quickly. Its turnover increased by 6 times compared to the year before, and shipping quantity of Notebook PC was up to 7 times. The tendency was getting better, but customers required returning goods or reworking the defective goods locally because of the poor quality. As a result, company suffered from a big loss because of a great amount of reworking cost.

"Why cannot we use preventive measures to improve design quality during R&D? How do they optimize design to meet customer demands? What should we do?" Andy, manager of R&D department, gazed at the scrap/reworking cost report and was lost in through after receiving the indication of Jeff (Fig. 1).

2 Case Company and Industrial Profile

Wistron is the OEM/ODM of notebook (NB) ranked top 3 in Taiwan. In 2008, it was aim to ship more than 2,000 notebooks. Wistron is also one of the professional designers and OEMs of the biggest information and communication product in the world, which currently has 3 R&D support centers, 6 manufacturing bases, 2 global service centers, and more than 60,000 professionals and solid global service network in the world. Products cover notebooks, desktop computers, servers, network household appliances, cable and wireless data communications, digital consumer electronics, etc.

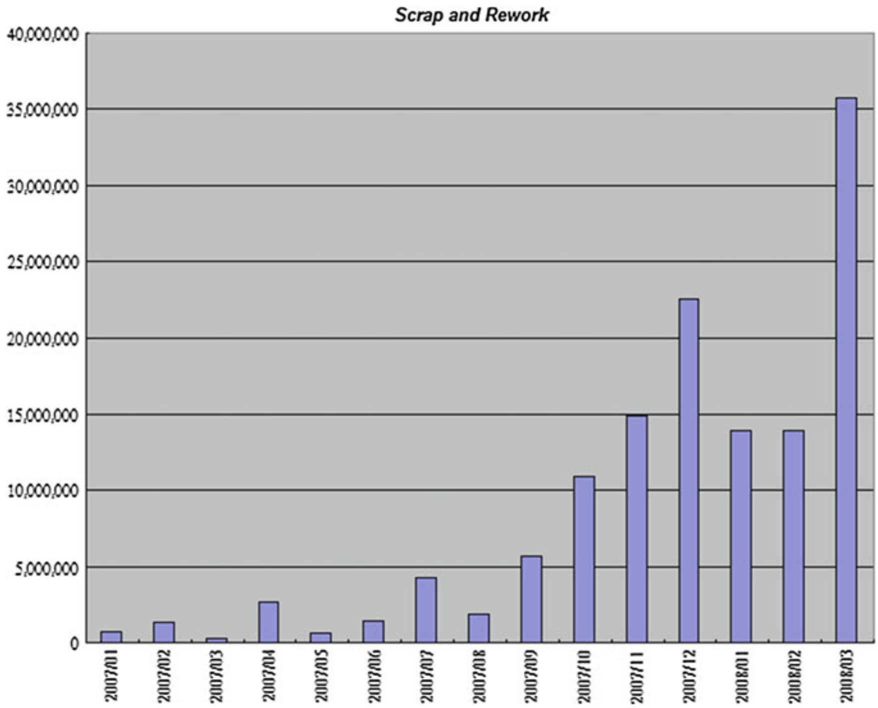


Fig. 1 2008 CoPQ (cost of poor quality) scrap/reworking cost

3 Establishment of Project Team and Improvement Items

The work started with definition of scope. Jeff faced up with quality problem, and the company suffered from high cost of reworking every month. He hence changed the work focus to Andy and thought: "under the leadership of Andy, Six Sigma is imported at the beginning of research and development, the preventive measures and design quality improvement are imported, and possible defective causes are analyzed and found to effectively control abnormal change and minimize the reject ratio and meanwhile reduce manufacturing cost. This way, will the core problem about the more shipment the higher the loss be solved?"

From the business scorecard of Jeff (Table 1), we can see that his goal of KPI is to make the cost of poor quality to be 6.0 % less than the business cost in 2007. In other words, they should find a way to save cost or bring profit for company and enhance customer satisfactions.

From the figure, we can know that the scrap and reworking costs caused by structure problem (Sub Y) accounts for 62 % (cost for design change in structure accounts for 90 %, and mold repairing cost accounts for 10 %). How did Andy find out biggest problem in the shortest time and raise an effective improvement plan?

Table 1 Business scorecard

Strategy direction		Performance assessment
Strategy (2–3 years)	Preliminary in 2008	Business result (2007 KPI)
• Become a world leader in research and development and manufacture of mobile industry, and focus on innovation design and improvement of manufacturing quality	• BB planning of six sigma	• Win 500 k/month, M10 RFQ
• Continuously provide NB production line with innovation products	• Design quality improvement: reduce scrap and reworking costs	• **CoPQ < 6.0 %**
• Expand handheld production line and become the leader	• Assembly design improvement	• All items will be shipped timely according to the plan
• Become the leader in NB industry share price/EPS		

It was the toughest time, but the team finally reached a compromise and made improvement from quality after discussing intensively. The scrap and rework costs (CoPQ $<$ 6.0 %) should be reduced to meet the performance goal of the league leader (other department managers also felt relaxing.). Finally the "costs for structure design change and reworking" were selected as the subject and the object for importing Six Sigma for quality improvement. After confirming the project subject, a series of activities were carried out. The reworking cost was caused by poor structure design (Small y), so the next target to improve can be formulated (Fig. 2).

Member of the project team had got ready and formulated project schedule Focusing on key problems, they used Six Sigma DMAIC and tools to analyze and solve the problem, and expected that quality improvement could be proved from the financial report after 6 months.

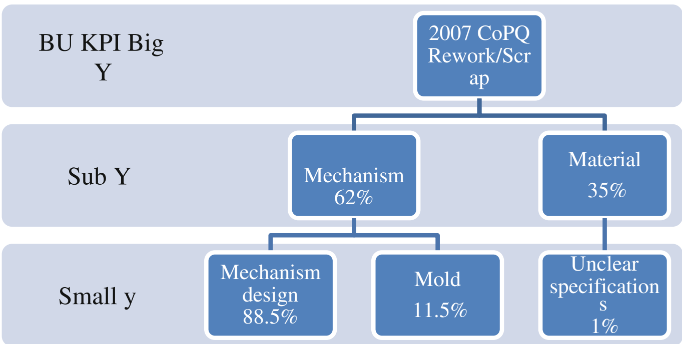


Fig. 2 Tree-diagram drill-down

The financial statement analysis (Fig. 3) clearly shows that the reworking cost for design change has been 98.5 % improved, scrap of structures material has been 78 % improved, and the CoPQ scrap/reworking cost after improving structure quality of the total project plan has been 83 % improved. The indirect benefits after carrying out the improvement program include: A standard design process is established so that colleagues have a good interactive and communicating channel, and as a result the overall efficiency is enhanced. The production per unit is increased, so the factory production cost MOH is reduced to provide the rate of equipment utilization. The reject ratio of production is reduced and the factory process is stable, so the production stock and material stock are reduced. Design documents are standardized to reduce mistakes so as to provide all staff with references. The design quality is enhanced, the assessment standard is established and product confidence level is increased.

The appearance of the completed new product and the key point for improving structure design quality of the new product. The DMAIC technique shall be used to find out key problems of the structure design and key factors affecting Y1, Y2 and Y3. The design scorecard and new process preventive measures shall be imported at the beginning of research and development of new products. The causes of defective products shall be actively analyzed and found out so Wistron can effectively control variation, minimize reject ratio, and meanwhile reduce manufacturing cost, the company can also prevent reoccurrence of defects and mistakes in order to lower down reworking cost caused by poor structure design at the same time (Figs. 4, 5).

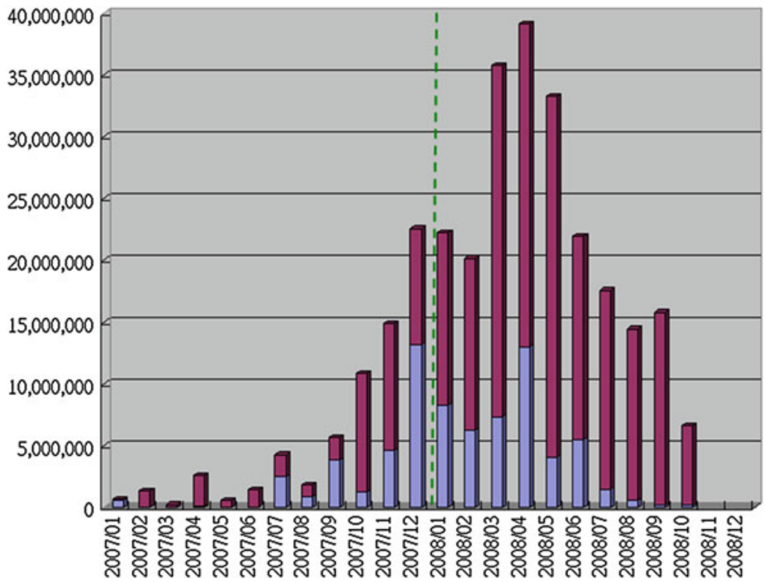


Fig. 3 Analysis of 2008 scrap/reworking (CoPQ) cost after improving project

Fig. 4 Appearance of completed new product

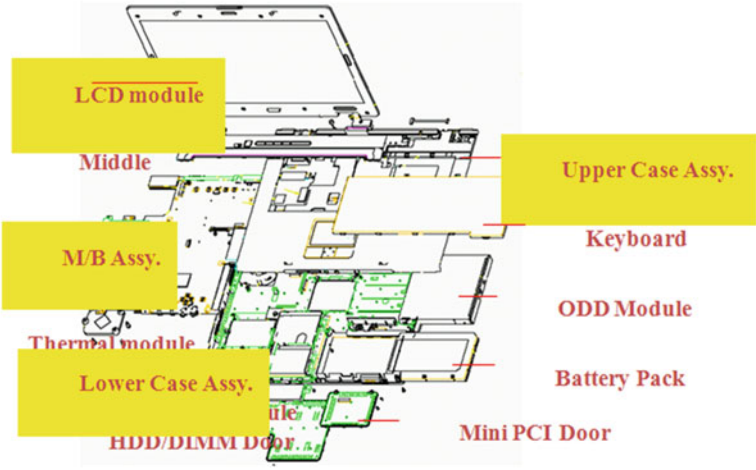


Fig. 5 Key point for improving structure design quality of new product

4 Road to Future Quality Improvement

The final goal of Six Sigma activity lies in business customers and creating all-around customers. When promoting the aforesaid steps, the real demands of customers must be understood, and the key processes and quality items should be confirmed based on customer viewpoint.

When members were indulging in celebrating, Jeff and Andy stepped into the office. Everyone guessed what will Jeff talk to Andy?

References

Breyfogle FW III (2003) Implementing six sigma: smarter solutions using statistical method, 2nd edn. Wiley Europe, New York
Harry M, Schroeder R (2000) Six sigma: the breakthrough management strategy revolutionizing the world's top corporations. Currency Doubleday, New York
Kuei C, Madu CN (2003) Customer-centric six sigma quality and reliability management. Int J Qual Reliab Manage 20(8):954–964
Lin Y (2003) Six sigma will determine your orders and promotion. Bus Week 795:110–112
Mazur GH (1993) QFD for service industries-from voice of customer to task delopyment. The 5th symposium on quality function deployment, Michigan
Wistron, website: http://www.wistron.com.tw/, 2012
Zheng R, Guo C (2001) Six sigma constructs enterprise competitive advantage. J Manage 326:76–79

Estimating Product Development Project Duration for the Concurrent Execution of Multiple Activities

Gyesik Oh and Yoo S. Hong

Abstract Many companies adopt concurrent engineering for their product development projects to reduce time to market. It is often the case that the multiple activities are overlapped in a concurrent engineering environment, while most of the product development research covers only the two-activity problems. The concept of degree of evolution has been proposed in literature to represent how close the unfinalized design of the downstream activity is to its final one, which is actually a measure of the real progress, reflecting the rework requirement due to overlapping. When more than three activities are concurrently executed, it is midstream activity whose degree of evolution is important, since it affects the rework duration for downstream and consequently the overall project duration. It is difficult to estimate the degree of evolution for midstream since involves has two uncertainties, one derived from incomplete information from upstream while the other from changing design information of itself. This paper models the degree of evolution for midstream activity taking into account the two uncertainties. On top of the model, this paper develops a methodology to calculate the project duration, which depends on the project managers' decision on information transfer frequency and overlapping ratio, when three activities are concurrently executed. This paper is expected to help firms forecast the effect of management decision about concurrent engineering dealing with overlapping among multiple activities.

Keywords Product development process · Concurrent engineering · Degree of evolution · Product development management · Overlapping · Multiple activities

---

G. Oh (✉) · Y. S. Hong
Department of Industrial Engineering, Seoul National University, Seoul, South Korea
e-mail: gushigi4@snu.ac.kr

Y. S. Hong
e-mail: yhong@snu.ac.kr

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_125,

1 Introduction

The companies adopt concurrent engineering in their product-development projects in order to reduce time-to-market. Concurrent engineering is the one of management methods, which allows overlapping between two dependent activities which were executed sequentially. Project duration under concurrent engineering is shorter than that under sequential development. In sequential development, downstream begins its work based on the finalized information from upstream. We call them a former activity and a latter activity respectively. A latter activity depends on the information from a former activity, therefore, and begins later than a former activity. Different from sequential development, a latter activity begins its work based on the imperfect design information of a former activity since a former activity is in progress. Although a latter activity needs to rework in order to adjust on the changed information from a former activity, it finishes its work earlier than under sequential development. In this reason, firms in many industries such as automobile, airplane, software and computer apply concurrent engineering to product development project (Clark and Fujimoto 1989; Cusumano and Selby 1997; Eisenhardt and Tabrizi 1995).

In the perspective of project management, it is important to decide the overlapping ratio and information transfer frequency between activities in concurrent engineering. As overlapping ratio increases, a latter activity begins its work earlier and project is finished earlier. However, rework duration increases since preliminary information transferred to a latter activity is more uncertain and likely to be changed. In order to alleviate the effect of uncertain information from a former activity, a latter activity receives updated information from a former activity and revises its work. A latter activity is not able to increase the number of information transfer infinitely since setup time for preparing rework is required for each rework. Setup time prolongs activity duration of a latter activity. Therefore, a project manager needs to optimize overlapping ratio and information transfer frequency in order to minimize project duration.

In modeling the concurrent execution of multiple activities, the modeling of midstream activity is difficult because it involves two uncertainties, one derived from incomplete information from upstream and other from changing design information of itself. The concept of degree of evolution has been proposed to represent the certainty of design in product development process. The degree of evolution refers to how close the unfinalized design of a former activity is to its final one. It is actually a measure of the real progress reflecting the rework requirement due to overlapping, which has influence on project duration. In two-activity problem, upstream has the uncertainty caused by changing information in progress. However, in multiple-activity problem, midstream, a former activity of downstream as well as a latter activity of upstream, has two uncertainties. Since upstream is in progress, transferred information from upstream entails uncertainty. Also, design information of midstream involves uncertainty. We model the degree of evolution for midstream in consideration of two uncertainties.

2 Model Illustration

We consider a simple project which consists of three activities and aims to minimize development duration. Three activities have sequential dependency relationships. Midstream depends on upstream and downstream does on midstream respectively. Based on the basic three-activity model, we will develop a general model for multiple activities in future research.

The project duration equals to time period from the beginning of upstream to the end of downstream. It is the summation of work duration before overlapping of upstream and midstream respectively, (a, b), and whole work duration of downstream, (c), as in Fig. 1. Since a latter activity relies on information of a former activity, it is not able to begin its work before a former activity achieves a certain amount of progress. Therefore, duration (a) and (b) are not decreased below the certain duration required by a former activity to reach a progress level at which a latter activity can start. We refer the moment as possible start time to each latter activity. In terms of downstream, work duration (c) is increased at the amount of rework duration, which depends on the information quality from a former activity. The real progress of an activity is important to develop a methodology since it affects both rework duration and possible start time.

We adopt the concept, the degree of evolution, to represent the real progress of a design activity. Krishnan et al. (1998) defines the degree of evolution as how close the unfinalized design is to its final one. The degree of evolution increases and reaches to one at the end of design activity. Whereas Krishnan et al. (1998) defines the degree of evolution for one design parameter, we extend the concept to a set of design parameters. We suggest that the degree of evolution is measured as the portion of fixed design parameters, which are not changed afterwards. A design activity in product development process is a decision making task to determine design parameters (Petkas and Pultar 2005; Eppinger and Browning 2012). As more design parameters are determined by designers and design becomes certain, the degree of evolution increases from zero to one. Therefore, we can use the portion of determined design parameters as the proxy for the degree of evolution for a design task.

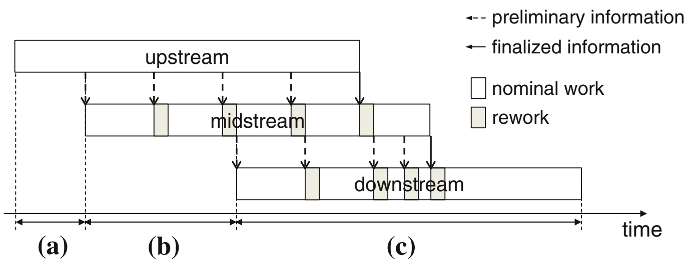


Fig. 1 Illustration of three-activity concurrent model

The degree of evolution for a former activity has an impact on rework duration of a latter activity. Since a former activity progresses, not all parameters of a former activity are fixed when it transfers design information to a latter activity. As Steward (1981) noticed, a latter activity assumes unfixed design parameters of a former activity to execute its work. When a former activity sends updated information, a latter activity needs to rework since design parameters of a former activity is different from its assumption. The more uncertain parameters based on which design is executed are, the longer rework duration is. Therefore, design execution based on information with the lower degree of evolution requires more rework for a latter activity.

Also, the degree of evolution of a former activity determines the possible start time of a latter activity. The critical degree of evolution for a former activity refers to the minimum degree of evolution based on which a latter activity is able to begin its work. Since a latter activity depends on the design information of a former activity, it requires a certain set of parameters of a former activity to begin. It is a pairwise concept between specific two dependent activities.

3 Degree of Evolution in Multi-Activity Concurrent Execution

In the perspective of upstream, the degree of evolution is the same as the portion of determined parameters. Since it is independent on other activities, its determined parameters are not changed after designers make a decision about it. Krishnan illustrates that there are various types of degree of evolution function such as linear, concave, convex and s-shape. In this research, we assume that the function of the degree of evolution is linear in order to simplify the analysis. General function types are able to be considered in future research.

Due to the uncertainty of information from upstream, the degree of evolution for midstream is lower than that performed based on the perfect information. Since midstream executes its work on the assumption of some design parameters of upstream, final parameters of upstream might be different from that assumed by midstream. If the difference is significant that what midstream has done is not compatible with updated information, midstream is required to rework the part which depends on upstream. As Fig. 2, the portion of determined parameters in midstream is decreased when it receives information from upstream and realizes the need of rework at t_2. The fixed parameters are fewer than determined parameters of midstream because of the uncertainty from upstream. The degree of evolution refers to the portion of fixed parameters which is not changed over time. Therefore, the degree of evolution for midstream is not $p_m(t_2)$ but $e_m(t_2)$ at time t_2.

The degree of evolution for midstream is important for downstream when it considers possible start time and rework duration. At t_1, downstream might begin its work since the portion of determined parameters in midstream reaches the

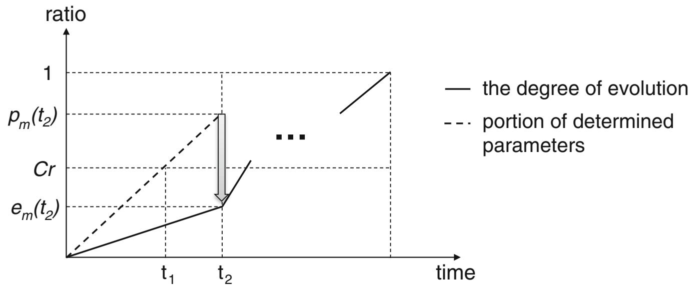


Fig. 2 Comparison between the degree of evolution and portion of determined parameters

critical degree of evolution, *Cr*. When midstream receives updated information from upstream at t_2, it needs to rework for determined design parameters. The portion of determined parameters decreases below the critical level. Consequently, what downstream has done on the basis of information from midstream at t_1 becomes meaningless since some of basis information from midstream changes. Therefore, the criteria of possible start time should not be the portion of determined parameters but the degree of evolution. In the same manner, rework duration for downstream needs to be calculated based on the degree of evolution for midstream.

We model the degree of evolution for midstream, considering both uncertainties. In Fig. 3, t_i represents the time when the *i*th information is transferred from upstream to downstream. Under this situation, the degree of evolution for midstream is calculated as Eq. (1).

$$e_m(t_i) = \{1 - (1 - e_u(t_{i-1})) \times I(u,m)\} \times f_m(\sum_{k=1}^{i} d(N_k)) \quad (1)$$

$e_u(t_{i-1})$ refers to the degree of evolution of upstream at t_i. Therefore, $1 - e_u(t_{i-1})$ represents the uncertainty of upstream design of the latest information transfer. $e_m(t_i)$ represents the degree of evolution for midstream at t_i before midstream receives information from upstream. The right term represents the certainty of

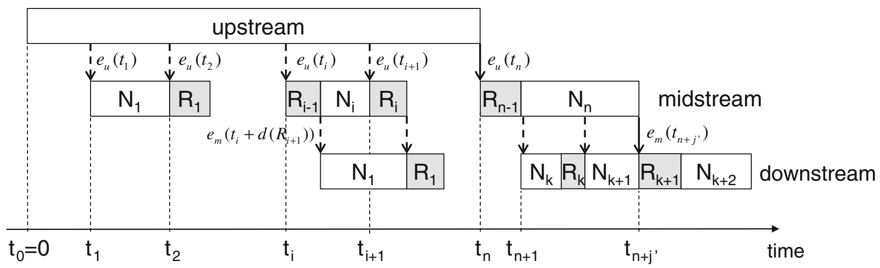


Fig. 3 Illustration of information transfer between *upstream* and *midstream*

midstream design itself. It is the degree of evolution function of sum of nominal work before t_i, $f_m(\sum_{k=1}^{i} d(N_k))$. N_k denotes the kth nominal design work. Since not all parameters of midstream depend on upstream, we refer to the portion at which midstream is dependent on upstream as the dependency of midstream on upstream, *I(u,m)*. Since midstream is affected at the portion of *I(u,m)*, uncertainty derived from upstream is $(1 - e_u(t_{i-1})) \times I(u,m)$. After rework, the design work of midstream has done based on the latest information from upstream at t_i with the degree of evolution as $e_u(t_i)$. Therefore, the degree of evolution after rework is calculated as Eq. (2).

$$e_m(t_i + d(R_{i-1})) = \{1 - (1 - e_u(t_i)) \times I(u,m)\} \times f_m(\sum_{k=1}^{i} d(N_k)) \quad (2)$$

4 Rework Duration

Rework duration has influence on the information transfer time and project duration. As in Fig. 3, midstream transfers its updated information after its rework. In the respect of project management, synchronization of information transfer between activities facilitate activities executes their work based on the latest information. However, midstream transfers information after rework duration since we consider rework duration in product development process. Therefore, midstream has sent information after rework duration since it receives information from upstream.

Rework consists of setup time and execution time. Setup time refers to the fixed duration for preparing rework before rework execution. Since upstream sends complex design information, midstream requires time to understand design information. Then, midstream checks the difference between its assumption and fixed design parameters from upstream in order to decide the direction of rework.

Execution time refers to duration required to revise what a latter activity has done in order to adjust on the updated information from a former activity. When information is transferred to downstream at t_{i+1}, the duration of work which is done on the latest information transferred at t_i is $t_{i+1} - t_i$. Among them, the portion of dependent parameters is the dependency of midstream on upstream. When designer conducts the same design again, work rate is higher than that of nominal work because of learning effect (Ahmadi et al. 2001). This research considers the learning effect and reflects it as *r*. Therefore, rework duration of midstream to adjust on updated information from upstream at t_{i+1} is the sum of setup time and execution time as Eq. (3).

$$d_m(R_i) = s + \frac{(t_{i+1} - t_i) \times I(u,m) \times (e_u(t_{i+1}) - e_u(t_i))}{r} \quad (3)$$

5 Three-Activity Project Modeling

We model the three-activity project in order to illustrate our methodology. The manager makes a decision about the overlapping ratio between upstream and midstream and the number of transfer from upstream and midstream. We denote them $\lambda(u,m)$ and $n(u,m)$ respectively. Under this decision, the *i*th time at which upstream transfers information to midstream, t_i, is $d_u\{1-\lambda(u,m)\times(1-i/n(u,m))\}$. The degree of evolution and rework duration is calculated through Eqs. (1) and (3) respectively. Checking the degree of evolution graph, the project manager perceives the possible start time of downstream.

Under the assumption of the linearity of degree of evolution function, it is possible to find the optimal start time of downstream and the optimal number of information transfer between midstream and downstream after the end of upstream. When upstream and midstream are overlapped, the time point of information transfer between midstream and downstream is fixed as the end of rework of midstream. When upstream is finished, the project modeling changes into two-activity project modeling between midstream and downstream. Since overlapping ratio is already determined before t_i, the optimal number of information transfer is derived as Eq. (4). d_m refers to nominal work duration

$$j(m,d)* = \sqrt{\frac{srd_m}{d_m(N_n)I(m,d)}} \tag{4}$$

Due to the limitation of space, proof is omitted. Since $j(m,d)*$ might not be integer, optimal number, $j(m,d)'$, is selected by comparing adjacent two integers.

We found that the optimal start time of downstream is the earliest information transfer time from midstream after midstream reaches the critical degree of evolution. Project duration is shorter when start time is t_i than t_{i+1}. Therefore, it is optimal decision that selects the start time of downstream as the earliest possible start time of downstream.

As a result, overall project duration under the decision on information transfer frequency and overlapping ratio between upstream and downstream is represented as Eq. (5).

$$pd = (1-\lambda(u,m))d_u + \sum_{i=1}^{cr}(d_m(N_i)+d_m(R_i)) + d_d + \sum_{k=1}^{l} d_d(R_k) \tag{5}$$

cr represents the minimum number of rework in order to reach the critical degree of evolution between midstream and downstream. Also *l* refers to the number of rework of downstream.

6 Conclusion

As the time to market becomes an important factor for product development, companies execute product development activities concurrently. However, due to uncertainty of design work, it is difficult to estimate project duration when multiple activities are concurrently executed. In order to figure out uncertainties, we adopt the concept of the degree of evolution and model it on midstream activity. On the top of the model, we derive the equation which estimates the project duration based on management decision variables, information transfer frequency and overlapping ratio between activities, under three-activity project environments. In future, we will develop methodology which is able to estimate project duration under multi-activity project environments.

References

Ahmadi R, Roemer TA, Wang RH (2001) Structuring product development processes. Eur J Oper Res 130(3):539–558

Clark K, Fujimoto T (1989) Reducing the time to market: the case of the world auto industry. dmi Rev 1(1):49–57

Cusumano MA, Selby RW (1997) How microsoft builds software. Commun ACM 40(6):53–67

Eisenhardt KM, Tabrizi BN (1995) Accelerating adaptive processes: product innovation in the global computer industry. Adm Sci Q 40(1):84–110

Eppinger SD, Browning TR (2012) Design structure matrix methods and applications. The MIT Press, Cambridge

Krishnan V, Eppinger SD, Whitney DE (1998) A model-based framework to overlap product development activities. Manage Sci 43(4):437–451

Petkas ST, Pultar M (2005) Modelling detailed information flows in building design with the parameter-based design structure matrix. Des Stud 27(1):99–122

Steward DV (1981) The design structure system: a method for managing the design of complex systems. Eng Manage, IEEE Trans 28(3):71–74

Modeling of Community-Based Mangrove Cultivation Policy in Sidoarjo Mudflow Area by Implementing Green Economy Concept

Diesta Iva Maftuhah, Budisantoso Wirjodirdjo and Erwin Widodo

Abstract One of the environmental damages in Indonesia is Sidoarjo mudflow disaster causing impact significantly in various sectors. These problems of course could lead to instability for the local social dynamics and the environment as well as the global economy. Cultivating mangrove vegetation is one of the answers to overcome these problems, especially to neutralize the hazardous waste contained in the mud and definitely to rebuild the green zone in the observed area. It is necessary to conduct a research on mangrove cultivation policy in Sidoarjo mudflow area in order to support green economy concept giving benefits to the economy, environment and society. Considering several numbers of variable which have complex and causal relationships in mangrove cultivation policy in line with green economy concept, and also the developing pattern of line with the changing time make the problem to be solved appropriately with system dynamics approach which is able to analyze and assess the mangrove cultivation policy in accordance with the principles of green economy concept. Therefore, by modeling the policy of mangrove cultivation based on the concept of green economy is expected to be able to reduce carbon emissions and to create a new ecosystem that could be used by communities to give added value and selling for Sidoarjo mudflow area.

Keywords Green economy · Policy · Sidoarjo mudflow · Community-based mangrove · System dynamics

D. I. Maftuhah (✉) · B. Wirjodirdjo · E. Widodo
Department of Industrial Engineering, Sepuluh Nopember Institute of Technology (ITS), Surabaya, Indonesia
e-mail: diesta11@mhs.ie.its.ac.id

B. Wirjodirdjo
e-mail: wirjodirdjo@gmail.com

E. Widodo
e-mail: erwin@ie.its.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_126,

1 Introduction

Green economy concept was introduced by the United Nations Environment Programme (UNEP 2011) as the concept of economic development that gives more attention to the use of natural resources and environment and the results in improving human well-being in the social aspect. Green economy is based on knowledge of ecological economics that aims to address the interdependence of human economies and natural ecosystems and the adverse effects of human economic activities on climate change and environmental degradation (Bassi 2011). Green economy is considered capable of creating jobs in harmony with nature, sustainable economic growth, and preventing environmental pollution, global warming, resource depletion, and environmental degradation. Degradation of environmental resources that occur on these days should increase the awareness of all parties to be responsible for improving the balance of the earth which is actually just a deposit for future generations.

In general, the concept of green economy is considered positive and should be developed and implemented. However, most developing countries also stressed that the implementation of green economy vary widely, as it covers a diverse elements, and need to be adapted to the characteristics and needs of each country. The implementation of the green economy approach is for integrated modeling of environmental systems aspects, social, and economic case studies of tourism in Dominica (Patterson et al. 2004). In addition, the concept of green economy simulation has also been analyzed in the ecological farming system with system dynamics approach as the previous paper (Li et al. 2012). The concept of green economy focus on the interaction of three things, namely the concept of environmental, economic, social and based on the utilization of energy (Bassi and Shilling 2010). Meanwhile, the world has recognized the importance of sustainable development issues by integrating the concept of sustainable development as an objective guide for policy-making and development, as described by modeling the green economy policies along with the measuring instrument through system dynamics, the ecological foot print (Wei et al. 2012). However, in implementing the policy, it is still difficult to implement the commitment towards the implementation of sustainable development. Based on observations so far, there has been no research on the implementation of the green economy, which comprehensively covers all aspects of the object of observation in finding solutions to the problem.

The research on mangrove field is still in a narrow scope, such as the form of expression of the mangrove viewed in terms of ethno-biology, management, and development (Walters et al. 2008), the environmental influences on the development of mangrove (Krauss et al. 2008), as well as specific approaches used to see the development of mangrove (Guebas and Koedam 2008) and managerial implication by using community-based mangrove management (Datta et al. 2012). However, all research is still limited to specific reviews of the mangrove, no study used a holistic approach to observe and model the dynamics of mangrove development and management, such as system dynamics. Similarly, the object of this research is Sidoarjo mudflow area, for this research are limited by coastal land use in Porong River related to pollution theoretically (Yuniar 2010) and mangrove vegetation types that have the best growth at planting media in Sidoarjo mudflow (Purwaningsih 2008). Based on the previous research, there is no research conducting mangrove utilization review policies related to the green economy concept with its modeling of system dynamics. This was of course there are still opportunities to do research on mangrove policy of Sidoarjo mudflow area by taking the concept of the green economy.

Based on three gaps, such as the need of Sidoarjo mudflow area to get real solutions, utilization of mangrove that has not been well integrated, as well as the research gap of green economy utilization which is still partially, so that a more in-depth study on this issue is needed. A system dynamics modeling and policy analysis that examines the use of mangrove cultivation in the affected area of Sidoarjo mudflow in accordance with the principles given the green economy of its conditions that has not been used optimally could be proposed. Therefore, the cultivation of mangrove vegetation through green economy approach is expected to neutralize the hazardous waste levels in the mud, and is able to play a role in reducing carbon emissions in the region, as well as to create a new ecosystem that could be utilized by the local community to increase the added value and the selling for Sidoarjo Mudflow area.

2 Research Methodology

Research methodology in designing simulation models of community-based mangrove through green economy concept using system dynamics methodology is divided into four main stages. The first stage is the variable identification and conceptualization of the model using causal loops diagram that shows a causal relationship. The second stage is designing system dynamics model which is needed to carry out the simulations by formulating the simulation model and applying the scenarios. The third stage is the creation of simulation models and the policy scenario using Stella © (iSee Systems) simulation software. Stella is one of the software used to build simulation models visually using a computer and has advantages, such as many users (users) and is often used in business and academic (Voinov 1999 in Costanza and Gottlieb 1998). And the fourth stage is an analysis and interpretation of the model which is included the impact of policy scenarios application. The methodology of this research is able to be seen in Fig. 1.

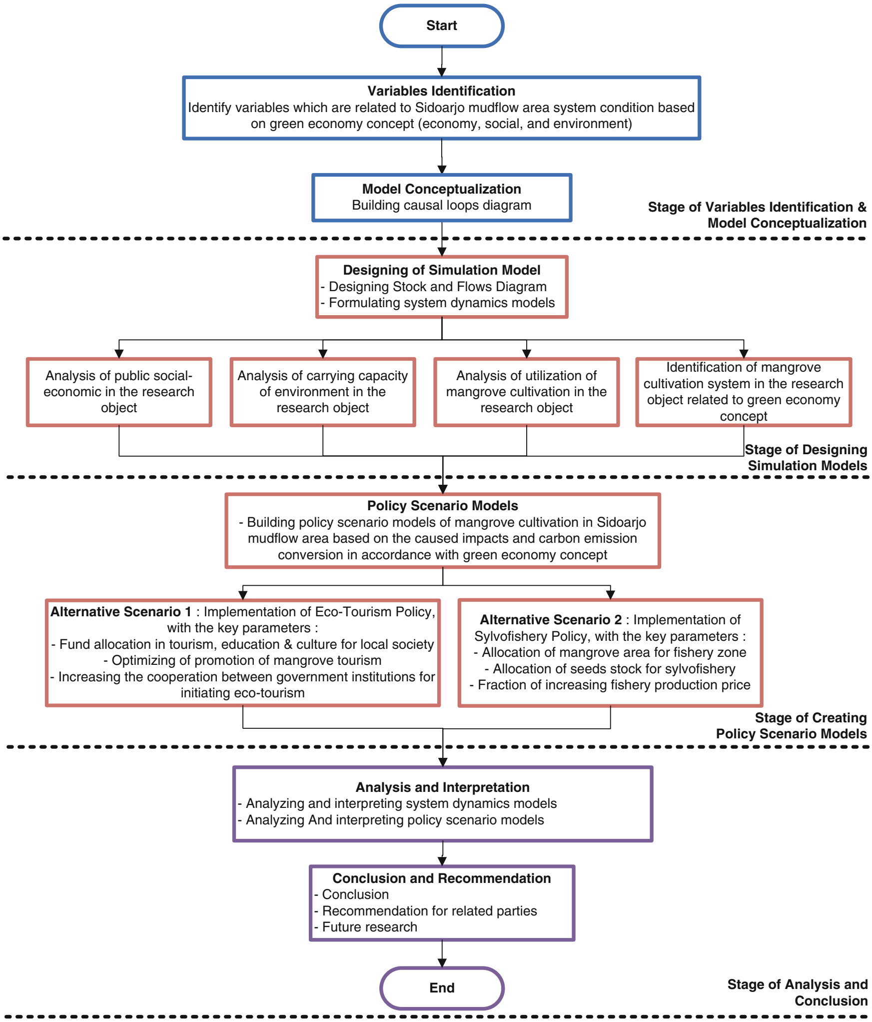


Fig. 1 Research methodology

3 Simulation Model Design

3.1 Variables Identification and Model Conceptualization

In modeling a system with system dynamics approach, is necessary to understand the elements related to identification and contributed in the development of the system, especially the stakeholders of the system. In this case, the observed object is mangrove cultivation system in Sidoarjo mudflow area. Identification of variables related to mangrove cultivation system is an important step to be done in as it

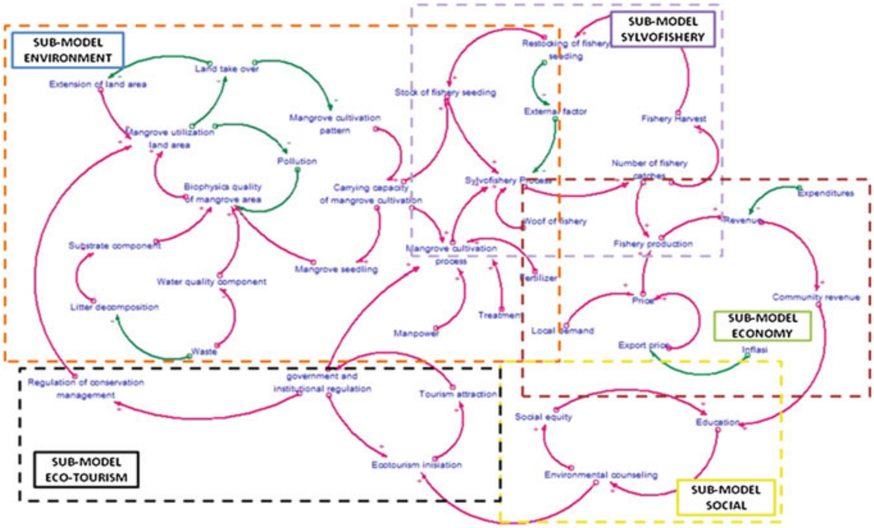


Fig. 2 Causal loops diagram

is an union of some aspects and elements based on green economy that are committed to cooperate in improving the green zone in the research object, especially the environmental carrying capacity. In general, some aspects that will be conducted in this research include environmental, economy, and social in accordance with green economy concept. Each of these elements has an important roles and function of the survival and progress of Sidoarjo mudflow area system.

Model presented by Forrester (1968) is the basic of experimental investigations that are relatively inexpensive and time-efficient than if it is conducted experiments on real systems. Conceptualization of the model begins with first by identifying the variables that interact in the system related mangrove cultivation system in Sidoarjo mudflow area based on green economy concept. The second is by creating a conceptual model of causal loops diagram and stock and flow diagram. The causal loops diagram of this research is able to be seen in Fig. 2. Causal loops diagram is made to show the main variables that will be described in the model. With the existence of causal loops, it is able to understand the relationship, and how far the influence of variables on system behavior is and how the impacts of each variable to the others are.

3.2 System Dynamics Simulation Model

System dynamics simulation model represented by stock and flow diagrams is designed based on causal loops diagram in Fig. 3. The purpose of making stock and flow diagram is to describe the interaction between variables in accordance with the logic structures used in software modeling. Modeling of the interaction of variable on the stock and flow diagrams produced three sectors that are interrelated, such as economy, environment, and social aspects. All sectors in stock and flows diagram are constructed to represent the interaction of green economy concept in mangrove cultivation system in Sidoarjo mudflow area in order to regain green zone area and increase the environmental carrying capacity. The stock and flows structure, formulation and data were designed. The three-sub models in Fig. 3 which are designed are environment, economy, and social model according to Wijaya et al. (2011) and Bassi and Shilling (2010). The design of the stock and flow diagrams are also considering the purpose of research, to know and see the development of mangrove cultivation system in the research object in developing policies that increase its environmental carrying capacity.

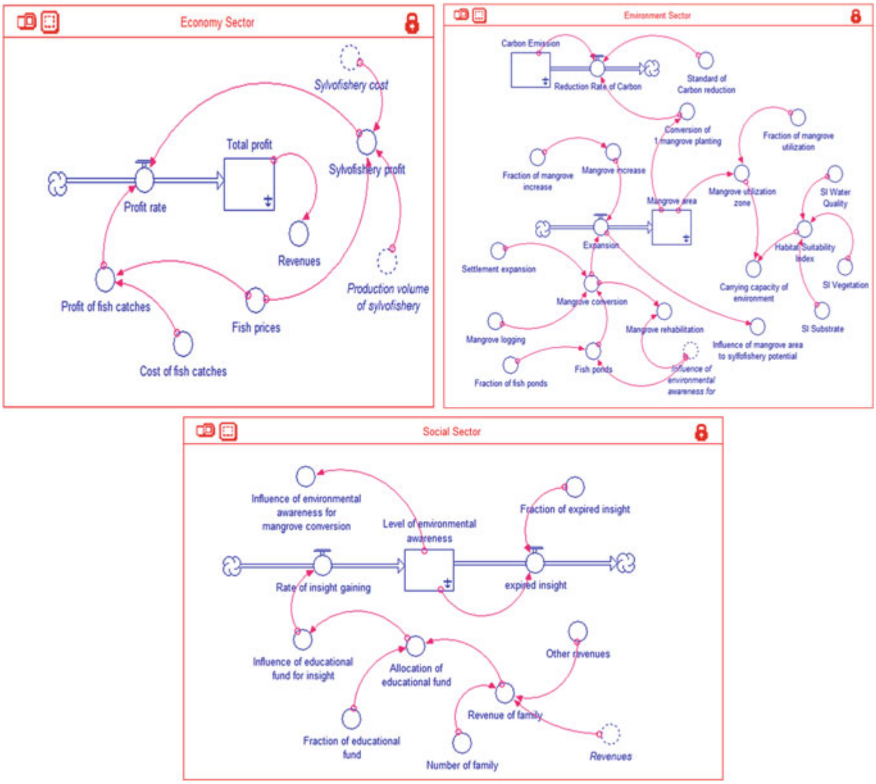


Fig. 3 Model of environment, economy, social aspects

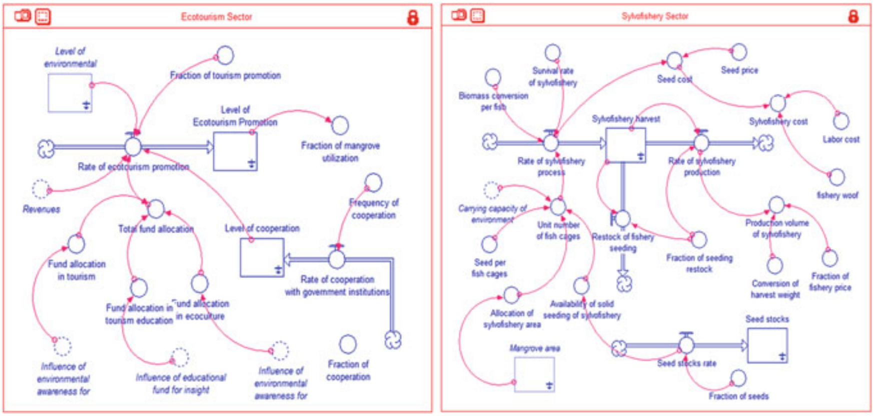


Fig. 4 Scenario model of sylvofishery and eco-tourism program

4 Policy Scenario Models

Based on created simulation models, it has been designed two alternative scenarios for supporting community-based mangrove and improving the green zone area in Sidoarjo mudflow area, such as sylvofishery and eco-tourism program (Glaser and Diele 2004 and Abidin 1999 in Datta et al. 2012) that could be seen in Fig. 4. The improvement scenarios are based on the conditions that allow it to be controlled by mangrove cultivation system based on green economy concept. Those improvement scenarios are explained below.

4.1 *Implementation of Sylvofishery (Mangrove-Based Fishery)*

In silvofishery development on the affected area of Sidoarjo mudflow, 20 % of area is planned to dam/watery land for fishery and 80 % is for mangrove (Harnanto 2011). The main key parameters for this policy are allocation of mangrove area for fishery zone, allocation of seeds stock for sylvofishery, and fraction of increasing fishery production price.

4.2 *Implementation of Eco-Tourism Program*

By programming eco-tourism in the research object, knowledge about mangrove and their resources for local community and other group at large will be increased. This program can provide educational value to always conserve the mangrove biodiversity in a sustainable manner. The main key parameters for this policy are fund allocation in tourism, education, and culture for local society, as well as optimizing of promotion of mangrove tourism, and increasing the cooperation between government institutions for initiating eco-tourism program.

5 Analysis and Conclusion

Based on the conceptual and scenario models, it could be concluded that variables of mangrove cultivation system play an important role on the regaining green zone area and increase the environmental carrying capacity in Sidoarjo mudflow area. In addition, this model could be benefit for especially environment, economy, and society. It is known that by implementing sylvofishery and eco-tourism program will produce faster recovery time in regaining the green zone and inversely with the reduction of carbon emission in the area. Moreover, these policy scenarios give managerial implications of green economy concept for local community to get some benefits from mangrove cultivation and to improve their revenues economically and greening their area environmentally. Nevertheless, it is needed to conduct future research in the same topic or related with the topic, especially for developing the simulation model in social and eco-tourism aspects and identifying variables in wider scope of research.

Acknowledgments This work is partially supported by Sidoarjo Mudflow Mitigation Institution (BPLS). We also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation, especially for Mr. Soegiarto as Head of Infrastructure in BPLS and his friends for their supports of domain knowledge and data collection.

References

Bassi AM (2011) Introduction to the threshold 21 (T21) model for green development. Millenium Institute

Bassi AM, Shilling JD (2010) Informing the US energy policy debate with threshold 21. J Technol Forecast Soc Change 77:396–410

Costanza R, Gottlieb S (1998) Modeling ecological and economic systems with STELLA: part II. J Ecol Model 112:81–84

Datta D, Chattopadhyay RN, Guha P (2012) Community based mangrove management: a review on status and sustainability. J Environ Manage 107:84–95

Forrester JW (1968) Principle of system. Wright-Allen Press, Inc, Massachusetts

Guebas FD, Koedam N (2008) Long-term retrospection on mangrove development using trans-disciplinary approaches: a review. J Aquat Bot 89:80–92

Harnanto A (2011) The Roles of Porong river in flowing Sidoarjo Mud to the sea. BPLS-Badan Penanggulangan Lumpur Sidoarjo, Surabaya

Krauss KW, Lovelock CE, McKee KL et al (2008) Environmental drivers in mangrove establishment and early development: a review. J Aquat Botany 89:105–127

Li FJ, Dong SC, Li F (2012) A system dynamics model for analyzing the eco-agriculture system with policy recommendations. J Ecol Model 227:34–45
Patterson T, Gulden T, Cousins K, Kraev E (2004) Integrating environmental, social, and economic systems—a dynamic model of tourism in Dominica. J Ecol Model 175:121–136
Purwaningsih E (2008) The impacts of Sidoarjo Mudflow for the growth of mangrove types, such as *Avicennia marina*, *Rhizophora apiculata* and *Rhizophora mucronata*. Thesis of master program of aquaculture, University of Brawijaya, Malang
UNEP (2011) Green economy-why a green economy matters for the least developed countries. St-Martin-Bellevue, France
Walters BB, Rönnbäck P, Kovacs JM et al (2008) Ethno-biology, socio-economic and management of mangrove forests: a review. J Aquat Botany 89:220–236
Wei S, Yang H, Song J et al (2012) System dynamics simulation model for assessing socio-economic impacts of different levels of environmental flow allocation in the Weihe River Basin, China. Eur J Oper Res 221:248–262
Wijaya NI et al (2011) General use zone governance by optimizing of *Scylla serrata* Utilization in Kutai National Park on East Kalimantan Province. Dissertation in Institut Pertanian Bogor
Yuniar WD et al (2010). Analysis of coastal land use related to pollution in Porong river. J Urban Reg Plann 2(2)

Three Approaches to Find Optimal Production Run Time of an Imperfect Production System

Jin Ai, Ririn Diar Astanti, Agustinus Gatot Bintoro and Thomas Indarto Wibowo

Abstract This paper considers an Economic Production Quantity (EPQ) model where a product is to be manufactured in batches on an imperfect production system over infinite planning horizon. During a production run of the product, the production system is dictated by two unreliable key production subsystems (KPS) that may shift from an in-control to an out-of-control state due to three independent sources of shocks. A mathematical model describing this situation has been developed by Lin and Gong (2011) in order to determine production run time that minimizes the expected total cost per unit time including setup, inventory carrying, and defective costs. Since the optimal solution with exact closed form of the model cannot be obtained easily, this paper considered three approaches of finding a near-optimal solution. The first approach is using Maclaurin series to approximate any exponential function in the objective function and then ignoring cubic terms found in the equation. The second approach is similar with first approach but considering all terms found. The third approach is using Golden Section search directly on the objective function. These three approaches are then compared in term computational efficiency and solution quality of through some numerical experiments.

Keywords EPQ model · Imperfect production system · Optimization technique · Approximation and numerical method

J. Ai (✉) · R. D. Astanti · A. G. Bintoro · T. I. Wibowo
Department of Industrial Engineering, Universitas Atma Jaya Yogyakarta,
Jl. Babarsari 43, Yogyakarta 55281, Indonesia
e-mail: jinai@mail.uajy.ac.id

R. D. Astanti
e-mail: ririn@mail.uajy.ac.id

A. G. Bintoro
e-mail: a.bintoro@mail.uajy.ac.id

T. I. Wibowo
e-mail: t8_t10@yahoo.co.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_127,

1 Introduction

The problem considered in this paper had been formulated by Lin and Gong (2011) as follow. A product is to be manufactured in batches on an imperfect production system over an infinite planning horizon. The demand rate is d, and the production rate is p. The imperfectness of the system is shown on two imperfect key production subsystems (KPS) that may shift from an in-control to an out-of-control state due to three independent sources of shocks: source 1's shock causes first KPS to shift, source 2's shock causes second KPS to shift, and source 3's shock causes both KPS to shift. Each shock occurs at random time U_1, U_2, and U_{12} that follows exponential distribution with mean $1/\lambda_1$, $1/\lambda_2$, and $1/\lambda_{12}$, respectively. When at least one KPS on out-of-control state, consequently, the production system will produced some defective items with fixed but different rates: α percentage when first KPS out-of-control, β percentage when the second KPS out-of-control, and δ percentage when the both KPS out-of-control. The cost incurred by producing defective items when the first KPS is shifted, the second KPS is shifted, and both KPS are shifted are π_1, π_2, and π_{12}, respectively. The optimization problem is to determining optimal production run time τ that minimizes the expected total cost per unit time including setup, inventory carrying, and defective costs. It is noted that the unit setup cost is A and inventory carrying per unit per unit time is h.

As derived in Lin and Gong (2011), the objective function of this optimization model is given by following equations.

$$Z(\tau) = \frac{Ad}{p\tau} + \frac{h(p-d)\tau}{2} + \frac{d(\pi_1 E[N_1(\tau)] + \pi_2 E[N_2(\tau)] + \pi_{12} E[N_{12}(\tau)])}{p\tau} \quad (1)$$

$$E[N_1(\tau)] = p\alpha\left(\frac{1-\exp[-(\lambda_2+\lambda_{12})\tau]}{\lambda_2+\lambda_{12}} - \frac{1-\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau]}{\lambda_1+\lambda_2+\lambda_{12}}\right) \quad (2)$$

$$E[N_2(\tau)] = p\beta\left(\frac{1-\exp[-(\lambda_1+\lambda_{12})\tau]}{\lambda_1+\lambda_{12}} - \frac{1-\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau]}{\lambda_1+\lambda_2+\lambda_{12}}\right) \quad (3)$$

$$\begin{aligned} E[N_{12}(\tau)] = p\delta\Bigg(&\frac{\exp[-(\lambda_1+\lambda_{12})\tau] + (\lambda_1+\lambda_{12})\tau - 1}{\lambda_1+\lambda_{12}} \\ &+ \frac{\exp[-(\lambda_2+\lambda_{12})\tau] + (\lambda_2+\lambda_{12})\tau - 1}{\lambda_2+\lambda_{12}} \\ &- \frac{\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau] + (\lambda_1+\lambda_2+\lambda_{12})\tau - 1}{\lambda_1+\lambda_2+\lambda_{12}}\Bigg) \end{aligned} \quad (4)$$

Although the problem is a single variable optimization, the optimal solution with exact closed form of the model cannot be obtained easily. Therefore, this paper considered three approaches of finding a near-optimal solution. These approaches are then compared through some numerical experiments.

2 Approaches of Finding a Near-Optimal Solution

2.1 First Approach

In this first approach, following Maclaurin series is applied to approximate any exponential function in the objective function.

$$\exp(-\lambda\tau) \approx 1 - \lambda\tau + \frac{1}{2!}(\lambda\tau)^2 - \frac{1}{3!}(\lambda\tau)^3 \tag{5}$$

Therefore after some algebra, the objective function can be approximated as following equations.

$$Z(\tau) \approx Z_1(\tau) = \frac{Ad}{p\tau} + \frac{H\tau}{2} - \frac{B\tau^2}{6} \tag{6}$$

$$H = h(p-d) + d(\pi_1\alpha\lambda_1 + \pi_2\beta\lambda_2 + \pi_{12}\delta\lambda_{12}) \tag{7}$$

$$B = d[\pi_1\alpha\lambda_1(\lambda_1 + 2\lambda_2 + 2\lambda_{12}) + \pi_2\beta\lambda_2(2\lambda_1 + \lambda_2 + 2\lambda_{12}) - \pi_{12}\delta(2\lambda_1\lambda_2 - \lambda_{12}^2)] \tag{8}$$

From calculus optimization, it is known that the necessary condition for obtaining the minimum value of Z_1 is set the first derivative equal to zero. Applying this condition for Eq. (6), it is found that

$$\frac{dZ_1(\tau)}{d\tau} = -\frac{Ad}{p\tau^2} + \frac{H}{2} - \frac{2B\tau}{6} = 0 \tag{9}$$

Equation (9) can be rewritten as

$$2B\tau^3 - 3H\tau^2 + 6Ad/p = 0. \tag{10}$$

If the cubic term in Eq. (10) is ignored, then a near-optimal solution of the first approach can be obtained as follow

$$\tau_1^* = \sqrt{\frac{2Ad}{p[h(p-d) + d(\pi_1\alpha\lambda_1 + \pi_2\beta\lambda_2 + \pi_{12}\delta\lambda_{12})]}} \tag{11}$$

2.2 Second Approach

The second approach is developed based on Eq. (9). Another near-optimal solution can be found as the root of this equation. Bisection algorithm can be applied here to find the root of this equation (τ_2*) with lower searching bound of $\tau_L = 0$ and upper searching bound

$$\tau_U = \sqrt{\frac{2Ad}{ph(p-d)}} \tag{12}$$

It is noted that the lower bound is selected equal to zero due to the fact that the optimal production run time have to be greater than zero. While the upper bound is selected as Eq. (12) due to the fact that the optimal production run time in the presence of imperfectness, i.e. with non negative values of α, β, and δ, is always smaller than the optimal production run time of perfect production system, i.e. with zero values of α, β, and δ. Substituting $\alpha = \beta = \delta = 0$ to Eq. (11) provides the same value as optimal production run time of classical and perfect EPQ (Silver et al. 1998), as shown in the right hand side of Eq. (12). The detail of bisection algorithm can be found in any numerical method textbook, i.e. Chapra and Canale (2002).

2.3 Third Approach

The third approach is using pure numerical method to find the minimum value of Z based on Eq. (1). The Golden Section method is applied here using the same bound as the second approach. Therefore, the searching of the optimal production run time of this approach (τ_3*) is conducted at interval $\tau_L \le \tau_3^* \le \tau_U$, where $\tau_L = 0$ and τ_U is determined using Eq. (12). Further details on the Golden Section method can be found in any optimization textbook, i.e. Onwubiko (2000).

3 Numerical Experiments

Numerical experiments are conducted in order to test the proposed approaches for finding the optimal production run time. Nine problems (P1, P2, …, P9) are defined for the experiments and the parameters of each problem are presented in Table 1. The result of all approaches are presented in Table 2, which comprise of the optimal production run time calculated from each approach (τ_1*, τ_2*, τ_3*) and their corresponding expected total cost [$Z(\tau_1$*), $Z(\tau_2$*), $Z(\tau_3$*)]. Some metrics defined below are also presented in Table 2 in order to compare the proposed approaches.

In order to compare the proposed approaches, since the optimal expected total cost cannot be exactly calculated, the best expected total cost is defined as following equation

$$Z^* = \min\{Z(\tau_1{}^*), Z(\tau_2{}^*), Z(\tau_3{}^*)\} \tag{13}$$

Table 1 Problem parameters of the numerical experiments

Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9
p	300	300	300	300	300	300	300	300	300
d	200	200	200	200	200	200	200	200	200
A	100	100	100	100	100	100	100	100	100
h	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
π_1	10	10	10	10	10	10	10	10	10
π_2	10	10	10	10	10	10	10	10	10
π_{12}	12	12	12	12	12	12	12	12	12
α	0.1	0.1	0.1	0.3	0.3	0.3	0.5	0.5	0.5
β	0.1	0.1	0.1	0.3	0.3	0.3	0.5	0.5	0.5
δ	0.16	0.16	0.16	0.48	0.48	0.48	0.8	0.8	0.8
λ_1	0.05	0.15	0.25	0.05	0.15	0.25	0.05	0.15	0.25
λ_2	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5
λ_{12}	0.02	0.06	0.1	0.02	0.06	0.1	0.02	0.06	0.1

If τ^* is the best value of production run time in which $Z^* = Z\ (\tau^*)$, the deviation of the solution of each approach from the best solution is calculated from following equation

$$\Delta\tau_i = \frac{|\tau_i{}^* - \tau^*|}{\tau^*} \times 100\,\% \tag{14}$$

Furthermore, the deviation of the expected total cost of each approach from the best one can be determined using following equation

$$\Delta Z_i = \frac{Z\left(\tau_i^*\right) - Z^*}{Z^*} \times 100\,\% \tag{15}$$

Regarding to solution quality, it is shown in Table 2 that the third approach is consistently providing the best expected total cost across nine test problems among

Table 2 Results of the numerical experiments

Result	P1	P2	P3	P4	P5	P6	P7	P8	P9
$\tau_1{}^*$	1.7085	1.0496	0.8239	1.0496	0.6198	0.4823	0.8239	0.4823	0.3746
$\tau_2{}^*$	1.8067	1.2035	1.0199	1.0897	0.6679	0.5350	0.8489	0.5104	0.4046
$\tau_3{}^*$	1.7986	1.1750	0.9642	1.0877	0.6633	0.5280	0.8479	0.5084	0.4016
$\Delta\tau_1$	5.01 %	10.67 %	14.55 %	3.51 %	6.56 %	8.65 %	2.83 %	5.14 %	6.72 %
$\Delta\tau_2$	0.46 %	2.43 %	5.78 %	0.18 %	0.70 %	1.33 %	0.11 %	0.40 %	0.72 %
$\Delta\tau_3$	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
$Z(\tau_1{}^*)$	76.18	120.96	151.69	124.89	208.55	265.54	159.60	269.73	344.77
$Z(\tau_2{}^*)$	76.09	120.34	150.38	124.82	208.12	264.61	159.54	269.39	344.02
$Z(\tau_3{}^*)$	76.09	120.31	150.20	124.82	208.12	264.59	159.54	269.38	344.02
ΔZ_1	0.12 %	0.54 %	0.99 %	0.06 %	0.21 %	0.36 %	0.04 %	0.13 %	0.22 %
ΔZ_2	0.00 %	0.02 %	0.12 %	0.00 %	0.00 %	0.01 %	0.00 %	0.00 %	0.00 %
ΔZ_3	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %

three approaches. It is also shown in the Table 2 that $Z(\tau_1^*) > Z(\tau_2^*) > Z(\tau_3^*)$, while the deviations of the expected total cost of the first and second approaches are less than 1.0 and 0.2 %, respectively. Furthermore, it is found that production run time found by the three approaches are $\tau_1^* < \tau^* = \tau_3^* < \tau_2^*$. The deviations of the first approach solution from the best solution are less than 14.6 %, while the deviations of the second approach solution from the best solution are less than 5.8 %.

These results show that the first approach is able to find reasonable quality solution of the problems although its computational effort is very simple compare to other approaches. It is also implied from these result that the Maclaurin approximation used in the second approach is effective to support the second approach finding very close to best solution of the problems, although the computational effort of the second approach is higher than the computational effort of the first approach. Since the third approach is using the highest computational effort among the proposed approaches, it can provide the best solution of the problems.

4 Concluding Remarks

This paper proposed three approaches for solving Lin and Gong (2011) model on Economic Production Quantity in an imperfect production system. The first approach is incorporating Maclaurin series and ignoring cubic terms in the first derivative of total cost function. The second approach is similar with the first approach but incorporating all terms in the total cost function, then using Bisection algorithm for finding the root of the first derivative function. The third approach is using Golden Section method to directly optimize the total cost function. Numerical experiments show that the third approach is able to find the best expected total cost among the proposed approaches but using the highest computational effort. It is also shown that the first approach is able to find reasonable quality solution of the problems despite the simplicity of its computational effort.

Acknowledgments This work is partially supported by Directorate of Higher Education, Ministry of Education and Culture, Republic Indonesia under *International Research Collaboration and Scientific Publication* Research Grant and Universitas Atma Jaya Yogyakarta, Indonesia. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Chapra SC, Canale RP (2002) Numerical method for engineers, 4th edn. McGraw-Hill, New York

Lin GC, Gong DC (2011) On an economic lot sizing model subject to two imperfect key production subsystems. In: Proceedings of IIE Asian conference 2011, Shanghai, China

Onwubiko C (2000) Introduction to engineering design optimization. Prentice Hall, New Jersey

Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling, 3rd edn. Wiley, New York

Rice Fulfillment Analysis in System Dynamics Framework (Study Case: East Java, Indonesia)

Nieko Haryo Pradhito, Shuo-Yan Chou, Anindhita Dewabharata and Budisantoso Wirdjodirdjo

Abstract Food fulfillment is one of the things that affect the stability of a country. The rapid population growth but not matched by the ability of food production will be a threat in the future, there is no balance between supply and demand. In 2011, there was rice shortage in East Java, which also resulted in the rice shortage at the national level, this phenomenon is caused anomaly weather, pests, land mutation, weak network Supply Chain Management, distribution, transportation, etc. that cause dependence on rice imports higher. This research purposes are to identify the holistic process of rice fulfillment in the context of supply chain system and analyzing possible risk raised as an important variables and provide a projection capabilities in the future by using a simulation scenario. The complexity of interaction between variables and the behavior of the system considered the selection of System Dynamics methods to solve problems. The advantages using System Dynamics as tools analysis is combine qualitative and quantitative method, also model can provide reliable forecast and generate scenarios to test alternative assumptions and decisions. Finally, the research contribution is formulated policy improvements in rice fulfillment, also provide more robust sensitivities and scenarios, so this research predict the impact of major changes in strategy accurately in uncertainty condition.

Keywords Rice fulfillment · Supply chain · System dynamics · Policy

N. H. Pradhito (✉) · S.-Y. Chou · A. Dewabharata
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: nieko.haryo.pradhito@gmail.com

B. Wirdjodirdjo
Deptartment of Industrial Engineering, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
e-mail: budisantoso.wirjodirdjo@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_128,

Table 1 Land area, production and productivity Indonesian

Sector	Harvest area (ha)	Productivity (Tons/Hectare)	Production (Tons)
Indonesia	13,443,443.00	5.14	69,045,523.25
East Java	1,975,719.00	6.17	12,198,089.11

Source Indonesian Statistics Central Bureau (2012)

1 Introduction

Fulfillment food needs is one of the strategic issues that are closely related to the stability condition of a country, including Indonesia. Rice is a staple food of the population of Indonesia since 1950, and now has reached the current consumption until 95 %, but on the other hand, the growth rate of rice production reached only 3 %.

Problems of rice, is a complex issue and holistic, so that the modeling needs to be simplified but still represent locations and representative of the system. To validate this model, it was chosen as a representative of East Java province on issues of production and supply of rice. Table 1 will be provides latest condition in 2012 about harvest area, productivity and production between total in Indonesia and East Java contribution.

The complexity of interaction between variables and the behavior of the system considered the selection of System Dynamics methods to solve problems. The advantages using System Dynamics as tools analysis is combine qualitative and quantitative method, also model can provide reliable forecast and generate scenarios to test alternative assumptions and decisions (Sterman 2000).

This research purposes are to identify the holistic process of rice fulfillment in the context of supply chain system and analyzing possible risk raised as an important variables and provide a projection capabilities in the future by using a simulation scenario, benefits of the research are to gain predictive effectiveness of the plan to achieve fulfillment rice from the key points in the policy that also involves farmers, trading in the market, purchasing power and dependence on rice.

2 Previous Related Work

Food fulfillment in which the pressures of a rising world population, climate change, water shortages, the availability of quality land for crop production and the rising cost of energy are all colliding. Agriculture in the 21st century will have to deal with major alterations in the physical landscape: arable land per capita is declining, supply of water, energy costs, pest and disease problems, climate changes. The key issues in supply chain management (SCM) in agriculture area are the formation of the supply chain and its efficient coordination with objectives

Table 2 Summary of previous research area using system dynamics

Author	Years	Case
Smith	1997	Economic
Cooke	2002	Disaster
Shuoping	2005	Logistic
Ho	2006	Earthquake
Deegan	2007	Flood
Zhai	2009	Water
Yang	2009	Inventory
Yang	2009	Financial
Cui	2011	Market
Erma	2011	Capacity
Sidola	2011	Risk
Patel	2010	Safety Stock

of customer satisfaction and sustaining competency. Uses system dynamic modeling approach so previous dynamic modeling works are reviewed.

In System Dynamics context, feedback structure of a system is described using causal loops. These are either *balancing* (capturing negative feedback) or *reinforcing* (capturing positive feedback). A balancing loop exhibits goal seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation (conforming to the economic notion of a stable equilibrium (Smith 2000). Table 2 will be provides several researches on other areas using System Dynamics.

3 System Dynamics Modeling and Validation

3.1 Causal Loops Diagram

Causal loop diagram is a tool to represent the feedback structure of system, it consists of variables connected by arrows denoting the causal influences among them. This diagram shows the cause and effect of the system structure. Each arrow represents a cause and effect relationship between two variables. The + and − signs represent the direction of causality. A + sign indicates can increase the result to destination variable. While the − sign indicates can decrease the result to the destination variable (Fig. 1).

However, the growth of demand will make the utilization higher. Causal loop diagrams emphasize the feedback structure of the system, it can never be comprehensive. We have to convert the causal loop diagram into flow diagram that emphasizes the physical structure of the model. It has a tendency to be more detailed than causal loop diagram, to force us to think more specifically about the system structure.

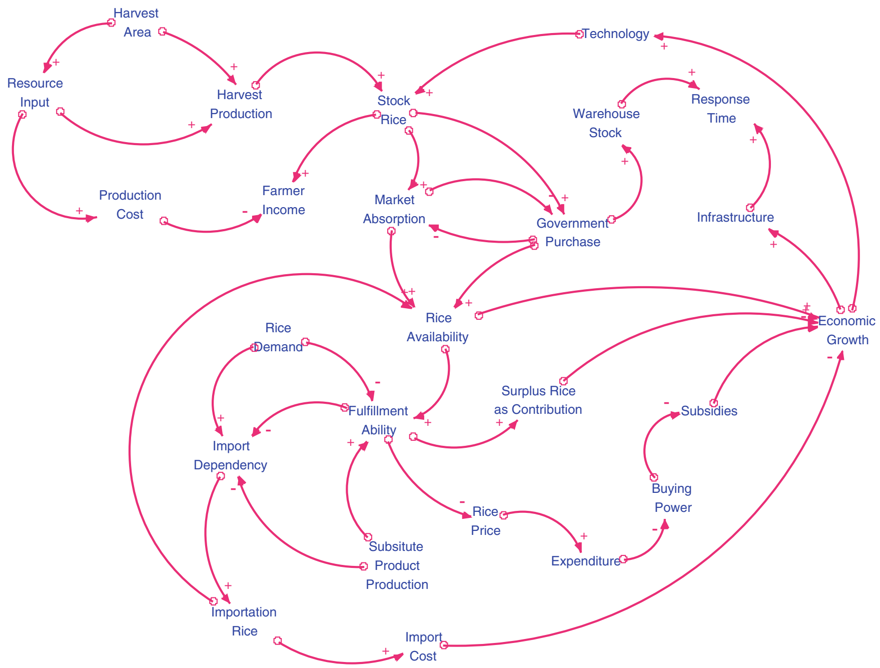


Fig. 1 Causal loops diagram

3.2 Rice Fulfillment Based on Existing Condition

In explanation of the analysis of the existing condition, Fig. 2 will be provide the mechanism of the rice supply chain will be more easily described in terms of the flow from upstream to downstream, where the earliest upstream processes called pre-harvest until in post harvest as the end of the process.

3.3 Parameter Estimation

Parameter estimation is required to develop mathematical models by utilizing data or observation from the real system. The estimation of parameters can be obtained in some ways such as statistics data, published reports, and statistical methods. Historical data are needed to see trends and forecasting analysis of the future, the behavior of the system can also be used to analyze the data validation by quantitative calculation. All the data collect from Indonesian Statistics Central Bureau and Indonesian Population Agency in East Java. Table 3 will be provides the historical data for the 10 years, more historical data, more accurately trend analysis.

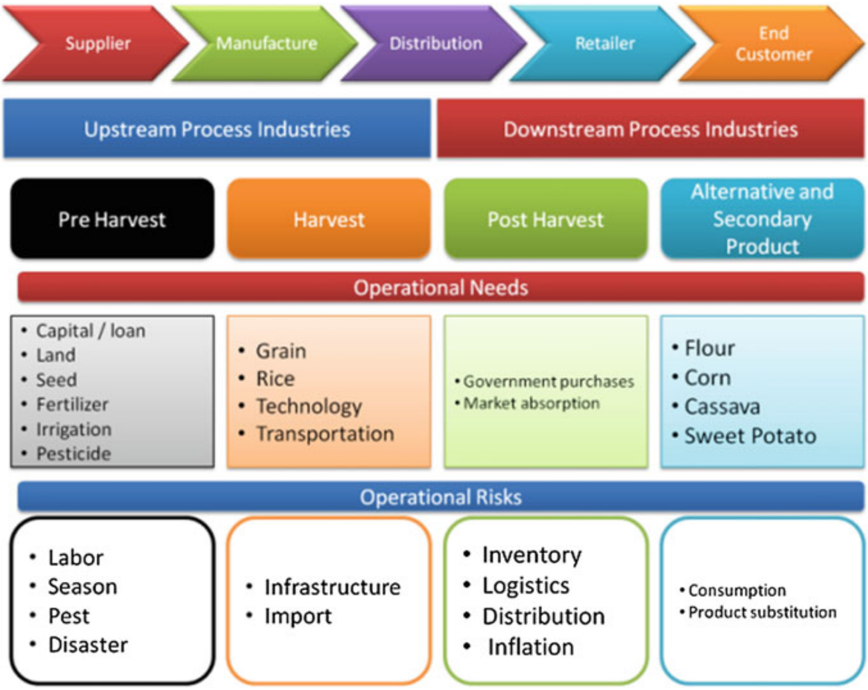


Fig. 2 Rice supply chain mechanisms

Table 3 Supply and demand sector from historical data

Years	Supply sector			Demand sector	
	Harvest area (Hectares)	Productivity (Tons/Ha)	Production (Tons)	Populations	Growth rate (%)
2003	1,695,514	5.258	8,915,013	35,130,220.16	1.16
2004	1,697,024	4.97	8,434,209	35,480,961.18	1.16
2005	1,693,651	5.318	9,006,836	35,835,204.00	3.01
2006	1,750,903	5.338	9,346,320	36,913,843.64	1.02
2007	1,736,048	5.416	9,402,436	37,290,364.85	3.01
2008	1,774,884	5.902	10,475,365	38,412,804.83	1.46
2009	1,904,830	5.911	11,259,450	38,973,631.78	2.77
2010	1,963,983	5.929	11,644,455	40,053,201.38	2.12
2011	1,926,796	5.489	10,576,183	40,902,329.25	2.88
2012	1,975,719	6.174	12,198,089	41,237, 728.35	0.82

Source Indonesian Statistics Central Bureau, Indonesian Population Agency (2012)

Table 4 Mathematical formula for supply sector model formulation

No.	Variables	Model buildings	Formulation
1.	Harvest paddy area	Stock	Paddy_Harvest_Area(t) = Paddy_Harvest_Area (t−dt) + (Paddy_Area_Rate) * dt INIT Paddy_Harvest_Area = 1,695,514
2.	Paddy area rate	Flow	Paddy_Harvest_Area*Paddy_Area_Growth
3.	Paddy area growth	Converter	Paddy_Area_Growth = GRAPH(TIME) (1.00, 0.001), (2.13, −0.002), (3.25, 0.034), (4.38, −0.008), (5.50, 0.022), (6.63, 0.073), (7.75, 0.031), (8.88, −0.019), (10.0, 0.025)

3.4 Model Formulation

Barlas (2000) give mathematical formulation example for supply and demand case, formulation of the model shows how the model is based on mathematical formulas and other quantitative approaches. Table 4 will be provide example how build formulation in mathematical model for supply sector.

The simulation based on the actual historical data for 10 years will be provide in Fig. 3 to show the behavior of the system.

3.5 Model Validation

Validation is a process of evaluating model simulation to determine whether it is an acceptable representation of the real system, historical data during the time horizon of simulation of the base model is required. For the validation, Eq. 1 is used for statistical data fitness:

$$Error\_rate = \frac{|\bar{S} - \bar{A}|}{\bar{A}}$$

where:

$$\bar{S} = \frac{1}{N}\sum_{i=1}^{N} S_i \qquad \bar{A} = \frac{1}{N}\sum_{i=1}^{N} A_i \tag{1}$$

From the simulation, the error rate paddy production as supply sector known that the result is 1.4 % and result for population as demand sector is 1.1 %, the result less than 5 % mean that the simulation valid for represent real problem.

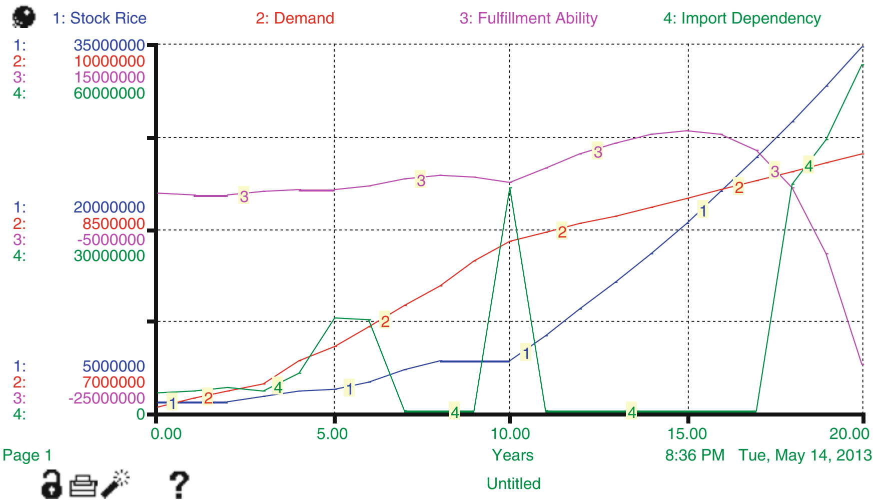


Fig. 3 Simulation result for existing condition

4 Scenario Planning

4.1 Structure Scenario

For the improvement scenario, this research provide strategy to utilize secondary source of carbohydrate food, especially for corn, cassava and sweet potato to adding the rice stock in nutrient context, Fig. 4 will be provide the simulation result for the scenario and how to improve the actual condition.

4.2 Evaluative Comparison

And from the scenario improvement from utilize secondary source of carbohydrate food, Fig. 5 will be show the improvement number by this scenario.

5 Discussion Analysis and Conclusion

This research start from identify holistic system of rice fulfillment to catch the big picture process, and then developing a System Dynamics model of rice availability in Supply Chain Management framework, the simulation projecting the rice availability in the future using a System Dynamics model. Improvement scenario

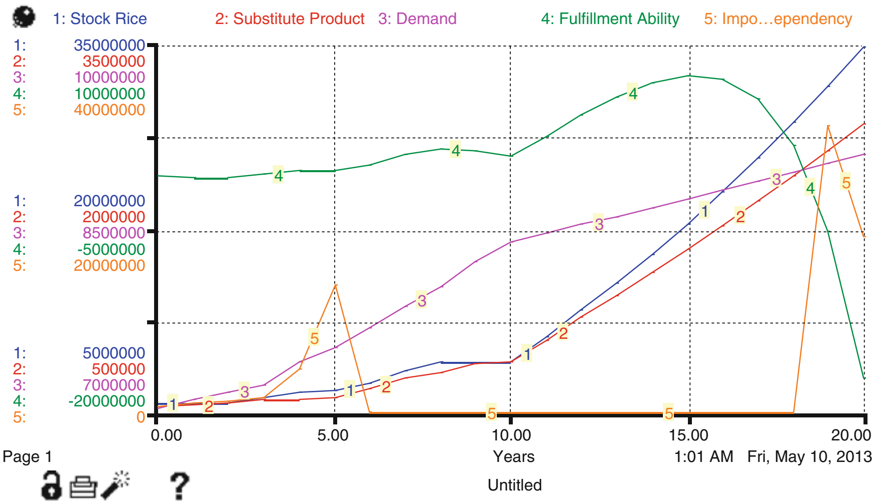


Fig. 4 Simulation result for existing condition

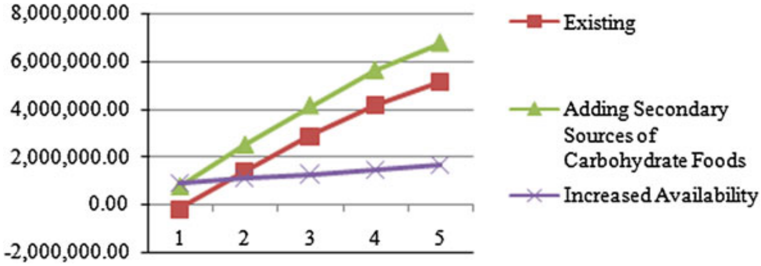


Fig. 5 Improvement number using scenario

as a better policy for achieving availability of rice by utilize secondary source of carbohydrate food as a substitute product to tackle importation rice dependency and as the recommendation, this scenario can support the fulfillment ability for 5 next years.

Acknowledgments This work is partially supported by Professor Shuo-Yan Chou, Professor Budisantoso Wirdjodirdjo, Anindhita Dewabharata and Erma Suryani. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Barlas Y (2000) 5.12 System dynamics: systemic feedback modeling for policy analysis
Indonesian_Statistics_Central_Bureau (2012) http://jatim.bps.go.id/e-pub/2012/prodpadipalawija2011/, http://jatim.bps.go.id/e-pub/2012/jtda2012/
Sterman JD (2000) Business dynamics. McGraw-Hill, New York

Activity Modeling Using Semantic-Based Reasoning to Provide Meaningful Context in Human Activity Recognizing

AnisRahmawati Amnal, Anindhita Dewabharata, Shou-Yan Chou and Mahendrawathi Erawan

Abstract As rapid increasing of World-Wide Web technology, ontology and pervasive/ubiquitous concept become one of the most interesting parts recently. According to ubiquitous issue, activity modeling which has capability to provide proper context information of the user becomes important part of context awareness. In order to develop required services in intelligence environment; to get deep knowledge provision framework; and precise activities relationship; context of knowledge should be determined based on socio-environment situation. Based on that background, this paper is aimed to develop activity model through activity recognition by implementing semantic based reasoning to recognize human activity.

Keywords Context-awareness · Activity modeling · Semantic-based reasoning

A. Amnal (✉) · A. Dewabharata · S.-Y. Chou
National Taiwan University of Science and Technology, Keelung Road Sec. 4, Daan District, Taipei, Taiwan
e-mail: m10101812@mail.ntust.edu.tw

A. Dewabharata
e-mail: d10101801@mail.ntust.edu.tw

S.-Y. Chou
e-mail: sychou@mail.ntust.edu.tw

M. Erawan
Information System Departments, SepuluhNopember Institute of Technology, Surabaya, Indonesia
e-mail: mahendra_w@its.edu.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_129,

1 Introduction

Human Activity Recognition (HAR) is researches mostly observe human actions to understand types of human activities perform within time interval. Dominantly, it observes a series of physical actions construct one physical activity (PA) and activities of daily livings (ADL) due to its benefit in healthcare application. Generally, people perform activities depend on their lifestyle, so that context-aware information developed should contains meaningful data to analyze human activities in their environment (Wongpatikaseree et al. 2012).

More than ability to recognize recent information about user activity, context-aware computing is also answering challenges in understanding dynamic changes from users. It is not only about how to adapt and sense environmental changes, but more about how to sense the context in current environments and react to such changing context automatically. Context-awareness system enables actors to interact through context-aware applications running on portable devices and other computing hardware platforms cohesively, allow software to adapt based on user location, gather actors and object nearby, and change those objects based on time (Dey and Abowd 1999). The system also facilitates the provision of information and assistance for the applications to make appropriate decisions in the right manner, at the right time, and at the right place (3Rs) (Xue and Keng Pung 2012).

In order to describe context as a whole, provide appropriate information and assist the application to make proper decisions, context modeling that involves all important entities and relation become crucial issues. The modeling of the context in this research will be based on the technology concept borrowed from semantic web, which is: the ontology. Rapid advances of world-wide web technology makes ontology become common concept that is used to represent formal knowledge and shared vocabulary as well as their properties and relationship in multiple specific domains with several advantages engaged (Noy and McGuinness 2001). Ontology concept is widely use because its ability to share common understanding of information among people or software agents, reuse domain knowledge, make domain assumptions explicit, etc. According to those advantages, context aware computing is developed from ontology and ubiquitous concept to perform computation from heterogeneous devices integrated to physical environment to make interaction between human–computer run smoothly.

Additionally, to check consistencies in the model, ontology reasoning also required to deduce knowledge from the model developed (July and Ay 2007; Wang et al. 2004). The ontology reasoning includes RDFS reasoning and OWL (Ontology Web Language) reasoning. The RDFS reasoning supports all the RDFS entailments described by the RDF Core Working Group. The OWL reasoning supports OWL/lite (OWL Web Ontology Language Overview) which includes constructs such as relations between classes (e.g. disjointness), cardinality (e.g. 'exactly one'), equality, characteristics of properties (e.g. symmetry), and enumerated classes.

User defined reasoning instead of OWL reasoning can help to provide flexible reasoning mechanism. Through the creation of user-defined reasoning rules within a set of first order logic, a wide range of higher-level conceptual context such as "what the user is doing" can be deduced from relevant low-level context. The user defined reasoning should be performed after the ontology reasoning because the facts which are receive from the ontology reasoning in the input for the user-defined reasoning.

According to the background, the objective of this study is to provide proper context information for recognizing human activity behavior viewed from the daily living and physical activities that is performed both in outdoor and indoor environment using semantic-based approach. In the end of the study, the performances of ontology and user defined reasoning show that rules deduce are consistence enough to recognize current activity of the people. Furthermore, study of this paper with some additional values in activity daily living treatment that involves more comprehensive aspects will give benefit in developing healthcare services application.

2 Literature Review

Context awareness is one of feature key in pervasive computing that enabling the application sense the changing of environments and adapt operation and behaviors adjusting available resources (Xue and Keng Pung 2012). Context awareness comes up with some notions about context data, context source, and context attribute, whereas all of them should be unity to build context awareness services.

Due to evolving nature of context aware computing, formalizing all context information by using context modeling is an important process. Context model should be able to capture set of upper-level entities, and providing flexible extensibility to add specific concepts in different application domains (Wang et al. 2004). Context model should be developed using common vocabulary that enable each domain to share common concept, but in the same time it also should be able to provide a flexible interface to define specific knowledge of application (Scott and Benlamri 2010). Previous work related to context modeling and context reasoning are have been conducted by (Wang et al. 2004) that evaluate feasibility of context modeling and context reasoning using Context Ontology (CONON).

In order to harvest deep understanding about context data, context sources, and context attributes, activity theory could be useful concept to capture important information engaged to the system. Activity theory is merely characterized as a conceptual framework to understand everyday practice in the real world depicted into set of concept and categories for communicating about nature of human activity (Kaptelinin and Nardi 1996).

Activity theory is broadly defined as a philosophical and cross-disciplinary framework for studying different forms of human practices as development processes, both individual and social levels interlinked at the same time by following

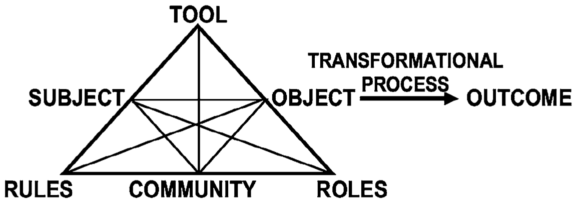


Fig. 1 The structure of human activity

three key principles (Kuutti 1996): (a) Activities as a basic units of analysis; (b) History and development; (c) Artifacts and mediation.

Essential of activity theory can be summarized by a couple of simple diagrams supported by triangle diagram (Fig. 1).

Instead of just presenting information to human, ontology is more beneficial in supporting knowledge sharing, context reasoning, and interoperability in ubiquitous and pervasive computing system (Chen et al. 2004). Furthermore, its ability to share common understanding of the information and domain knowledge reuse simplify developer to extend domain of interest in the future, whereas domain ontology that is developed will provide specific knowledge for application and metadata or schema to subordinate instance-base that is updated when application executed (Hong et al. 2007; Noy and McGuinness 2001). Explicit knowledge of ontology can be used to reason context information by applying rules using ontology and user defined reasoning, where integration of semantic-based reasoning with ontology model allow the system to deal with rapidly changing context environment and having relatively low computational complexity (Bikakis et al. 2008).

3 Ontology-Based Approach for Activity Modeling

3.1 Activity Modeling

Generally the most common ontology-based approach for activity modeling consists of a specific semantic data from observation of indoor, outdoor, and smart home surround, such as time, user location, or object, but it still needs improvement in recognition ability for some ambiguous cases. In the effort to improve recognition ability, the model in Fig. 2 developed to presents the semantic of each class and relationship between classes through ontology into 5 domain concepts, which are: *Location* class to define environment type captured that is contains environment, indoor corridor, and smart home room; *Activity* class to describe the type of activity monitored and observed, consists of Activity Daily Living, Physical Activity, Activity Behavior, and Physical Activity Effect; *People* class to document user profile; *Sensor Manager* class to infer activity and sensor that become high level information and low level raw data; and *Wireless Network*

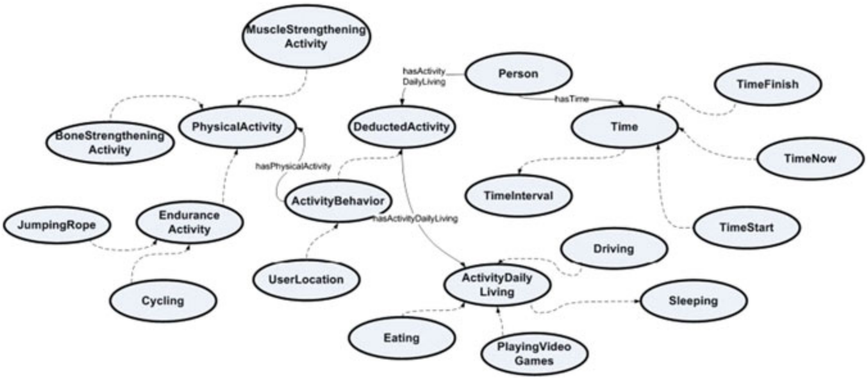


Fig. 2 Part of activity modeling using ontology-based approach

Devices class that document all wireless sensors that are used to gain context in system.

Context model is structured around a set of abstract entities as well as a set of abstract sub-classes, whereas each entity associated in its attributes and relationship that is represented in OWL as *DatatypeProperty* and *ObjectProperty* (Wang et al. 2004). According to Fig. 2, object properties that represent relationship between entities in class level can be seen more deeply in Table 1. Some sharing relationships that are occur enables system to provide extension of the new concepts in a specific domain in the future.

3.2 Ontology Reasoning

Ontology reasoning is mechanism that aimed to check consistency of context and deducing high level, implicit context from low-level, explicit context that can be processed with logical reasoning (Wang et al. 2004). To explain the role of context reasoning in activity modeling, activity daily living scenario is present to deduct user activity at home.

For the example, we'll present condition when the light in gym room is on, treadmill machine is also on, people location is at home and the position is running, then it can inferred that people is doing treadmill in gym at home. In order to get the result, ontology reasoning and user-defined resoning is conducted. According to the model, *UserLocation* class, *PhysicalActivity* Class, *Location* Class, and *WirelessNetworkDevices* Class are required to deduct high level activity related to user activity, while relationship between classes are linked using *"hasDailyLivingActivity"*, *"hasPhysicalActivity"*, and *"isCapturedOf"* properties. *UserLocation* class also used to capture people location, with property *"isLocatedIn"* link *UserLocation*class to *LocationNow* class value.

Table 1 Part of object properties list used in activity modeling

Class level		
Domain	Object property	Range
DeducedActivity	HasDailyLivingActivity	ActivityDailyLiving
Person	HasDailyLivingActivity	ActivityDailyLiving
DeducedActivity	HasTime	Time
Person	HasTime	Time
DeducedActivity	IsCapturedOf	LowLevelNature
ActivityBehavior	HasPhysicalActivity	PhysicalActivity
Person	HasPhysicalActivity	PhysicalActivity
UserLocation	IsLocatedIn	LocationNow
Position	IsLocatedIn	LocationNow
NearbyServices	IsLocatedIn	LocationNow
EnvironmentServices	IsLocatedIn	Environment
IndoorCorridorServices	IsLocatedIn	IndoorCorridor
RoomServices	IsLocatedIn	Room
Position	IsLocatedIn	LocationNow
Person	IsLocatedIn	LocationNow
SensorManager	IsLocatedIn	LocationNow
Position	HasLocationBasedServices	NearbyServices
Person	HasLocationBasedServices	NearbyServices
LowLevelNature	HasLocationBasedServices	NearbyServices MobileSensors
EnvironmentServices	HasRawDataSignal	MobileSensors
IndoorCorridorServices	HasRawDataSignal	VideoCamera or Microphone
RoomServices	HasRawDataSignal	SmartBuildingSensors or VideoCamera or Microphone

Figure 3 present that *UserLocation* class also inherit property *"isCapturedOf"* from *Activity* class that means people activity is also captured by *LowLevelNature*class that get the raw data from several sensors depend on people position detected. *LowLevelNature* is a class that sense raw data signal from *WirelessNetworkDevices* class, which is linked by *"hasRawDataSignal_1"* property. This class also provides some service from *LocationBasedServices"* through*"hasLocationBasedServices"* property according to people position that is also sensed using property *"isLocatedIn"*.

Knowledge representation can be gained from OWL individual that act as Jess facts, where the rules that is determined become Jess rules (Fig. 4). Performing inference using rules from OWL knowledge base then will show the result about user activity recognition (Fig. 5).

Class and relationship rules determined then become knowledge of the context and also fact that has able to deduct using some rules we are determined. In order to accomplish the result, Jess system is used as one of rule engines that is work well with Java that is consists of a rule base, a fact base, and an execution engine to match fact base by reason OWL individual.

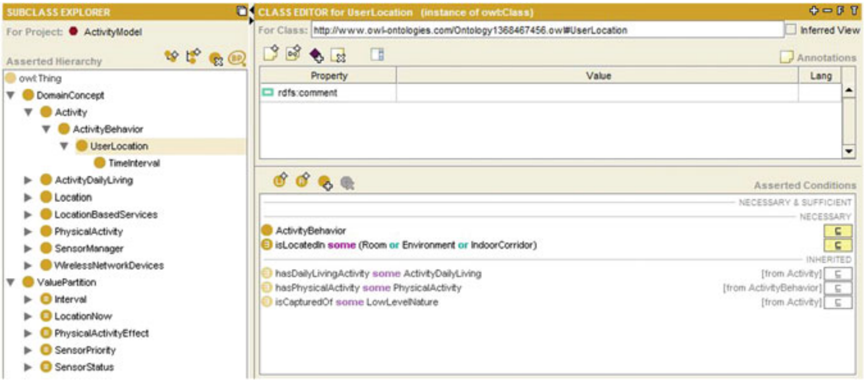


Fig. 3 *Userlocation* class using OWL reasoning rules

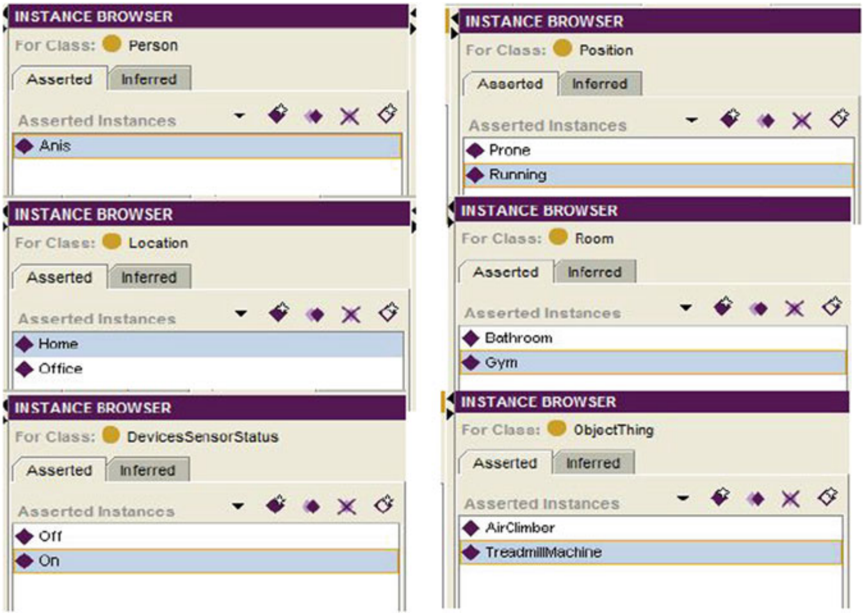


Fig. 4 User defined rules activity recognition

```
Jess> (defrule getActivity (object (is-a http://www.owl-ontologies.com/Ontology1368804236.owl#Location) (http://www.owl-ontologies.
com/Ontology1368804236.owl#LocationNow ?ln)) (object (is-a http://www.owl-ontologies.com/Ontology1368804236.owl#Position) (http:
//www.owl-ontologies.com/Ontology1368804236.owl#PositionP ?p)) (object (is-a http://www.owl-ontologies.com/Ontology1368804236.
owl#Room) (http://www.owl-ontologies.com/Ontology1368804236.owl#RoomName ?rn) (http://www.owl-ontologies.
com/Ontology1368804236.owl#RoomStatus ?rs)) (object (is-a http://www.owl-ontologies.com/Ontology1368804236.owl#ObjectThing)
(http://www.owl-ontologies.com/Ontology1368804236.owl#ObjectName ?on) (http://www.owl-ontologies.com/Ontology1368804236.
owl#ObjectStatus ?os)) (object (is-a http://www.owl-ontologies.com/Ontology1368804236.owl#Person) (http://www.owl-ontologies.
com/Ontology1368804236.owl#Name ?n) (http://www.owl-ontologies.com/Ontology1368804236.owl#UserLocationActivity ?la&: (= ?la ?
ln)) (http://www.owl-ontologies.com/Ontology1368804236.owl#UserPositionActivity ?up&: (= ?up ?p)) (http://www.owl-ontologies.
com/Ontology1368804236.owl#UserRoomActivity ?ra&: (= ?ra ?rn)) (http://www.owl-ontologies.com/Ontology1368804236.
owl#UserRoomActivityStatus ?ras&: (= ?ras ?rs)) (http://www.owl-ontologies.com/Ontology1368804236.owl#UserEquipmentName ?uen&:
(= ?uen ?on)) (http://www.owl-ontologies.com/Ontology1368804236.owl#UserEquipmentStatus ?ues&: (= ?ues ?os))) => (printout t ?n
"doing " ?p "in" ?rn "at" ?ln "using" ?on crlf))
TRUE
Jess> (run)
Anis Amna"doing"Running"in"PrivateGym"at"Home"using"Treadmill Machine
```

Fig. 5 Jess rule reasoning result

4 Conclusions

Our study in this paper showed that activity modeling that is developed using semantic-based approach can provide meaningful context to recognize human activity behavior in pervasive computing. Furthermore, after it's checked by using OWL and user defined reasoning as the feature of Protégé, context model is able to recognize human activity.

Acknowledgments This work is partially supported by Prof. Shuo-Yan Chou and Mr. Anindhita Dewabharata. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Bikakis A, Patkos T, Antoniou G, Plexousakis D (2008) A survey of semantics-based approaches for context reasoning in ambient intelligence. Commun Comput Inf Sci 11:14–23

Dey AK, Abowd GD (1999) Towards a better understanding of context and context-awareness. Comput Syst 40:304–307

Hong CS, Kim H-S, Cho J, Cho HK, Lee H-C (2007) Context modeling and reasoning approach in context-aware middleware for urc system. Int J Math Phys Eng Sci 1:208–221

Chen H, Perich F, Finin T, Joshi, A (2004) SOUPA: standard ontology for ubiquitous and pervasive applications. In: The First annual international conference on mobile and ubiquitous systems networking and services 2004 MOBIQUITOUS 2004

July O, Ay F (2007) Context Modeling and Reasoning using Ontologies. Network, pp 1–9

Kaptelinin V, Nardi BA (1996) Activity theory and human-computer interaction. Activity theory and human-computer interaction. MIT Press

Kuutti K (1996) Activity theory as a potential framework for human-computer interaction research. Context Conscious Act Theory Human–Comput Inter

Noy N, McGuinness D (2001) Ontology development 101: a guide to creating your first ontology. Development 32:1–25

Scott K, Benlamri R (2010) Context-aware services for smart learning spaces. IEEE Trans Learn Technol 3:214–227

Wang XH, Zhang DQ, Gu T, Pung HK (2004) Ontology based context modeling and reasoning using OWL. In: IEEE annual conference on pervasive computing and communications workshops 2004

Wongpatikaseree K, Ikeda M, Buranarach M, Supnithi T, Lim AO, Tan Y (2012) Activity Recognition Using context-aware infrastructure ontology in smart home domain. In: 2012 Seventh international conference on knowledge, information and creativity support systems. doi:10.1109/KICSS.2012.26

Xue W, Keng Pung H (2012) Context-Aware middleware for supporting mobile applications and services. In: Kumar A, Xie B (eds) Handbook of mobile systems applications and services. CRC Press, Boca Raton

An Integrated Systems Approach to Long-Term Energy Security Planning

Ying Wang and Kim Leng Poh

Abstract While heavy attempts have been made to evaluate energy systems, few can gain wide acceptance or be applied to various jurisdictions considering their lack of comprehensiveness and inability to handle uncertainties. This paper first proposes a MCDM approach using Fuzzy Analytic Hierarchy Process (FAHP) to assess security status in energy system. An Energy Security Index I_{ES} making comprehensive yet clear reference to the current scope of energy security is introduced as the indicator. Next, the paper proposes an integrated framework to develop long-term security improvement plan in energy system. The framework is constructed with a holistic planning cycle to evaluate energy security policies' effectiveness, project estimated I_{ES} with optimized energy portfolio, and verify the results generated. The framework is established with integrated analytical process incorporating FAHP, which better accommodates the complexities and uncertainties throughout planning. Meanwhile, the complete planning cycle enhances the tool validity. This framework would be useful in helping policy makers obtain a helicopter view of the security level of their energy system, and identify the general improvement direction. An application of the proposed framework to Singapore context shows "Reduce and Replace" strategy should be implemented and 77 % improvement in I_{ES} is expected by 2030 comparing to business-as-usual scenario.

Keywords Energy security policies · Integrated assessment · Analytical planning · Fuzzy logic · Portfolio optimization · Multi-criteria decision making

Y. Wang (✉) · K. L. Poh
Department of Industrial and Systems Engineering, National University of Singapore,
1 Engineering Drive 2, Singapore 117576, Singapore
e-mail: cynthia.wang.ying@gmail.com

K. L. Poh
e-mail: pohkimleng@nus.edu.sg

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_130,

1 Introduction

As instability continues to intensify in the Middle East after the Arab Spring, security of energy sources has become one of the main concerns internationally. However, regardless of the universally agreed significance of energy security and heavy attempts in energy security measurements, these measurements can hardly gain wide acceptance because of the large amount of related issues encompassed by energy security (Martchamadol and Kumar 2012). Single-aspect indicators can hardly provide all-round assessments while existing aggregated indicators usually have restricted application to specific countries or energy sources to address specific criteria. Additionally, while there exist separate studies to assess energy security policies, no synthetical measurements are conducted to evaluate the status and the policies as a whole. These studies miss the section to project and demonstrate the effectiveness of proposed policies, which undermines the persuasiveness.

This paper aims to fill the gap by proposing a general framework with a holistic evaluation and planning cycle which is able to assess and project the long-term energy security level of a jurisdiction based on the optimized fuel mix portfolio, evaluate varies energy strategies and testify their effectiveness. An illustration of the framework is provided by applying to the Singapore context.

2 A Fuzzy MCDM Model for Energy Security Evaluation

This section proposes an Energy Security Index (I_{ES}) to help policy makers assess and understand the nation's current energy security level. The index is formulated by evaluating fuel security levels using ratings approach to AHP incorporating with fuzzy logic and then taking a weighted average based on the nation's energy portfolio. This method is believed can comprehensively evaluate the security level and well accommodate the uncertainties in human subjective judgments.

2.1 Frame of AHP Model

Figure 1 shows the complete AHP hierarchy containing criteria and corresponding rating intensities for evaluating fuel security level and the score generated is defined as Fuel Security Index (Is). The proposed model separates the assessment criteria into two sub-sets, namely, physical availability and price component (International Energy Agency 2007). While physical availability is derived based on the "Five Ss" concept (Kleber 2009), the second sub-set targeting economic concern is classified into: Setup Cost, Fuel Cost, and Operation and Maintenance (O&M) Cost.

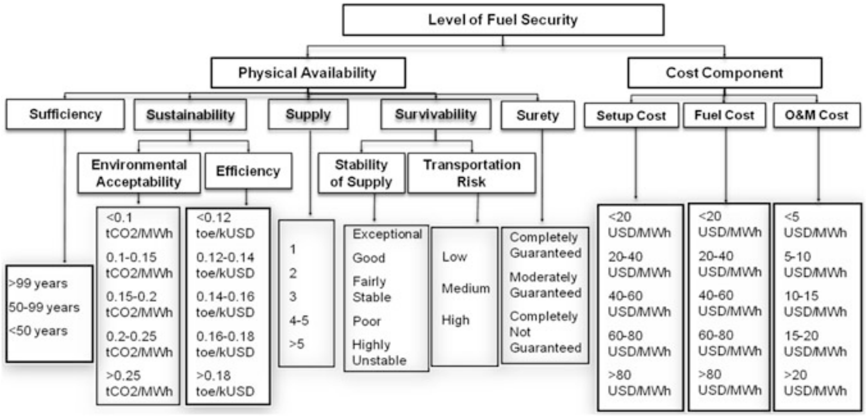


Fig. 1 Proposed AHP model for fuel security evaluation

2.2 *Fuzzy AHP*

Energy related decision making is a process filled with uncertainties due to the complex nature of energy security problem, including the multi-dimensional definition of the term, the contributing factors on national and international level, the fast changing energy situation around the globe, etc. Meanwhile, subjective human judgments weigh heavily in the decision making. These factors show the necessity for the model to handle ambiguity and uncertainty in subjective human assignment of quantitative weights. In this study, the incorporation of traditional AHP with fuzzy logic is proposed to be the solution. It ensures the model's capability to handle vague input so that holistic solution can be expected.

2.3 *Formulation of Energy Security Index*

After obtaining the Fuel Security Indexes (I_S) and electricity generation fuel mix for a specific nation, Energy security Index (I_{ES}) can be derived by using weighted average (Lim 2010) where higher value representing a higher level of energy security. The formulation is as follows:

$$I_{ES} = \sum\nolimits_{k=1}^{N} p_k I_s^k, \ (I_{ES} \in [0, 1]). \quad (1)$$

k Index of fuel sources, $\mathrm{k} = 1, 2, \ldots, \ \mathrm{N}$

p_k The share of fuel alternative k in the total energy consumption $\left(\sum_{k=1}^{N} p_k = 1\right)$

I_s^k Fuel Security Index for fuel alternative k $(I_{ES} \in [0, 1])$

2.4 Evaluation of Energy Security Level in Singapore

Right now Singapore generates electricity with three major types of sources: natural gas, petroleum products, and biofuel (Energy Market Authority 2012). Based on Singapore context, weights for the criteria and sub-criteria are determined by performing pairwise comparisons with the triangular fuzzy number between each criterion with respect to the goal and between each sub-criterion with respect to the upstream criteria. Assuming a 0.5 confidence level, I_S is derived and Energy Security Index (I_{ES}) based on the current fuel mix in Singapore is formulated. The results are listed in Table 1.

According to the proposed measurement index, with a range of 0–1, the score of current energy security level is 0.355. The current energy security level highly relies on the security level of natural gas, since it counts for almost 79 % of the total consumption. The relative insecurity of natural gas implies there is great potential to improve Singapore's current energy security level.

3 Fuzzy Analytical Planning Approach to Energy Security Policy Decision Making and Energy Portfolio Planning

3.1 Forward–Backward Planning

The conventional AHP model deals with static situation only. However, evaluation of energy security level is a stochastic problem considering the continuous change in fuel mix and fuel properties of a nation. The gap in-between drives the requirement of an advanced method to better handle the complexity and uncertainty. This study uses forward and backward planning developed by Saaty and Kearns (Saaty 1980) to tackle the problem.

3.2 Outline of Proposed Framework

In this section, a framework with holistic evaluation and planning cycle is proposed to ensure the validity of the tool. The tool uses forward–backward planning

Table 1 Summary of model results

Alternative	Fuel security index (I_s^k)	The share of fuel alternative k (p_k) (%)
Petroleum products	0.2185	18.70
Natural gas	0.3720	78.70
Biofuel plant	0.8109	2.60
Energy security index (I_{ES}) 0.355		

incorporating fuzzy AHP in order to better accommodate complexities and uncertainties. The AHP method can help decompose a problem into sub-problems, which results in the methodology summarized in Fig. 2. In the next section, a step-by-step illustration of the proposed methodology is provided with an application in Singapore's context.

4 Application to Energy Security Improvement Strategy Formulation in Singapore

4.1 First Forward Process

The first forward process projects the most likely level of energy security. This scenario is formulated with current electricity generation fuel mix and energy strategy unchanged, say, the business-as-usual (BAU) scenario. It uses the Energy Security Index (I_{ES}) proposed in Sect. 3 as the indicator. The value is calculated to be 0.355 which indicates great improvement potential of BAU scenario. We therefore proceed to the next phase and detect possible solutions.

4.2 First Backward Process

The backward planning discovers the most effective energy security improvement strategy in the Singapore context. The proposed solutions for energy security improvement, according to Larry Hughes's research, can be categorized into three strategies (2009):

Reduce: This study solely considers reducing energy demand via energy efficiency since reduction in service level or sacrifice citizens' living standard is not desired in Singapore.

Replace: Replacing the insecure fuel sources with more secure ones can be realized by diversifying suppliers for current fuel sources, or reconstructing the infrastructures and plant to switch to a secure alternative.

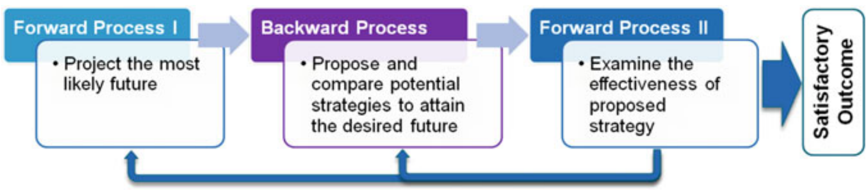


Fig. 2 Summary of proposed framework outline

Restrict: Maintenance of existing infrastructure and fuel sources, but limiting the additional demand to be generated with secure sources only.

Since energy efficiency projects are profitable, considering the limited budget available, two alternative strategies are proposed to Singapore government to select from: *Reduce and Replace*, or *Reduce and Restrict*.

On the other hand, although there exists great potential to improve energy security in Singapore as identified in the first forward analysis, Singapore has limited access to alternative fuel sources due to its small and restricted landscape. As such, the possible alternative fuel sources can be taken into account limit to: Liquefied Natural Gas (LNG), Coal Plant with Carbon Capture & Storage (CCS), and Solar Power. Implementing the fuzzy AHP model used in Sect. 3, the corresponding Fuel Security Index (I_S) is derived in Table 2. The model shows biofuel and solar power are the most secure source, while LNG and coal plant with CCS can perform better comparing to petroleum products and natural gas.

In addition, a trade-off analysis with respect to physical availability and price component is conducted to further compare among the fuel alternatives. Two efficiency frontiers are plotted for fossil fuel and renewable source respectively. According to Fig. 3, petroleum products is generally dominated and thus considered an inferior source. This implies the source is expected to be replaced once “Reduce & Replace” strategy is carried out. Otherwise, if “Reduce & Restrict” strategy is put into application, petroleum products is impossible to be the solution for new demand. Therefore, the two potential energy strategies for Singapore are defined. The first backward analysis hierarchy is structured in Fig. 4 and the outcome is listed in Table 3.

With a slightly higher score, Reduce and Replace should be preferred in the Singapore context. This may due to its larger potential to improve from the current situation. We therefore proceed to the second forward planning to examine the finding.

4.3 Second Forward Process

The second forward process aims to verify if the strategy selected previously is the most effective. The verification is conducted by comparing the updated I_{ES} when aforementioned energy strategies are implemented correspondingly.

4.3.1 Reduce and Restrict

If “Reduce and Restrict” strategy is carried out, the new energy demand beyond the current consumption level is assumed to be covered by the secure sources

Table 2 Summary of model results

Alternative	LNG	Coal plant with CCS	Solar power
Energy security index (I_{ES})	0.5149	0.4874	0.8882

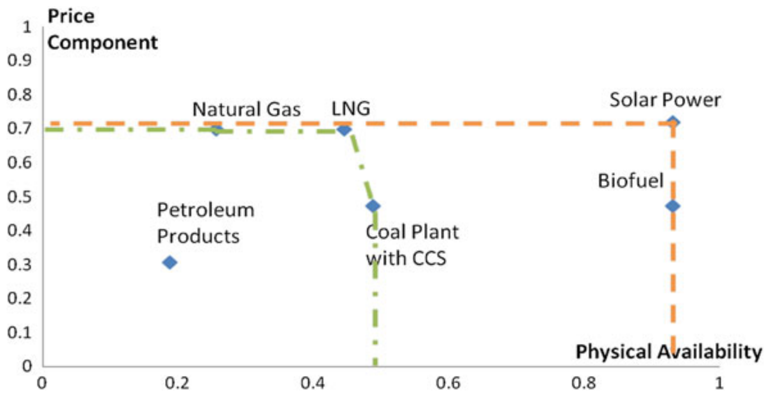


Fig. 3 Trade-off analysis of possible fuel alternatives

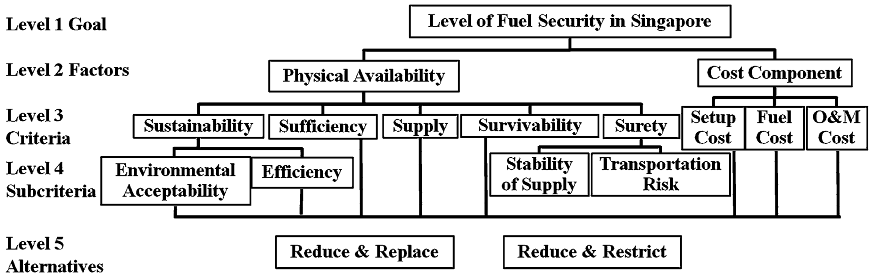


Fig. 4 Hierarchical structure of energy strategy assessment

Table 3 Summary of model results

Alternative	Reduce and replace	Reduce and restrict
Score	**0.780**	0.705

biofuel and solar power. The future energy consumption trend is captured with an uni-variant regression model of GDP versus energy consumption. Making a 20-year projection, the energy consumption level in 2030 is estimated at roughly 1.6 times the consumption level in 2010. This indicates newly constructed biofuel plant and solar power plant should cover additional 60 % of the current consumption. The optimal portfolio of the fuel mix can be determined using the linear programming.

Ideally, the optimal I_{ES} can be achieved when all new demand is covered by solar power, the fuel alternative with the highest Fuel Security Index. The model shows by 2030 Singapore's I_{ES} will experience 55 % improvement and reach the level up to 0.5498.

4.3.2 Reduce and Replace

In this scenario, a similar model is created to measure I_{ES}. To ensure a fair comparison, equivalent cost should be assumed for the two scenarios. In addition, considering the limited access to renewable energy due the geographical restrictions of Singapore, the share of renewable energy is assumed to be capped at 40 % so that to make the model more realistic. The optimal portfolio of the fuel mix can be determined using the linear programming.

Ideally, the optimal I_{ES} can be achieved when 40 % of total demand is covered by solar power, the fuel alternative with the highest I_S, while the rest 60 % of the demand is mainly supplied by LNG, the most secure fossil fuel alternative. The implementation of "Reduce & Replace" policy can help improve Singapore's I_{ES} by 77 % and reach the level up to 0.6281 by 2030.

As a result, the convergent outcome of the first backward process and second forward process validates the effectiveness and advantage of "Reduce & Replace" strategy. Therefore the forward–backward planning is completed and the best strategy is determined.

5 Conclusion

In this paper, an energy security index I_{ES} is developed with comprehensive and clear reference to the current scope of energy security. In the next phase, an integrated framework with a holistic planning cycle is proposed to evaluate the effectiveness of policies, project the estimated I_{ES}, and verify the results with optimized long-term energy portfolio. An application to the Singapore context shows that "Reduce & Replace" strategy should be implemented and 77 % improvement of I_{ES} is expected by 2030. The incorporation of fuzzy logic with AHP in the model takes into accounts the uncertainties and ambiguousness for policy makers' subjective judgment and ensures the tool's capability to handle them. Meanwhile, policy makers can better handle the complexity of the problem by adding more iteration to forward–backward planning if necessary. The proposed framework can be useful in helping policy makers to obtain a helicopter view of their nation's energy security level and identify long-term energy security planning.

Acknowledgments This work is partially supported by Department of Industrial and Systems Engineering, National University of Singapore. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Energy Market Authority (2012) Singapore energy statistics 2012. Singapore

Hughes L (2009) The four 'R's of energy security. Energy Policy 37:2459–2461

International Energy Agency (2007) Energy security and climate policy. Paris, France

Kleber D (2009) Valuing energy security. J Energy Secur. http://www.ensec.org/index.php?option=com_content&view=article&id=196:the-us-department-of-defense-valuing-energy-security&catid=96:content&Itemid=345. Accessed 12 Nov 2012

Lim WZ (2010) A multi-criteria decision analysis and portfolio optimization approach to national planning for long-term energy security. B. engineering dissertation, National University of Singapore

Martchamadol J, Kumar S (2012) An aggregated energy security performance indicator. Appl Energy 103:653–670

Saaty TL (1980) The analytic hierachy process. United States, New York

An EPQ with Shortage Backorders Model on Imperfect Production System Subject to Two Key Production Systems

Baju Bawono, The Jin Ai, Ririn Diar Astanti and Thomas Indarto Wibowo

Abstract This paper is an extension of the work of Lin and Gong (2011) on Economic Production Quantity (EPQ) model on an imperfect production system over infinite planning horizon, where the production system is dictated by two unreliable key production subsystems (KPS). While any shortage on the inventory of product was not allowed in the model of Lin and Gong (2011), planned shortage backorders is considered in the model proposed in this paper. The mathematical model is developed in order to determine production run time (τ) and production time when backorder is replenished (T_1) that minimizes the expected total cost per unit time including setup, inventory carrying, shortage, and defective costs. Approaches to solve the model are also being proposed in this paper, altogether with some numerical examples.

Keywords Economic production quantity model · Shortage backorders · Imperfect production system · Optimization technique · Approximation method

B. Bawono (✉) · T. J. Ai · R. D. Astanti · T. I. Wibowo
Department of Industrial Engineering, Universitas Atma Jaya Yogyakarta, Jl. Babarsari 43, Yogyakarta 55281, Indonesia
e-mail: baju@mail.uajy.ac.id

T. J. Ai
e-mail: jinai@mail.uajy.ac.id

R. D. Astanti
e-mail: ririn@mail.uajy.ac.id

T. I. Wibowo
e-mail: t8_t10@yahoo.co.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_131,

1 Introduction

Productivity is generally defined as the ratio between output and input. The input can be man, material, machine, money, and method. In manufacturing industry, where the output is tangible product, the productivity can be measured by how many or how much the output resulted. Productivity might be affected by one of the input mentioned above, such as machine. Machine is one element of the production subsystem. The machine is reliable if it can perform as good as the standard. However, in reality there is a condition where, the machine does not perform well or it is called imperfect condition. This condition might happen due to, for example, machine breakdown. As illustration, boiler breakdown in a Crude Palm Oil (CPO) industry will increase the concentration of ALB in the oil so that it will decrease the quality of CPO (Sulistyo et al. 2012). Therefore, the output of the CPO is also decreased. In other word, the productivity of the industry is decreased.

The economic production quantity (EPQ) model developed by many researchers in the past, such as Silver et al. (1998) under the assumption the production subsystem is perfect (no breakdown). However, this ideal condition is rarely happened in the real situation. If this model is applied in the real situation where the production subsystem is imperfect, then, the target production is never be reached. The EPQ model considering imperfect production subsystem have been proposed by some researchers, such as Rosenblatt and Lee (1986). They assumed that in the production system there may exist an imperfect condition where the in-control state changed to out-control state where the random time to change is assumed following exponential distribution. As the result, the system might produce defective product. Following this work, some models dealt with various additional system setting had been proposed, such as (Lee and Rosenblatt 1987, 1988, 1989; Lee and Park 1991; Lin et al. 1991; Ben-Daya and Hariga 2000; Hsieh and Lee 2005). In those previous models, the imperfectness of production system is assumed to be dictated by single key production subsystem (KPS) only. Lin and Gong (2011) recently extended the study by proposing an EPQ model where the production system is imperfect and dictated by two imperfect KPS's over an infinite planning horizon. Ai et al. (2012) continued this work by considering finite planning horizon.

While those above mentioned researches discussed on EPQ model without shortage, the research conducted by Chung and Hou (2003) extended the work of Rosenblatt and Lee (1986) by incorporating the shortage into their model. Shortage itself can be defined as the situation when the customer order arrive but the finished good are not yet available. When all customer during the stockout period are willing to wait until the finished goods are replenished then it is called as completely backorder case. Shortage is common in practical situation, when the producer is realized that its customers loyal to their product.

This paper is extending the work of Chung and Hou (2003) and Lin and Gong (2011) by combining both works into a new EPQ model that consider 2 (two) imperfect KPS and shortage. The organization of this paper is as follow: Sect. 2

describes the mathematical model development, Sect. 3 discusses the solution methodology of the proposed method, Sect. 4 presents the numerical example, followed by some concluding remarks in Sect. 5.

2 Mathematical Model

This paper considers a production lot sizing problem where a product is to be manufactured in batches on an imperfect production system over an infinite planning horizon, in which shortage of product is allowed at the end of each production cycle and all shortage is backordered. The demand rate is d, and the production rate is p. As defined in Lin and Gong (2011) and Ai et al. (2012), the imperfectness of the system is shown on two imperfect key production subsystems (KPS) that may shift from an in-control to an out-of-control state due to three independent sources of shocks: source 1's shock causes first KPS to shift, source 2's shock causes second KPS to shift, and source 3's shock causes both KPS to shift. Each shocks occur at random time U_1, U_2, and U_{12} that follows exponential distribution with mean $1/\lambda_1$, $1/\lambda_2$, and $1/\lambda_{12}$, respectively. When at least one KPS on out-of-control state, consequently, the production system will produced some defective items with fixed but different rates: α percentage when first KPS out-of-control, β percentage when the second KPS out-of-control, and δ percentage when the both KPS out-of-control. The cost incurred by producing defective items when the first KPS is shifted, the second KPS is shifted, and both KPS are shifted are π_1, π_2, and π_{12}, respectively.

The production cycle of this situation can be described as Fig. 1, in which the inventory level is increased during the production uptime (τ) at rate ($p - d$) and decreased at rate $-d$ during the production downtime. It is shown in Fig. 1, the production cycle length T can be divided into four sections, each of them with length T_1, T_2, T_3, and T_4, respectively. The backorders are replenished in Sect. 1, in which the inventory level is increased from $-B_{max}$ to 0. The inventories are accumulated during Sect. 2, in which inventory level at the end of this section is $I_{\max}$. After that, the inventory level is decreased to 0 during Sect. 3 and the shortage happened in Sect. 4.

The optimization problem is to determining optimal production run time τ and production time when backorder is replenished T_1, that minimizes the expected total cost per unit time including setup, inventory carrying, shortage and defective costs.

In single production cycle, although shortages are exist, the number of product being produced ($p.\tau$) is equal to the demand of product ($d.T$) in that cycle. Therefore $T = p\tau/d$. If the setup cost is denoted as A, based on (1), the setup cost per unit time (C_1) can be defined as

$$C_1 = \frac{A}{T} = \frac{Ad}{p\tau} \tag{1}$$

The average inventory per production cycle as function of τ and T_1 can be expressed as

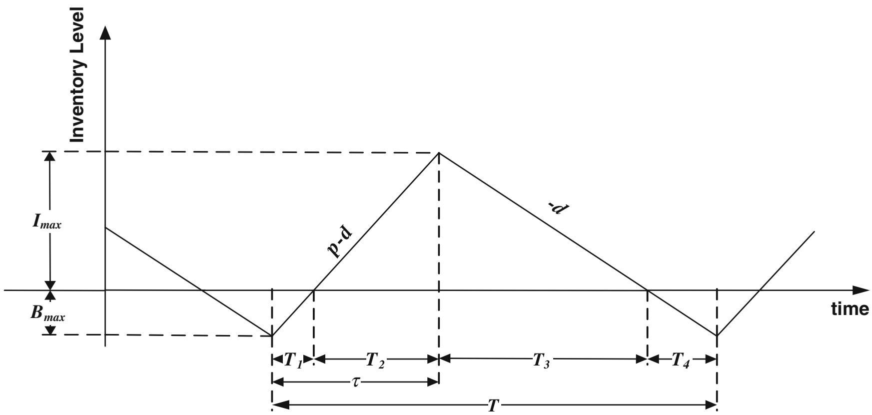


Fig. 1 Production cycle

$$\bar{I}(T_1, \tau) = \frac{(p-d)\tau}{2} - (p-d)T_1 + \frac{(p-d)T_1^2}{2\tau} \tag{2}$$

Therefore, if unit inventory holding cost per unit time is defined as h, the inventory carrying cost per unit time (C_2) can be defined as

$$C_2 = \frac{h(p-d)\tau}{2} - h(p-d)T_1 + \frac{h(p-d)T_1^2}{2\tau} \tag{3}$$

The average shortage per production cycle as function of τ and T_1 can be expressed as

$$\overline{B}(T_1, \tau) = \frac{(p-d)T_1^2}{2\tau} \tag{4}$$

Therefore, if unit shortage cost per unit time is defined as s, the shortage cost per unit time (C_3) can be defined as

$$C_3 = \frac{s(p-d)T_1^2}{2\tau} \tag{5}$$

The results from Lin and Gong (2011) are presented below to obtain the defective cost per unit time (C_4), in which the unit defective cost when the first KPS is shifted, the second KPS is shifted, and both KPS are shifted is defined as π_1, π_2, and π_{12}, respectively.

$$C_4 = \frac{d(\pi_1 E[N_1(\tau)] + \pi_2 E[N_2(\tau)] + \pi_{12} E[N_{12}(\tau)])}{p\tau} \tag{6}$$

$$E[N_1(\tau)] = p\alpha\left(\frac{1-\exp[-(\lambda_2+\lambda_{12})\tau]}{\lambda_2+\lambda_{12}} - \frac{1-\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau]}{\lambda_1+\lambda_2+\lambda_{12}}\right) \tag{7}$$

$$E[N_2(\tau)] = p\beta\left(\frac{1-\exp[-(\lambda_1+\lambda_{12})\tau]}{\lambda_1+\lambda_{12}} - \frac{1-\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau]}{\lambda_1+\lambda_2+\lambda_{12}}\right) \quad (8)$$

$$\begin{aligned} E[N_{12}(\tau)] = p\delta\Bigg(& \frac{\exp[-(\lambda_1+\lambda_{12})\tau]+(\lambda_1+\lambda_{12})\tau-1}{\lambda_1+\lambda_{12}} \\ & + \frac{\exp[-(\lambda_2+\lambda_{12})\tau]+(\lambda_2+\lambda_{12})\tau-1}{\lambda_2+\lambda_{12}} \\ & - \frac{\exp[-(\lambda_1+\lambda_2+\lambda_{12})\tau]+(\lambda_1+\lambda_2+\lambda_{12})\tau-1}{\lambda_1+\lambda_2+\lambda_{12}}\Bigg) \end{aligned} \quad (9)$$

Therefore, the expected total cost per unit time can be stated as

$$Z[\tau, T_1] = C_1 + C_2 + C_3 + C_4$$

$$\begin{aligned} Z[\tau, T_1] = & \frac{Ad}{p\tau} + \frac{h(p-d)\tau}{2} - h(p-d)T_1 + \frac{h(p-d)T_1^2}{2\tau} + \frac{s(p-d)T_1^2}{2\tau} \\ & + \frac{d(\pi_1 E[N_1(\tau)] + \pi_2 E[N_2(\tau)] + \pi_{12} E[N_{12}(\tau)])}{p\tau} \end{aligned} \quad (10)$$

3 Solution Methodology

Following Lin and Gong (2011), all exponential terms in the total cost expression can be approximate by MacLaurin series:

$$\exp(-\lambda\tau) \approx 1 - \lambda\tau + \frac{1}{2!}(\lambda\tau)^2 - \frac{1}{3!}(\lambda\tau)^3 \quad (11)$$

Therefore the total cost expression can be rewritten as

$$Z[\tau, T_1] \approx \frac{Ad}{p\tau} + h(p-d)\left[\frac{\tau}{2} - T_1\right] + \frac{(h+s)(p-d)T_1^2}{2\tau} + \frac{H\tau}{2} - \frac{K\tau^2}{6} \quad (12)$$

$$H = d(\pi_1\alpha\lambda_1 + \pi_2\beta\lambda_2 + \pi_{12}\delta\lambda_{12}) \quad (13)$$

$$K = d[\pi_1\alpha\lambda_1(\lambda_1 + 2\lambda_2 + 2\lambda_{12}) + \pi_2\beta\lambda_2(2\lambda_1 + \lambda_2 + 2\lambda_{12}) + \pi_{12}\delta(\lambda_{12}^2 - 2\lambda_1\lambda_2)] \quad (14)$$

It is well known from calculus optimization that the necessary condition for minimizing $Z[\tau, T_1]$ are the first partial derivatives equal to zero. Applying this condition for Eq. (12), it is found that

$$\frac{\partial}{\partial\tau} Z[\tau, T_1] = \frac{H}{2} + \frac{h(p-d)}{2} - \frac{K\tau}{3} - \frac{Ad}{p\tau^2} - \frac{(h+s)(p-d)T_1^2}{2\tau^2} = 0 \quad (15)$$

$$\frac{\partial}{\partial T_1} Z[\tau, T_1] = -h(p-d) + \frac{(h+s)(p-d)T_1}{\tau} = 0 \tag{16}$$

Solving Eq. (16) for T_1, it is found that

$$T_1^* = \frac{h}{(h+s)} \tau^* \tag{17}$$

Substituting Eq. (17) to Eq. (15), it is obtained that

$$\frac{H}{2} + \frac{hs(p-d)}{2(h+s)} - \frac{K\tau}{3} - \frac{Ad}{p\tau^2} = 0 \tag{18}$$

If the term $K\tau/3$ is neglected or approximated as zero, it found after some algebra that

$$\tau^* = \sqrt{\frac{2Ad}{p\left[H + hs\left(\frac{p-d}{h+s}\right)\right]}} = \sqrt{\frac{2Ad}{p\left[d(\pi_1\alpha\lambda_1 + \pi_2\beta\lambda_2 + \pi_{12}\delta\lambda_{12}) + hs\left(\frac{p-d}{h+s}\right)\right]}} \tag{19}$$

The sufficient condition of this result can be easily proven, since the Hessian matrix is positive definite.

4 Numerical Examples

To illustrate the proposed model and solution methodology, the numerical example is conducted on 8 (eight) sample problems as it is shown in Table 1.

Table 1 Parameters and solutions of sample problems

Parameters	Prob 1	Prob 2	Prob 3	Prob 4	Prob 5	Prob 6	Prob 7	Prob 8
d	200	200	200	200	200	200	200	200
p	300	300	300	300	300	300	300	300
α	0.1	0.1	0.3	0.3	0.1	0.1	0.3	0.3
β	0.1	0.1	0.3	0.3	0.1	0.1	0.3	0.3
δ	0.16	0.16	0.48	0.48	0.16	0.16	0.48	0.48
λ_1	0.05	0.05	0.05	0.05	0.15	0.15	0.15	0.15
λ_2	0.1	0.1	0.1	0.1	0.3	0.3	0.3	0.3
λ_{12}	0.02	0.02	0.02	0.02	0.06	0.06	0.06	0.06
π_1	10	10	10	10	10	10	10	10
π_2	10	10	10	10	10	10	10	10
π_{12}	12	12	12	12	12	12	12	12
A	100	100	100	100	100	100	100	100
h	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
s	0.16	0.24	0.16	0.24	0.16	0.24	0.16	0.24
Solutions								
τ^*	1.761	1.747	1.061	1.058	1.061	1.058	0.622	0.622
T_1^*	0.587	0.437	0.354	0.265	0.354	0.265	0.207	0.155
$Z[\tau^*, T_1^*]$	75.73	76.32	125.6	126	125.6	126	214.3	214.5

5 Concluding Remarks

This paper extend the work of Chung and Hou (2003) and Lin and Gong (2011) by incorporating 2(two) imperfect KPS considering shortage on EPQ model. Based on the numerical example it can be shown that the proposed model and its solution methodology works on 8 (eight) sample problems. Further work will be conducted to find another solution methodology approaches and to do the sensitivity analysis on the proposed model. In addition, formulating an EPQ model with 2(two) imperfect KPS considering shortage can be further investigated for finite planning horizon.

Acknowledgments This work is partially supported by Directorate General of Higher Education, Ministry of Education and Culture, Republic of Indonesia through *Hibah Bersaing* Research Grant and Universitas Atma Jaya Yogyakarta, Indonesia. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Ai TJ, Wigati SS, Gong DC (2012) An economic production quantity model on an imperfect production system over finite planning horizon. In: Proceedings of IIE Asian conference 2012, Singapore

Ben-Daya M, Hariga M (2000) Economic lot scheduling problem with imperfect production processes. J Oper Res Soc 51:875–881

Chung KJ, Hou KL (2003) An optimal production run time with imperfect production processes and allowable shortages. Comput Oper Res 30:483–490

Hsieh CC, Lee ZZ (2005) Joint determination of production run length and number of standbys in a deteriorating production process. Eur J Oper Res 162:359–371

Lee HL, Rosenblatt MJ (1987) Simultaneous determination of production cycle and inspection schedules in a production system. Manage Sci 33:1125–1136

Lee HL, Rosenblatt MJ (1989) A production and maintenance planning model with restoration cost dependent on detection delay. IIE Trans 21:368–375

Lee HL, Rosenblatt MJ (1988) Economic design and control of monitoring mechanisms in automated production systems. IIE Trans 20:201–209

Lee JS, Park KS (1991) Joint determination of production cycle and inspection intervals in a deteriorating production system. J Oper Res Soc 42:775–783

Lin GC, Gong DC (2011) On an Economic lot sizing model subject to two imperfect key production subsystems. In: Proceedings of IIE Asian conference 2011, Shanghai, China

Lin TM, Tseng ST, Liou MJ (1991) Optimal inspection schedule in the imperfect production system under general shift distribution. J Chin Inst Ind Eng 8:73–81

Rosenblatt MJ, Lee HL (1986) Economic production cycles with imperfect production processes. IIE Trans 18:48–55

Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling, 3rd edn. Wiley, New York

Sulistyo ARL, Astanti RD, Dewa DMRT (2012) Rancangan Preventive Maintenance dengan Pendekatan TPM di PT Perkebunan Nusantara VII. Unpublished thesis at Universitas Atma Jaya Yogyakarta

Reducing Medication Dispensing Process Time in a Multi-Hospital Health System

Jun-Ing Ker, Yichuan Wang and Cappi W. Ker

Abstract The process of prescribing, ordering, transcribing, and dispensing medications is a complex process and should efficiently service the high volume of daily physician orders in hospitals. As demand for prescriptions continues to grow, the primary issue confronting the pharmacists is overloading in dispensing the medication and tackling the mistakes caused by misinterpretation of the prescriptions. In this paper, we compared two prescribing technologies, namely no carbon required (NCR) and digital scanning technologies to quantify the advantages of the medication ordering, transcribing, and dispensing process in a multi-hospital health system. NCR technology uses a four parts physician order form with no carbon required copies, and digital scanning technology uses a single part physician order form. Results indicated a reduction of 54.5 % in queue time, 32.4 % in order entry time, 76.9 % in outgoing delay time, and 67.7 % in outgoing transit time in digital scanning technology. Also, we present the cost analysis to justify the acquisition of the Medication Order Management System (MOMS) to implement digital scanning technology.

Keywords Prescription order handling · Medication dispensing process · Medication order management · Medical errors reduction

J.-I. Ker (✉)
Industrial Engineering, Louisiana Tech University, Ruston, LA 71272, USA
e-mail: Ker@latech.edu

Y. Wang
Department of Aviation and Supply Chain Management, Auburn University,
Auburn, AL 36830, USA
e-mail: yzw0037@auburn.edu

C. W. Ker
Engineering and Technology Management, Louisiana Tech University,
Ruston, LA 71272, USA
e-mail: cwk005@latech.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_132,

1 Introduction

The process of prescribing, ordering, transcribing, and dispensing medications is a complex process and should efficiently service the high volume of daily physician orders in hospitals. According to the National Community Pharmacists Association (NCPA)'s report (NCPA 2012), the number of prescriptions being dispended in a pharmacy per day in the United States rose approximately 12 % (from 178 to 201) from 2006 to 2011. Additionally, the annual sales amount of prescription drugs being prescribed is 277.1 billion in 2012, and the projected figure will reach to 483.2 billion in 2021 (Keehan et al. 2012). As demand for prescriptions continues to grow, the primary issue confronting pharmacists is overloading in dispensing medications and tackling the mistakes caused by misinterpretation of the prescriptions (Jenkins and Eckel 2012). These mistakes can lead to medication related errors, which may endanger patient safety.

Another problem for pharmacists is the long delays in receiving medications, leading to doses being administered long after the standard administration times determined by the hospital pharmacy. The common causes of delays include prescribing error, poor drug distribution practices, drug and its device related problems, and illegible or unclear handwritten prescriptions (Cohen 2007). Interpreting the faint or illegible prescription is a major cause of delay in the transcribing process. Drugs with similar looking names can be incorrectly dispensed due to unclear handwriting. Currently, the adoption of emerging technology in hospitals reveals prominent effects on improving the existing operational process of medical service. This is particularly important for pharmacies. The use of information technologies (IT), such as computerized physician order entry system, has shown promise at not only reducing prescribing related errors (Ammenwerth et al. 2008; Jimenez Munoz et al. 2011; Samliyan et al. 2008; Shawahna et al. 2011) but also decreasing dispensing delays (Chuang et al. 2012; Jenkins and Eckel 2012).

Based on previous studies, we found that the issue of reducing the medical errors through IT has been documented well. The study for improving the dispensing delays, however, still remains underspecified. To address this gap, the aim of this study was to assess the timelines of various processes (i.e., queue time, order entry time, outgoing delay time and outgoing transit time) involved in administering the medication by comparing the two prescribing technologies: no carbon required (NCR) and digital scanning technologies. Also, we present the cost analysis to justify the implementing MOMS that uses digital scanning technology.

2 Literature Review

2.1 From Drug Prescribing to Dispensing in Hospitals

The prescribing medication is the physician's most frequently used, efficacious, and most dangerous tool used, outside of surgical interventions. A prescription is a written, verbal or electronic order from a practitioner or designated agent to a pharmacist for particular medication. The prescribing process is an important component of workflow in every physician practice and hospital unit. Pharmacies in hospitals have been using different prescribing methods. The traditional approach to medication management such as handwritten prescription is inefficient and error-prone (Berwick and Winickoff 1996). Illegible or unclear prescriptions result in more than 150 million calls from pharmacists to physicians and nurses, asking for clarification, a time-consuming process that costs the healthcare system billions of dollars each year in wasted time (Institute for Safe Medication Practices 2000).

Having received the prescription by the pharmacists at the computer workstation, the pharmacist enters the prescription into the pharmacy information system, checks for any known contraindications, and dispenses the medication. Before drugs are dispensed, labels are printed and the drugs are packed with the labels in single unit packages. This process which is widely used in the hospitals in United States has become known as a unit dose drug distribution system (Benrimoj et al. 1995). This distribution system is based on a pharmacy coordination method of dispensing and controlling medication in healthcare settings (American Society of Hospital Pharmacists 1989). The advantages of this system include reduction in medication errors (Allan and Barker 1990), reduction in drug inventory costs and minimized drug wastages. However, as demand for mediations and prescriptions continue to be in explosive growth in recent years, this system cannot be satisfied for dealing with high volumes of prescription, thereby leading to dispensing delays.

2.2 Significance of IT Usage in Hospitals

In the past two decades, researchers have started to identify needed interventions and justify related unnecessary spending to enhance safety and quality of the prescribing process by employing various technologies (e.g., automation method, the use of digital label) (Kohn et al. 1999; Flynn et al. 2003). Since the study of Kohn et al. (1999) spurred interest in employing technologies to simplify the prescribing process, the adoption of the drug prescribing process has shifted from paper-based prescribing process to electronic prescribing process (Åstrand et al. 2009).

Current studies show that many IT tools or systems for prescribing and dispensing practices are available in the market and have the abilities to enhance the accuracy of drug dispensing practices and improve the efficiency of prescribing practices. For example, pharmacists at one US hospital used a computerized prescription order entry system to review all prescriptions, which alerted the prescriber and pharmacist to dosage errors and reduced misinterpretation of prescriptions (Jayawardena et al. 2007). Åstrand et al. (2009) surveyed 31,225 prescriptions by comparing the proportions of ePrescription and non-electronic prescriptions with the prescriber at the time of dispensing and found that the ePrescription method would enhance safety and quality for the patient, especially in improving efficiency and cost-effectiveness within the healthcare system.

3 Research Methodology

3.1 Hospital Selection

This study was conducted to examine the timelines of various processes involved in administering the medication process at two public hospitals in Louisiana. In 2012 Hospital A had approximately 450 licensed inpatient beds and 430,000 outpatient visits, and Hospital B had approximately 250 licensed inpatient beds and 141,000 outpatient visits. The pharmacies at both hospitals were chosen to be involved in this study, as both had different prescribing technologies. The pharmacy at Hospital A used NCR copies which were used for prescribing, and Hospital B used digital scanning technology.

3.2 Data Collection

Data was collected over a two week period from both hospital pharmacies to determine the time elapsed from when the orders were sent to the pharmacy from the nursing station to the time the medication was sent back to the nursing station from the pharmacy.

An investigator can achieve high levels of precision by increasing the sample size. Should there be constraints, because of budgetary limitations or a shortage of time, some proper sample size has to be determined. Equation (1) was used to calculate the required sample size "n" for estimating the mean. For this data, we set d to 2 s; σ was estimated to be 9.4 by the sample standard deviation; and the value of critical deviate with a 0.001 α error was 2.326. After calculating, the sample size needed to achieve this accuracy level was 107. Hence, a sample size of 110 was selected.

$$n = \frac{t_{2/\alpha}\sigma^2}{d^2} \tag{1}$$

where

d Desired precision (or maximum error)

$t_{\alpha/2}$ Critical deviate for specified reliability $1-\alpha$

σ Population standard deviation

3.3 Drug Distribution Systems Studies

The two methods of drug distribution were NCR technology and digital scanning technology in the selected pharmacy respectively. The detailed information for both methods is described in the next two sections.

3.3.1 No Carbon Required Technology

At Hospital A, the physician used NCR technology. The NCR technology is where medication orders are written on a "no carbon required" physician order form. The NCR copies have four parts altogether. The first part is the chart copy, on which the physician writes and puts on a patient's chart. The remaining three copies are the pharmacy copies on which the order is imprinted. Those copies are sent to the pharmacy through a "tubing system" by the unit secretary or nurse for the pharmacists to fill in the prescriptions.

3.3.2 Digital Scanning Technology

At Hospital B, the physician used digital scanning technology. Computerized digital scanning of original physician orders eliminates the distortion that is experienced with NCR copies. It allows the pharmacist at order entry to enlarge the image, turn the image, and change the contrast of the image, all which are used to improve readability. The important benefit of the digital scanning technology is that, it reduces turn-around time in receiving the order and it documents electronically the time is was scanned, and the time it was processed. Digital scanning technology provides an instant prioritizing of orders, placing STAT (a medical abbreviation for urgent or rush) orders at the top of the computer queue in red in order to alert the pharmacist.

3.4 Parameter Measured

To compare the two technologies, the following parameters were studied: (1) Queue time refers to the time spent when the prescription waits in the queue until it is attended or viewed by the pharmacist at the order entry station. In case of NCR technology the prescription after time stamped is placed in the queue. For digital

Table 1 The ANOVA results of each observed time

Methods		Queue time	Order entry time	Outgoing delay time	Outgoing transit time
NCR copies	Mean	654.70	224.76	38.23	129.43
(N = 110)	Variance	416,300.20	36,621.70	3877.66	6228.03
Digital scanning	Mean	297.81	151.95	8.83	41.77
(N = 110)	Variance	70,475.93	113,018	265.36	87.65
Percentage of time reduction		54.50 %	32.40 %	76.90 %	67.72 %
F value		28.78	3.90	22.95	133.82
P value		0.000***	0.049*	0.000***	0.000***

Note All tests are two-tailed. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

scanning technology, the prescription starts in the queue as soon as the prescription is scanned; (2) Order entry time refers to the time spent when the pharmacist at the order entry station starts and ends entering the prescription into the pharmacy information system. In NCR technology, this time starts when the pharmacist picks the prescription and ends after entering the prescription. For digital scanning technology, the timing starts as soon as the prescription image is viewed on the screen and ends when order entry is completed; (3) Outgoing delay time refers to the time spent when the tube enters the system but before it is sent from the pharmacy to the nursing station; (4) Oncoming transit time measures the time a tube spent in traveling from the pharmacy to the nursing station.

4 Research Results

The statistical analysis results (See Table 1) show that the digital scanning technology outperformed the NCR technology in all measures. Results indicated a reduction of 54.5 % in queue time, 32.4 % in order entry time, 76.9 % in outgoing delay time, and 67.7 % in outgoing transit time in digital scanning technology. Additionally, the results of ANOVA found significant differences in times between the NCR technology and the digital scanning technology for the prescription.

The comparison of cost analysis between NCR technology and digital scanning technology was conducted at Hospital A for a five-year period. We selected four high cost items that includes pharmacist time spent, prescription papers, the introducing cost of MOMS that utilizes the digital scanning technology, and paper shredding costs. The pharmacist time spent, denoted as T, includes time a pharmacist spent in (1) handling the tube and (2) filling, labeling, and stamping the prescription orders. Equation (2) shows the calculation of T (in hours).

$$\mathrm{T} = [AX + (B + C)Y)]/3,600 \tag{2}$$

Table 2 The comparison of cost analysis between two technologies (five-year period)

	NCR copies	MOMS (digital scanning technologies)
Pharmacist cost	US$589,027.93 (US$54.09* 5.967 h * 365 days * 5 years)	US$0.00 (no tube to handle and all orders are scanned)
Prescription paper cost	Inpatient: US$1,800,000.00 (US$1.00/sheet*30,000 sheets/month * 60 months)	Inpatient: US$396,000.00 (US$0.22/sheet*30,000 sheets/month * 60 months)
	Outpatient: US$541,200.00 (US$0.22/sheet*41,000 sheets/month * 60 months)	Outpatient: US$541,200.00 (US$0.22/sheet*41,000 sheets/month * 60 months)
MOMS cost	US$0.00 (No new server and stations)	US$54,480.00 (for 2 servers) US$104,040.00 (for 7 stations)
Shredding cost	US$6,334.20 (US$0.102/lb*1035 lb/month*60 months)	US$0 (No prescription sheets to shred)
Total cost	US$2,936,562.13	US$1,095,720.00
Monthly cost	US$48,942.70	US$18,262.00

where
X Average number of incoming tubes per day
Y Average number of order forms per day
A Time to handle tube (in seconds)
B Time to punch each order (in seconds)
C Time to fill each order (in seconds)

During the study period, it was found that X = 500, Y = 970, A = 10 s, B = 2 s, and C = 15 s. These standard time data came from analyzing the tube time spent plus filling time spent using occurrence sampling and the stopwatch methods. These results were determined after assuming 15 % allowances. Table 2 shows the cost analysis results. Note that the total inpatient-carbon prescription order handling time was 5 h and 58 min (5.967 h) for a pharmacist that cost $54.09 per hour at both hospitals.

5 Conclusion

This study shows the use of digital scanning technology in a multi-hospital health system reduces medication dispensing time during the drug distribution process. The cost analysis also justifies the implementation of MOMS. The time and cost savings can be viewed as an opportunity to reduce delays in delivering medications, reduction of missing doses and improving service to the patients.

References

Allan EL, Barker KN (1990) Fundamentals of medication error research. Am J Hosp Pharm 47:555–571

American Society of Hospital Pharmacists (1989) Statement on unit dose drug distribution. Am J Hosp Pharm 46:2346

Ammenwerth E, Schnell-Inderst P, Machan C, Siebert U (2008) The effect of electronic prescribing on medication errors and adverse drug events: a systematic review. J Am Med Inform Assoc 15:585–600

Åstrand B, Montelius E, Petersson G, Ekedahl A (2009) Assessment of ePrescription quality: an observational study at three mail-order pharmacies. BMC Med Inform Decis 9:8

Benrimoj SI, Thornton PD, Langford JH (1995) A review of drug distribution systems: part 1-current practice. Aust J Hosp Pharm 25:119–126

Berwick DM, Winickoff DE (1996) The truth about doctors' handwriting: a prospective study. British Med J 313:1657–1658

Chuang MH, Wang YF, Chen M, Cham TM (2012) Effectiveness of implementation of a new drug storage label and error-reducing process on the accuracy of drug dispensing. J Med Syst 36:1469–1474

Cohen MR (2007) Medication errors, 2nd edn. American Pharmacists Association, Washington

Flynn EA, Barker KN, Carnahan BJ (2003) National observational study of prescription dispensing accuracy and safety in 50 pharmacies. J Am Pharm Assoc 43:191–200

Institute for Safe Medication Practices (2000) A call to action: eliminate handwritten prescriptions within 3 years. http://www.ismp.org/newsletters/actecare/articles/whitepaper.asp. Accessed 12 May 2013

Jayawardena S, Eisdorfer J, Indulkar S, Pal SA et al (2007) Prescription errors and the impact of computerized prescription order entry system in a community-based hospital. Am J Ther 14:336–340

Jenkins A, Eckel SF (2012) Analyzing methods for improved management of workflow in an outpatient pharmacy setting. Am J Health-Syst Pharm 69:966–971

Jimenez Munoz AB, Muino Miguez A, Rodriguez Perez MP, Duran Garcia ME, Sanjurjo Saez M (2011) Comparison of medication error rates and clinical effects in three medication prescription-dispensation systems. Int J Health Care Qual Assur 24:238–248

Keehan SP, Cuckler GA, Sisko AM, Madison AJ et al (2012) National health expenditure projections: modest annual growth until coverage expands and economic growth accelerates. Health Aff 31:1600–1612

Kohn LT, Corrigan JM, Donaldson MS (eds) (1999) To err is human: building a safer health system. National Academy Press, Washington

National Community Pharmacists Association (NCPA) (2012) 2012 NCPA digest in-brief. NCPA, Virginia

Samliyan TA, Duval S, Du J, Kane RL (2008) Just what the doctor ordered. Review of the evidence of the impact of computerized physician order entry system on medication errors. Health Serv Res 43:32–53

Shawahna R, Rahman Nu, Ahmad M, Debray M, Yliperttula M, Decleves X (2011) Electronic prescribing reduces prescribing error in public hospitals. J Clin Nurs 20:3233–3245

A Pareto-Based Differential Evolution Algorithm for Multi-Objective Job Shop Scheduling Problems

Warisa Wisittipanich and Voratas Kachitvichyanukul

Abstract This paper presents a multi-objective differential evolution algorithm (MODE) and its application for solving multi-objective job shop scheduling problems. Five mutation strategies with different search behaviors proposed in the MODE are used to search for the Pareto front. The performances of the MODE are evaluated on a set of benchmark problems and the numerical experiments show that the MODE is a highly competitive approach which is capable of providing a set of diverse and high-quality non-dominated solutions compared to those obtained from existing algorithms.

Keywords Multi-objective · Differential evolution · Job shop scheduling problems · Evolutionary algorithm

1 Introduction

Multi-objective optimization (MO) toward Pareto-based methods has increasingly captured interests from both practitioners and researchers due to its reflection to most real-world problems containing multiple conflicting objectives. Compared to an aggregated weighted approach, Pareto-based approaches offer an advantage for decision makers to simultaneously find the trade-offs or non-dominated solutions on the Pareto front in a single run without prejudice. Evolutionary Algorithms

W. Wisittipanich (✉)
Industrial Engineering Dept, Chiang Mai University, 239 Huay Kaew Road,
Muang District, Chiang Mai 50200, Thailand
e-mail: warisa@eng.cmu.ac.th

V. Kachitvichyanukul
Industrial and Manufacturing Engineering Dept, Asian Institute of Technology,
P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
e-mail: voratas@ait.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_133,

(EAs) is the most commonly selected solution techniques to search for the Pareto front due to their high efficiency to find good solution quality within reasonable time.

Differential Evolution (DE) algorithm, proposed by Storn and Price in (1995), is one of the latest EAs which has been widely applied and shown its strengths in many application areas. Nevertheless, only few research works have attempted to apply DE to find solutions for MO problems. Abbass et al. (2001) presented a Pareto-frontier DE approach (PDE) where only non-dominated solutions are allowed to participate in generating new solutions. However, if only few non-dominated solutions are found in the beginning, the chances of discovering new better solutions may be limited, and the solutions may get trapped at local optima. Madavan (2002) introduced the combination of the newly generated population and the existing parent population which results in double population size. The non-dominated solutions are then selected from this combination to allow the global check among both parents and offspring solutions; however, the drawback is the requirement of additional computing time in the sorting procedure of the combined population.

Although Multi-objective job shop scheduling problem (MOJSP) has been subjected to many researchers, the numbers of research works on MOJSP are still limited. Lei and Wu (2006) developed a crowding measure-based multi-objective evolutionary algorithm (CMOEA) for JSP. The CMOEA uses crowding measure to adjust the external population and assign different fitness for individuals to simultaneously minimize makespan and the total tardiness of jobs. Ripon et al. (2006) presented a jumping genes genetic algorithm (JGGA) for MOJSP. The jumping operations in JGGA exploit scheduling solutions around the chromosomes whereas the general genetic operators globally explore solution from the population. The results showed that the JGGA is capable of searching a set of well diverse solutions near the Pareto-optimal front while the consistency and convergence of non-dominated solutions are well maintained. Chiang and Fu (2006) proposed a genetic algorithm with cyclic fitness assignment (CFGA) which effectively combines three existing fitness assignment mechanisms: MOGA, SPEA2 and NSGA-II to obtain better performance and avoid rapid loss of population diversity. Lei and Xiong (2007) presented an evolution algorithm for multi-objective stochastic JSP in which archive maintenance and fitness assignment were performed based on crowding distance. Lei (2008) designed a Pareto archive particle swarm optimization (PAPSO) by combining the selection of global best position with the crowding measure-based archive maintenance to minimize makespan and total tardiness of jobs. The PAPSO is capable of producing a number of high-quality Pareto optimal scheduling plans.

This paper is inspired by the efficiency of the MODE algorithm proposed in Wisittipanich and Kachitvichyanukul (2012) for solving many continuous optimization problems. In this paper, the MODE is extended to solve MOJSP. The performances of the MODE are evaluated on a set of benchmark JSP problems and compared with existing solution methods.

2 MODE Algorithm

2.1 MODE Framework

Similar to the classic DE algorithm, MODE starts with randomly generated initial population of size *N* of *D*-dimensional vectors and evaluate objective value of each solution vector. However, in MO problems, there is no single solution but rather a set of non-dominated solutions. Therefore, the selection based on only one single solution in the classic DE algorithm may not be applicable in MO environment. The MODE framework is illustrated in Fig. 1.

The MODE adopts the concept of Elitist structure in NSGA-II (Deb et al. 2002) to store a set of non-dominated solutions in an external archive, called Elite group. In MODE, as the search progress, instead of applying the sorting procedure to every single move of a vector, the sorting is only performed on the set of newly generated trial vectors after all vectors completed one move to identify the group

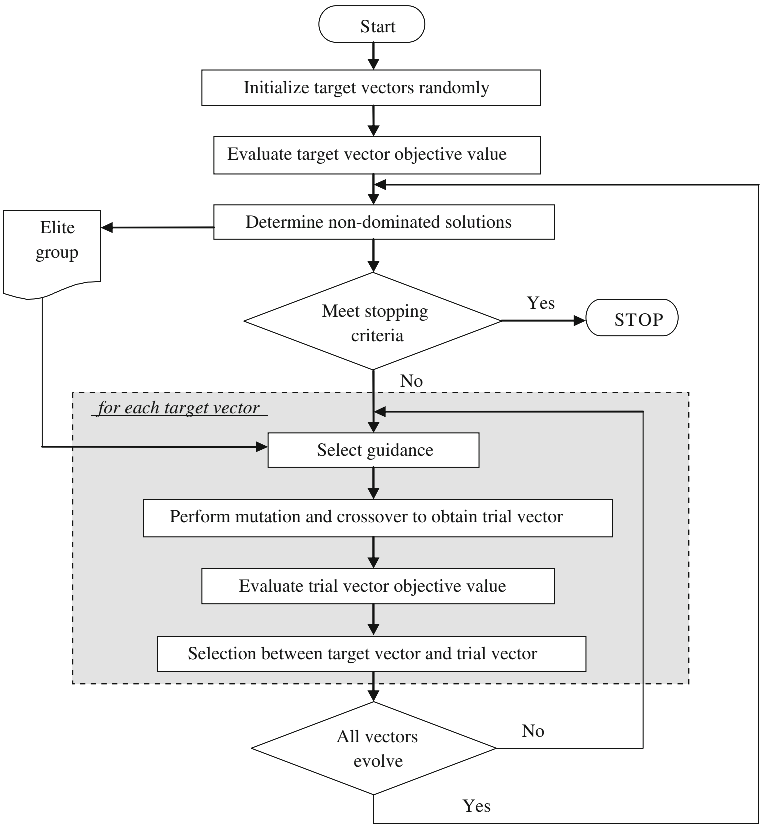


Fig. 1 MODE framework

of new non-dominated solutions. The reason is to reduce computational time. This sorting procedure applies to the group of new solutions and current solutions in the external archive and store only non-dominated solutions into an archive for the Elite group. Then, Elite group screens its solutions to eliminate inferior solutions. As a result, the Elite group in the archive contains only the best non-dominated solutions found so far in the searching process of the MODE population.

2.2 Mutation Strategies

One of the critical decisions in MO problems is the selection of candidates among the Elite group as guidance toward the Pareto frontier. In the MODE, five mutation strategies with distinct search behavior are proposed as the movement guidance of vectors in order to obtain the high quality Pareto front.

- MODE-ms1: Search around solutions located in the less crowded areas
- MODE-ms2: Pull the current front toward the true front
- MODE-ms3: Fill the gaps of non-dominated front
- MODE-ms4: Search toward the border of the non-dominated front
- MODE-ms5: Explore solution space with multiple groups of vectors

Mutation strategies MODE-Ms1 and MODE-Ms3 aim to improve the distribution of solutions on the front. Mutation strategy MODE-Ms2 intends to pull to the current front toward the true Pareto front, and mutation strategy MODE-Ms4 try to explore more solutions around the border to increase the spread of the non-dominated front. As mentioned, each mutation strategy exhibits different search behavior with its own strengths and weaknesses. Thus, mutation strategy MODE-Ms5 aims to extract the strengths of various DE mutation strategies and to compensate for the weaknesses of each individual strategy in order to enhance the overall performance by combining four groups of vectors with multiple mutation strategies in one population. For more details on each strategy, see Wisittipanich and Kachitvichyanukul (2012).

3 Multi-objective Job Shop Scheduling Problem

The classical JSP schedules a set of n jobs on m different machines subjected to the constraints that each job has a set of sequential operations and each operation must be processed on a specified machine with deterministic processing time known in advance. In this paper, the objective is to simultaneously minimize two objectives; makespan and total tardiness.

1. Makespan: makespan = max $[C_j]$ where C_j is the completion time of job j
2. Total tardiness of jobs: Total tardiness = $\sum_{j=1}^{n} \max\left[0, L_j\right]$ where L_j is the lateness of job j

In this study, solution mapping procedures presented in the paper work of Wisittipanich and Kachitvichyanukul (2010) is implemented. Random key representation encoding scheme (Bean 1994) and permutation of job-repetition (Bierwirth 1995) are adopted to generate the sequence of all operations. Then, the operation-based approach (Cheng et al. 1996) is used as decoding method to generate an active schedule. For more details on the encoding and decoding schemes, see Wisittipanich and Kachitvichyanukul (2010).

4 Computational Experiments

The performances of the MODE algorithm are evaluated using 9 benchmark problems taken from JSP OR-Library. To determine the total tardiness of a schedule, this study adopts the due date setting according to Lei and Wu (2006). The release date of all jobs is set to be 0.

In this study, the population size and number of iteration are set to 500 and 200 respectively. The scale factor value F is set to random value to retain population diversity. Crossover rate (C_r) is linearly increased from 0.1 to 0.5 to maintain the characteristic of generated trial vectors at the beginning of the search and yield more deviations for the generated trial vectors as the search progresses. The maximum members in Elite archive are set as 100. If the number of new non-dominated solutions found by the population exceeds the limit of this archive, the solutions with lower crowding distance will be removed.

4.1 Experimental Results

The performances of the MODE algorithm are compared to SPEA (Zitzler and Thiele 1999) and CMOEA (Lei and Wu 2006). Table 1 shows some of the best solutions obtained from the experiment. The notation (x, y) represents (makespan, total tardiness). It is noted that, for each instance, the non-dominated solutions are determined from 10 independent runs.

As shown in Table 1, SPEA, CMOEA, MODE-ms1, MODE-ms2, MODE-ms3, MODE-ms4, and MODE-ms5 perform well in generating a set of non-dominated solutions. The makespan values are just about 3–20 % bigger than the optimal makespan, and some makespan values are very close to the optimal results; while the total tardiness of these solutions are reasonable. In most cases, the minimum values of makespan and total tardiness of jobs found by MODE-ms1, MODE-ms-2, MODE-ms3, and MODE-ms5 are lower than those obtained from SPEA and

Table 1 Comparison results on benchmark problems

Instance	SPEA	CMOEA	MODE-ms1	MODE-ms2	MODE-ms3	MODE-ms4	MODE-ms5
ABZ5	(1306,439)	(1277,422)	(1249,367)	(1255,403.5)	(1238,408)	(1265,393)	(1251,529)
	(1316,486)	(1296,360)	(1254,362.5)	(1259,318)	(1264,434)	(1290,387)	(1256,467)
			(1266,273)	(1261,270)	(1270,398)	(1295,385)	(1258,297)
			(1275,234)	(1272,90)	(1274,393)	(1296,377)	(1261,295)
			(1281,232)	(1298,25)	(1275,355)	(1319,276)	(1269,229)
			(1282,164)	(1320,0)	(1276,348)	(1340,184)	(1280,228)
ABZ7	(790,487)	(786,350)	(718,583)	(732,712)	(739,991)	(749,1133)	(724,777)
	(783,396)	(789,465)	(722,499)	(734,630)	(740,845)	(761,1060)	(725,663)
	(794,354)	(792,353)	(723,461)	(736,609)	(748,751)	(766,1021)	(728,571)
			(724,400)	(738,597)	(753,719)	(774,890)	(730,541)
			(735,395)	(740,572)	(760,664)	(788,700)	(732,337)
ABZ8	(805,707.5)	(817,293)	(739,610.5)	(754,932)	(769,1011.5)	(790,1114.5)	(750,929.5)
	(808,624.5)	(819,552.5)	(743,495.5)	(760,905.5)	(771,981.5)	(798,929.5)	(751,600.5)
	(810,582.5)	(824,251)	(752,464.5)	(761,824.5)	(777,861.5)	(811,877.5)	(753.578.5)
			(778,452.5)	(762,759.5)	(778,833.5)	(821,859.5)	(758,521)
			(799,435)	(768,664.5)	(788,794.5)	(827,829.5)	(759,516.5)
ORB1	(1160,718)	(1160,858)	(1108,481.5)	(1132,648.5)	(1112,668)	(1187,832)	(1113,755.5)
	(1193,413)	(1161,393.5)	(1126,452.5)	(1148,384.5)	(1118,529)	(1197,791)	(1119,657)
	(1191,469)	(1188,381.5)	(1132,373.5)	(1151,204)	(1150,509)	(1198,743.5)	(1128,605.5)
			(1141,320)	(1183,190)	(1198,395)	(1203,722.5)	(1137,592)
			(1146,261.5)	(1252,170.5)	(1205,310.5)	(1243,674)	(1178,325.5)
ORB3	(1164,890)	(1167,367)	(1062,710)	(1102,844)	(1102,1176)	(1156,1181)	(1070,772)
	(1165,793)	(1173,364)	(1070,489)	(1108,716)	(1106,1104)	(1172,1081)	(1076,737)
	(1158,799)	(1191,596)	(1078,480)	(1121,693)	(1114,970)	(1197,864)	(1099,733)
			(1104,479)	(1122,578)	(1118,864)	(1203,709)	(1112,666)
			(1119,444)	(1125,559)	(1126,842)	(1283,670)	(1116,619)

(continued)

Table 1 (continued)

Instance	SPEA	CMOEA	MODE-ms1	MODE-ms2	MODE-ms3	MODE-ms4	MODE-ms5
ORB5	(1002,1)	(988,23)	(922,386)	(915,411)	(907,644)	(929,742)	(916,612)
	(1012,5)	(989,45)	(928,247)	(927,367)	(908,643)	(942,713)	(927,558)
		(994,18)	(939,198)	(934,328)	(911,597)	(955,709)	(929,367)
			(953,170)	(938,298)	(912,567)	(959,655)	(932,241)
			(962,146)	(947,203)	(922,551)	(972,583)	(955,143)
LA26	(1405,4436)	(1366,3539)	(1272,3814)	(1296,3614)	(1327,4804)	(1375,5003)	(1304,4045)
	(1428,4346)	(1375,3537)	(1282,3427)	(1316,3377)	(1330,4571)	(1379,4973)	(1306,3073)
		(1394,4063)	(1304,3344)	(1325,3347)	(1341,4443)		
			(1306,3286)	(1341,3205)	(1344,3888)		
			(1320,3098)	(1348,3132)	(1384,3833)		
LA27	(1451,2960.5)	(1451,2968.5)	(1347,4487.5)	(1332,3116)	(1362,4258.5)	(1421,4766.5)	(1322,3850.5)
	(1452,2512.5)	(1452,2611.5)	(1350,3395)	(1372,3115.5)	(1366,3806.5)	(1441,3978.5)	(1336,3649.5)
			(1353,3340)		(1416,3752.5)		(1337,3614.5)
			(1367,3339.5)				(1370,3571.5)
LA28	(1400,3111)	(1398,3553)	(1316,3766)	(1321,3489)	(1338,4455)	(1367,4586)	(1303,3775)
	(1414,2926)	(1410,3339)	(1318,3520.5)	(1324,3482)	(1342,4247)	(1417,4508.5)	(1326,3539)
			(1319,3431)	(1343,2600)	(1350,3489)	(1433,4116)	(1341,3445)
			(1348,2422)	(1451,2543.5)	(1356,3134)	(1477,3964)	(1344,2888)
			(1368,2365)			(1541,3955)	

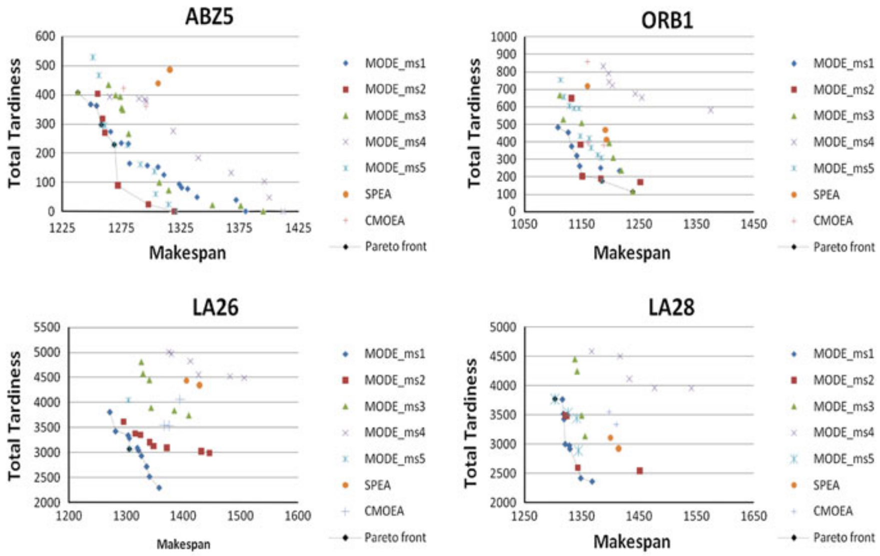


Fig. 2 Comparison of non-dominated solutions

CMOEA. In addition, MODE-ms1, MODE-ms-2, MODE-ms3, and MODE-ms5 clearly outperform SPEA and CMOEA since the majority of the solutions obtained by SPEA and CMOEA are dominated. However, the performance of MODE-ms4 is generally inferior to other MODE strategies, SPEA, and CMOEA since the solutions obtained from MODE-ms4 is mostly dominated by others. Figure 2 illustrates the comparison of non-dominated solutions generated from SPEA, CMOEA and all MODE strategies. It is important to note that the Pareto Front is obtained from the best non-dominated solutions found by all algorithms.

It can be easily seen from Fig. 2 that the non-dominated solutions obtained from SPEA and CMOEA are dominated by those from MODE-ms1, MODE-ms2, MODE-ms3, and MODE-ms5. Most of solutions on the Pareto front are from MODE-ms1, MODE-ms2, MODE-ms3, and MODE-ms5. MODE-ms4 again shows its poor performances since the solutions are very far from the Pareto front and mostly dominated by other algorithms.

5 Conclusions

This study presents an implementation of the MODE algorithm for solving multi-objective job shop scheduling problems with the objective to simultaneously minimize makespan and total tardiness of jobs. The MODE framework uses Elite group to store solutions and utilizes those solutions as the guidance of the vectors. Five mutation strategies with different search behaviors are used in order to search for the Pareto front. The performances of MODE are evaluated on a set of benchmark JSP problems and compared with results from SPEA and CMOEA. The results demonstrate that the MODE algorithm is a competitive approach and capable of finding a set of diverse and high quality non-dominated solutions on Pareto front.

References

Abbass HA, Sarker R, Newton C (2001) PDE: a Pareto-frontier differential evolution approach for multi-objective optimization problems. In: Proceedings of the 2001 congress on evolutionary computation, vol 2, pp 971–978

Bean JC (1994) Genetic algorithms and random keys for sequencing and optimization. ORSA J Comput 6(2):154–160

Bierwirth C (1995) A generalized permutation approach to job shop scheduling with genetic algorithms. OR Spectrum 17(2–3):87–92

Cheng R, Gen M, Tsujimura Y (1996) A tutorial survey of job-shop scheduling problems using genetic algorithms: I. representation. Com Ind Eng 30(4):983–997

Chiang TC, Fu LC (2006) Multiobjective job shop scheduling using genetic algorithm with cyclic fitness assignment. In: Proceedings of 2006 IEEE congress on evolutionary computation. Vancouver, Canada. 16–21 July 2006, pp 3266–3273

Deb K, Pratap A, Agarwal S, Meyarivan T (2002) A fast and elitist multiobjective genetic algorithm: NSGA-ii. IEEE Trans Evol Comput 6(2):182–197

Lei D (2008) A Pareto archive particle swarm optimization for multi-objective job shop scheduling. Com Ind Eng 54(4):960–971

Lei D, Wu Z (2006) Crowding–measure-based multiobjective evolutionary algorithm for job shop scheduling. Int J Adv Manuf Tech 30(1–2):112–117

Lei DM, Xiong HJ (2007) An efficient evolutionary algorithm for multi-objective stochastic job shop scheduling. In: Proceedings of the 6th international conference on machine learning and, cybernetics. 19–22 August 2007, pp 867–872

Madavan NK (2002) Multiobjective optimization using a Pareto differential evolution approach. In: Proceedings of the, evolutionary computation. 12–17 May 2002, pp 1145–1150

Ripon KSN, Tsang CH, Kwong S (2006) Multi-objective evolutionary job-shop scheduling using jumping genes genetic algorithm. In: Proceeding of international joint conference on neural networks. 16–21 July 2006, pp 3100–3107

Storn R, Price K (1995) Differential evolution: a simple and efficient adaptive scheme for global optimization over continuous spaces. Technical Report TR-95-012, Berkeley, CA: International Computer Science

Wisittipanich W, Kachitvichyanukul V (2010) Two enhanced differential evolution algorithms for job shop scheduling problems. Int J Prod Res 50(10):2757–2773

Wisittipanich W, Kachitvichyanukul V (2012) Mutation strategies toward Pareto front for multi-objective differential evolution algorithm. Int J Oper Res (article in press)

Zitzler E, Thiele L (1999) Multiobjective evolutionary algorithms: a comparative case study and the strength Pareto approach. IEEE Trans Evol Comput 3(4):257–271

Smart Grid and Emergency Power Supply on Systems with Renewable Energy and Batteries: An Recovery Planning for EAST JAPAN Disaster Area

Takuya Taguchi and Kenji Tanaka

Abstract This paper describes the design method of smart grid energy systems based on the simulation for introducing renewable energy (RE) and secondary batteries. The emergency power is also available. Managing RE systems and battery storage can minimize the cost of electricity by optimization balance between supply and demand as well as can reduce environmental impacts. Also the systems enable us to use emergency power supply for accidents and disasters, and to enhance robustness of electric power systems. To actualize the electricity management systems, the object-oriented and time-marching energy management simulator is developed which simulates power production, transmission and distribution, charge and discharge, and consumption of electricity every half hour. By using that simulator, peak and amount of power supply can be decreased. As a case study, we applied the systems with photovoltaic power (PV) generation and secondary batteries to reconstructed elementary schools that were damaged by Tohoku earthquake and tsunami on March 11, 2011, and consequently the validity of the analysis was obtained. Furthermore, it was verified the case that the systems were applied to business, which involves more profits than public facilities, and we examined requirements for business.

Keywords Smart grid · Operations management · Renewable energy · Battery · Earthquake disaster revival

T. Taguchi (✉)
Department of System Innovation, University of Tokyo, Tokyo, Japan
e-mail: taguchi@triton.naoe.t.u-tokyo.ac.jp

K. Tanaka
Graduate School of Engineering, University of Tokyo, Tokyo, Japan
e-mail: kenji_tanaka@sys.t.u-tokyo.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_134,

1 Introduction

Nowadays, the expectancy for Renewable Energy (RE) is increased. Many countries implemented Feed-in tariff policies in order to encourage investments in RE, and consequently that led to significant amounts of RE generation in the world. However, Excess of applications for RE is likely to lower efficiency and robustness in grid because the output power of RE fluctuate much. Therefore, storage battery systems have been used to manage the power fluctuation. Nonetheless, optimal sizes of RE and storage batteries depend on power demand of consumers and climate in that area. Secondary batteries have also used for emergency power supply. It is required to design the size of RE appliances and secondary battery systems and emergency management. The goal of this paper is to introduce power management systems, which reduce power supply from grid and supply power in the case of blackout, with feasible capacities of PV and batteries in reconstructed schools in EAST JAPAN disaster area.

2 Literature Review

Kanchev et al. (2011) studies energy management systems in RE generation and storage batteries and discuss algorithms of charge/discharge of batteries. However, they did not describe technique about the optimization of sizes of RE and storage batteries. Shibata (2011) proposed how to optimize those systems on the basis of power demand and climate data in the past. Nevertheless, little is known about emergency power supply in his paper.

Considering these problems from the studies above, the purpose of this study is to design and optimize the sizes of RE and batteries in the power, economical, and emergency assessments. In addition, as a case study, we applied the systems with RE and secondary batteries to reconstructed elementary schools that were damaged by Tohoku earthquake and tsunami on March 11, 2011, and consequently the validity of the analysis was examined.

3 Model

3.1 Overview of the Model

In order to design optimal sizes of RE (or PV) and battery, we have developed a time-marching energy management simulator that simulates production, transmission and distribution, charge and discharge, and consumption of electricity every half hour. In authors' simulation system, changes of power demand and RE along temporal axes, the amounts of RE and battery are set as input data. And then

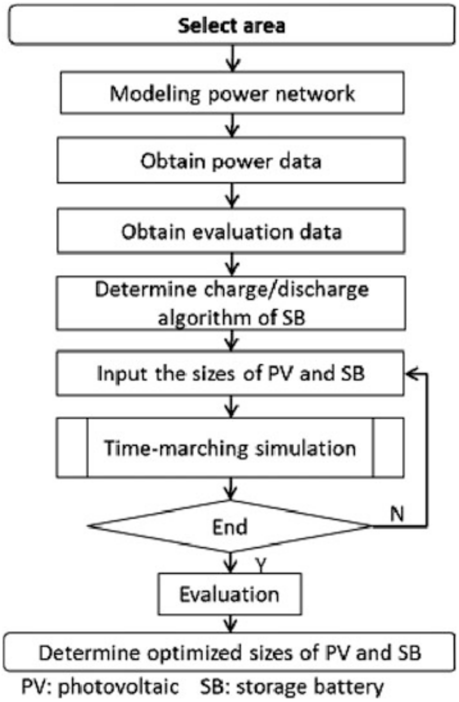


Fig. 1 Flow of the simulation

the effect of each scenario, in which different sizes of RE and battery are introduced, is obtained as output data by conducting time-marching simulation.

The steps of the model which design optimal sizes of RE and battery are shown in Fig. 1. First, the target area of the simulation is selected. Second, power network model is developed. Third, power demand data and RE data are obtained. Demand data and RE data are expressed in the same format. In this paper, each power data is for 365 days, 48 steps in a day. Fourth, data for evaluation such as unit price of RE, battery is obtained. Fifth, the algorithm that operates storage battery, which manages when and how much electric energy is charged or discharged, is selected. The sixth flow, combinations of the sizes of RE and battery are read into the time-marching energy management simulator. After the results of all the combinations are calculated, the calculation outputs are evaluated based on evaluation criteria. Finally, optimal sizes of RE and battery are designed.

3.2 Algorithm of Charge/Discharge of Storage Battery

Planning charge/discharge storage on the basis of power demand and generated power by RE needs algorithm of charge/discharge of storage battery. We should develop and choose optimal algorithm of them according to the purpose of that

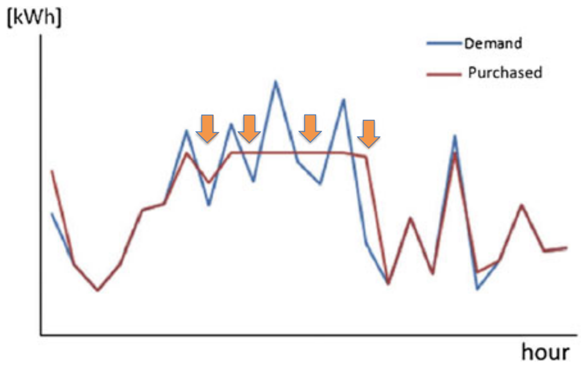


Fig. 2 The conceptual graph of peak-cut algorithm

project. On this paper, we developed "Peak-Cut Algorithm", which goal is to reduce maximum of purchased power supply in simulation period. The main reason why we use this algorithm is to minimize electricity charge cost. Figure 2 is conceptual graph of Peak-Cut Algorithm.

3.3 *Output Data and Assessment Criteria*

Each scenario is evaluated for the following three assessments; Power assessment, Economical assessment, and Emergency assessment (Table 1). Power assessment is to evaluate the amount and maximum of electricity. "Peak-cut" means how much maximum of power is reduced. Economical assessment is the evaluation concerned about profit. Emergency assessment is to evaluate the effect of disaster measure in each scenario.

3.3.1 Emergency Assessment

Design for emergency power supply in this paper means that the sizes of RE generation and storage batteries are optimized for the purpose of supplying electricity in case of disaster. We used reduction power demand which makes "Zero emission time ratio" 100 % as emergency assessment criteria. "Zero emission time ratio" is defined the time proportion when that area can be independent of the grid and supply power only by the systems with RE and battery. The calculate formula is shown in (1).

$$P = T(d)/T(0) \tag{1}$$

P Zero emission time ratios

Table 1 Assessment criteria

Power assessment	Energy sufficiency
	Peak-cut
	Power loss
Economical assessment	Reduction of electricity charge
	Payout period
Emergency assessment	The ratio of zero emission hours

T(d) The number of day when power is not purchased from the grid through out the day, provided "d" % of power demand is reduced

4 Case Study

4.1 Simulation Setup

We applied that model and simulation to the elementary school in Ofunato city, Iwate prefecture, which was damaged by Tohoku earthquake and tsunami on March 11, 2011. Besides, PV power was used as RE generator in this case study. The amount of power demand in this school is 119 MWh and the power cost is 2,250,000 JPY (about 22,500 USD) in fiscal 2010. Power demand data was made from two factors, monthly power demand data of the school from April 2010 to March 2011, and daily fluctuation data of faculty of economics of the university of Tokyo. PV power data was made from solar radiation and temperature in Ofunato city in Iwate prefecture. Figure 3 displays daily power demand and PV power data.

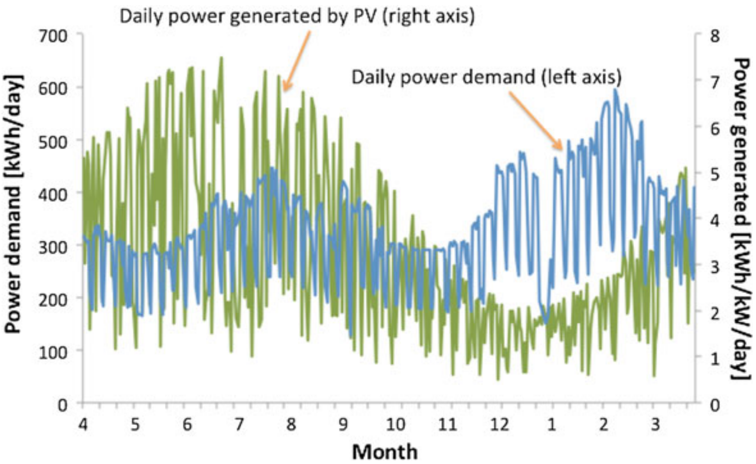


Fig. 3 Power demand and PV supply trend throughout a year

Table 2 PV and battery capacity in each scenario

	PV (kW)	Storage battery (kWh)
Scenario 1	15	50
Scenario 2	20	50
Scenario 3	30	100

Table 3 Economical criteria

Unit price of PV		300,000 (JPY/kW)
Unit price of lithium battery		100,000 (JPY/kWh)
Basic charge of power from the grid		1,348 (JPY/kW)
Commodity charge of power from the grid	Daytime	14 (JPY/kWh)
	Nighttime	9 (JPY/kWh)

We demonstrated three scenarios shown at Table 2. We evaluated these scenarios at three assessment criteria indicated at Table 1. Economical criteria such as the unit price of PV and battery are shown at Table 3. Also, service life of the systems of PV and batteries is given as 15 years. In addition, state of charge (SOC) of battery is set as 20–90 % of its capacity.

4.2 *Simulation Results*

4.2.1 Power Assessment

Table 4 shows the outputs of demonstration concerned with electricity power in each scenario. Peak of purchased power for a year is reduced to 29.4 % in scenario 3. Although, the size of PV in scenario 2 (15 kW) is larger than that of scenario 1 (20 kW), peak-cut ratio in both scenarios have little differences. It means that the effect of peak-cut depends more upon the PV size than the storage size. Besides, energy sufficiency in any scenario increases roughly in proportion of PV size because power loss is small compared with PV generated power.

Figures 4 and 5 display power indexes in winter and spring about scenario 3 (PV: 30 kW, Battery: 100 kWh). Power generated by PV, purchased power, power demand and power loss are shown by left axis. State of Charge (SOC) of secondary battery is shown by right axis. In winter, when power demand is high but power generated is low, purchased power is saved to about 60–70 %. Nevertheless, the

Table 4 Results of power assessment

Criteria	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
Energy sufficiency	14.6	19.3	28.8
Peak-cut	16.7	17.8	29.4
Power loss compared with PV generated	0.1	0.7	1.2

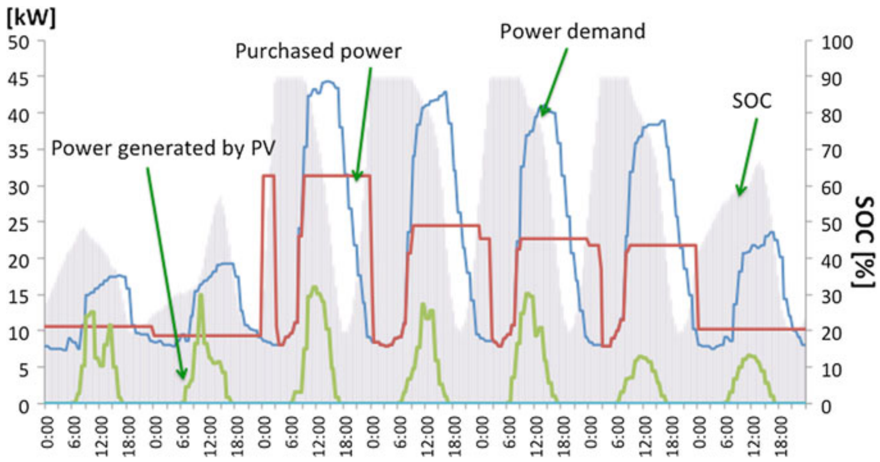


Fig. 4 Power indexes in the week of winter (2.10–2.16)

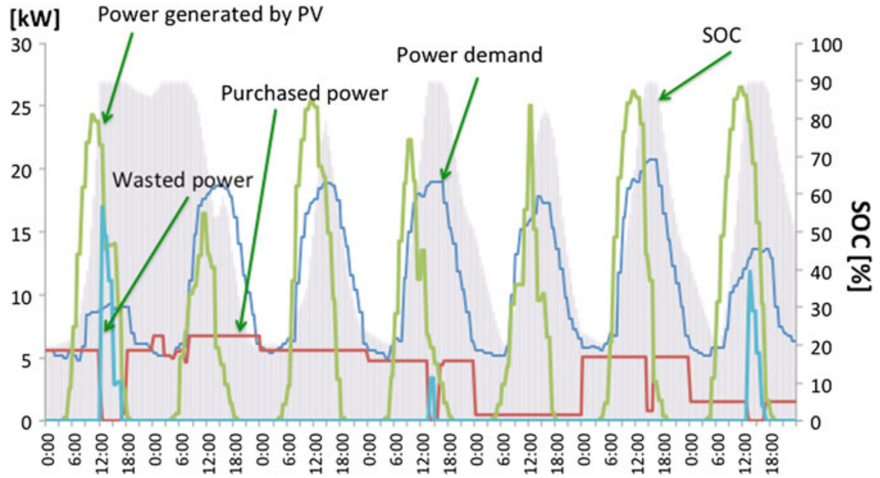


Fig. 5 Power indexes in the week of spring (5.18–5.24)

size of PV and battery is too small to smooth purchased power line. On the other hand, in spring, when power demand is small but power generated is high, peak at lunchtime is removed. In addition, power loss occurs on weekends in spring because power demand on weekends is lower than that on weekdays and SOC is high limited. However, the amount of power loss is negligibly small.

4.2.2 Economical Assessment

Table 5 shows the outputs of simulation concerned with economical evaluation. Similar to peak-cut ratio, reduction of basic charge in scenario 1 and scenario 2 have little differences because basic charge depends on maximum electricity power. Payout period was higher than service life of the systems with PV and battery in any scenario. Therefore, its introduction leads to loss in total. Public area such as school emphasizes facility for disaster and does not ask for profit, and accordingly is likely to introduce the system with PV and battery. By contrast, it is difficult for private company, which profit is important for, to introduce it in present economical conditions. We examined requirements for business by calculating IRR (Internal Rate of Return). Table 6 indicates IRR each PV unit price and service life when rising electricity to 120 % charge and using cheaper lead battery (20,000 JPY/kWh), which conditions are feasible, are presumed. Well-timed introduction that system for each company depends on how important

Table 5 Results of economical assessment

	Unit	Scenario 1	Scenario 2	Scenario 3
Reduction of electricity charge		17.7 %	21.4 %	32.5 %
Reduction of commodity charge		18.1 %	23.1 %	33.9 %
Reduction of basic charge		16.7 %	17.8 %	29.4 %
Implementation cost	JPY	9.5E+06	1.1E+07	1.9E+07
Annual income	JPY/year	4.0E+05	4.8E+05	7.3E+05
Payout period	year	23.9	22.8	25.9

Table 6 IRR based on each PV price and service life

		Service life (year)										
		15 (%)	16 (%)	17 (%)	18 (%)	19 (%)	20 (%)	21 (%)	22 (%)	23 (%)	24 (%)	25 (%)
	300	−2.7	−1.8	−1.1	−0.4	0.1	0.6	1.0	1.4	1.8	2.1	2.3
The price of Pv modules (K JPY/kW)	290	−2.3	−1.4	−0.7	−0.1	0.5	0.9	1.4	1.7	2.1	2.4	2.6
	280	−1.9	−1.0	−0.3	0.3	0.8	1.3	1.7	2.1	2.4	2.7	2.9
	270	−1.5	−0.6	0.1	0.7	1.2	1.7	2.1	2.4	2.7	3.0	3.3
	260	−1.0	−0.2	0.5	1.1	1.6	2.0	24	2.8	3.1	3.4	3.6
	250	−0.6	0.2	0.9	1.5	2.0	24	2.8	3.2	3.5	3.7	4.0
	240	−0.1	0.7	1.3	1.9	2.4	2.8	3.2	3.5	3.8	4.1	4.3
	230	0.4	1.1	1.8	2.3	2.8	3.2	3.6	3.9	4.2	4.5	4.7
	220	0.9	1.6	2.3	2.8	3.3	3.7	4.0	4.4	4.6	4.9	5.1
	210	1.4	2.1	2.8	3.3	3.7	4.1	4.5	4.8	5.1	5.3	5.5
	200	2.0	2.7	3.3	3.8	4.2	4.6	4.9	5.2	5.5	5.7	5.9
	190	2.5	3.2	3.8	4.3	4.7	5.1	5.4	5.7	6.0	6.2	6.4
	180	3.1	3.8	4.4	4.9	5.3	5.6	5.9	6.2	6.5	6.7	6.8
	170	3.8	4.4	5.0	5.4	5.8	6.2	6.5	6.7	7.0	7.2	7.3
	160	4.4	5.1	5.6	6.0	6.4	6.8	7.1	7.3	7.5	7.7	7.9
	150	5.1	5.7	6.3	6.7	7.1	7.4	7.7	7.9	8.1	8.3	8.4

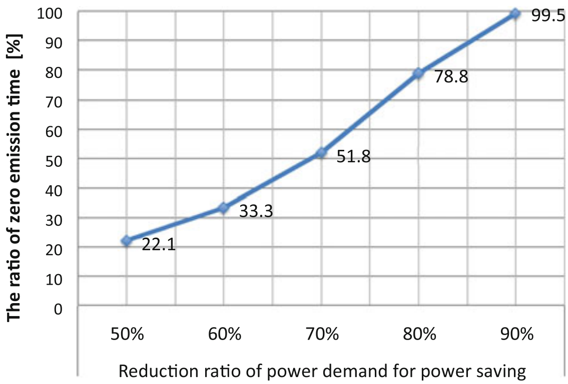


Fig. 6 Relationship between power saving and zero emission time

disaster measure is for the company. To take an example, small office, which is not used as refugee shelter in emergency situation, introduces that system with PV and battery in the condition that high IRR is expected.

4.2.3 Emergency Assessment

The graph in Fig. 6 illustrates the ratio of zero emission time for each reduction ratio of power demand at scenario 3. When power demand is saved 50 and 90 % of regular case, zero emission time reached 22.1 and 99.5 % respectively. If that area saves 90 % of electricity demand in the case of disaster, the facility accomplishes about 100 % self-sufficiency.

5 Conclusions

Conclusions of this paper describe below.

- We proposed the design of electricity management systems where sizes of RE and storage batteries is optimized by means of power demand and weather data in an area.
- As a case study, we design the electricity management system in a reconstructed elementary school, which were damaged by Tohoku earthquake and tsunami on March 11, 2011, and consequently the validity of the analysis was obtained.

Acknowledgments This work is partially supported by Social System Design Co. (http://www.socialsystemdesign.co.jp/) and its general manager Hideaki Miyata. We would like to express our deep appreciation for their kindness.

References

Kanchev H, Lu D, Colas F, Lazarow V, Francois B (2011) Energy management and operational planning of a microgrid with a PV-based active generator for smart grid applications. IEEE Ind Electron Mag 58(10):4583–4592

Shibata K (2011) Study on optimal design in smart house and power management with renewable energy system controlled by secondary batteries. Dissertation, University of Tokyo

Establishing Interaction Specifications for Online-to-Offline (O2O) Service Systems

Cheng-Jhe Lin, Tsai-Ting Lee, Chiuhsiang Lin, Yu-Chieh Huang and Jing-Ming Chiu

Abstract Information technology products such as smart phones, tablet PCs, eBooks and the intelligent-interactive digital signage have evolved and perfectly merged with the service systems to provide user-friendly user-interfaces and innovative service patterns. Online-to-offline (O2O) service model is one of the newest developments in the service systems where users in the physical world can interact with service providers in the cyberspace through various devices. Although traditional HCI studies have provided various research frameworks to describe interfaces and activities involved, there is a lack of interaction specifications which can clearly describe HCI in the realm of O2O service systems. This study developed a formal language that facilitates establishment of HCI specifications for O2O applications in proximity commerce based on interaction styles consisting of 4 interaction types represented in an interaction diagram. The formal language thus provides a common ground for service provider and service implementer to communicate and develop a concrete prototype effectively.

C.-J. Lin (✉) · T.-T. Lee · C. Lin
National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: Robert_cjlin@mail.ntust.edu.tw

T.-T. Lee
e-mail: charlenelee0912@gmail.com

C. Lin
e-mail: cjoelin@mail.ntust.edu.tw

Y.-C. Huang · J.-M. Chiu
Institute for Information Industry, The Innovative DigiTech-Enabled Applications and Services Institute, Taipei, Taiwan, Republic of China
e-mail: ychuang@iii.org.tw

J.-M. Chiu
e-mail: jmchiu@iii.org.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_135,

Keywords: O2O commerce · Human–computer interaction · Interaction specification

1 Introduction

In recent years, information technology products such as smart phones, tablet PCs, eBooks and the intelligent-interactive digital signage have evolved and perfectly merged with the service systems to provide user-friendly user-interfaces and innovative service patterns. A pattern is a solution to a problem in a context (Sharp et al. 2002). Different service patterns for a service system re therefore different ways to deliver desired user experience by interaction design. One intention of creating such service patterns are to communicate with each other in a design team based on the name of the pattern. Another intention is to produce a literature that documents user experience in a compelling form. A service pattern can be formed by a series of interactive steps, and the structure of those steps in this paper is called an "interaction style." The interaction styles consist of various types of interaction, which describe how a single step of interaction can be completed by a user with control or display devices. Since every service pattern is unique based on how steps of interaction are constructed (interaction styles) and how interaction is actually performed in each step (interaction types), the description of the service pattern can be used as a specification for human–computer interaction (HCI) to precisely describe the requirements and identify the components in HCI.

In the process of creating a service pattern, one may begin with working out how to design the physical interface (prototyping) or deciding what interaction styles to use (envisioning). Several prototyping approaches were commonly used including holistic design, sketching techniques or using scenarios and story boards. Holistic design approaches focused on how the interface should look in terms of their appearance and representation. Designers used cards with pictures of possible screens shots which users can manipulate to show how interaction can work (Ehn and Sjøgren 1991). Sketching techniques used explicit interface metaphors to create a cardboard as an analogy of the system and those metaphors help visually brainstorming best alternatives for the interface design (Verplank and Kim 1987). A scenario is a personalized story with characters, events, products and environments to help designer from concrete ideas of situations and a storyboard consisting of sequences of snapshots of visualized interaction is often used with a scenario to investigate possible interface problems (Nielsen 2002). Although abovementioned prototyping methodologies were often used in designing the interface, designers and service providers need repetitive communication and time-consuming discussion to minimize the gaps between ideas in their mind and then reach a common ground of concepts. The ineffectiveness of using these methodologies to work out a concrete design is partially attributable to their ambiguity in specifications and a lack of systematic description for interaction styles.

The term “interaction style” was used to describe ways in which users communicate or interact with computer systems. Five common interaction styles in HCI literature were command entry, menus, dialogues, form-fills, and direct manipulations (Preece et al. 1994). Commands can be single characters, short abbreviations or whole words which express instruction to the computer directly. Menus are sets of options displayed on the screen where the selection of one option results in executing the corresponding command. Dialogues can refer to rudimentary type of menus where the expected input is limited and the interaction takes up a form of a series of choices and response from the user. Form-fills are usually used when several different categories of data are fed into the system. In direct manipulation, there are usually icons representing objects and they can be manipulated to achieve desired commands. Those interaction styles are sufficient for traditional human–computer interaction when desktop or laptop computers were used. However, modern online-to-offline (O2O) applications of mobile computing devices in proximity commerce require non-traditional descriptions for innovative interaction styles. An O2O application in proximity commerce generally incorporates online service providers and resources (such as Cloud computing servers) to create an agent in the cyber space. When interacting with the online agent, users in the real world can experience the provided service through electronic portals (such as smart phones or intelligent digital signage) and obtain physical products. For example, Quick Response (QR) code is frequently used in O2O applications to enable communications between users and computers. By scanning QR codes with a smart phone, the user can be directed to a designated cyberspace, interact with online agent and obtain a coupon based on which a physical product can be redeemed. This interaction is beyond traditional interaction styles in that it cannot be classified into any of the abovementioned categories. Another example is using gyro sensors in the mobile computing devices to detect motions of the user as a way of interaction so that an instruction can be given accordingly. Versatile applications of various types of sensors in proximity commerce should be considered in the new systematic language to describe human–computer interaction, and the language should be able to give clear specifications for service providers to choose and designers to follow, i.e. a common ground for both sides in a design team to communicate.

The purpose of this paper is to propose such a systematic language that can be used as specifications of human–computer interaction to describe service patterns, especially for O2O application in proximity commerce. The language includes 4 basic interaction types, and an example is made to demonstrate how those interaction types can be used to describe an interaction style through a diagram representation. The contribution this language and future study directions are briefly discussed.

2 The Interaction Specification

2.1 Interaction Types

Four basic interaction types are developed to systematically describe a single step that may be included in interaction. The former 3 types (button, cursor and sensing) represent mostly controlling components that can be used to receive commands from users and give instructions to the service system. The display type mainly provides feedback to users regarding users' input and the system's state. In some circumstances, the display type can also be used to inform users necessary information for interaction. A summary of 4 types of interaction is listed in Table 1.

The button type is the most fundamental type of interactive patterns. Any interaction through either a physical button, a pseudo button on a touchscreen or an icon that signifies a change of status can qualify as a buttoning interaction. The activation of the button can be triggered by a single-click or a double-click, and the activation of the button can take its effect at the time when it is pressed (land-on), or at the time when it is released (lift-off). The physical buttons usually require single-clicks while icons usually need double-clicks. Land-on activation is common for the physical buttons while lift-off activation is believed to benefit accuracy for touch buttons (Colle and Hiszem 2004). Once a button is activated, it may maintain its status until it is touched again (self-sustaining) or recover its original state immediately after a trigger is sent (pulse). For button interaction, fingers or hand-arms are the most frequently used body part by users.

The cursor type interaction aims to acquire a single position or an entire path of a movement. The tracking of the cursor's position can be either discrete or

Table 1 O2O interaction types

Style	Parameter	Values
Button	Form	Physical/touch/Icon
	Activation	Single-click/double-click/land-on/lift-off
	Status	Self-sustaining/pulse
	Body part	Finger/hand-arm
Cursor	Target	Position/path
	Tracking	Discrete/continuous
	Activation	External/contact
	Body part	Head/finger/hand-arm/upper body/whole body
Sensing	Sensor	Video camera/depth camera/infrared (IR) sensor/electromagnetic sensor/gyro sensor
	Target	Physical objects/gesture/posture/motion
	Activation	Presence/identification/recognition
	Body part	Finger/hand-arm/upper body/whole body
Display	Channel	Visual/auditory
	Presentation	Light/text/graphics/sound/voice/video

continuous, depending on applications. For example, the position of a cursor can be continuously tracked to acquire a single target by averaging all positions obtained during a period of time (e.g. in a balance game, Fig. 1 on the left). In contrast, a path can be formed by several discrete positions (e.g. in a drawing application, Fig. 1 on the right). The activation of cursor tracking can be triggered either by an external signal (e.g. a button pressed or a target sensed) or by contact with a target area. For example, the slide to unlock function found on most mobile phones is a cursor type interaction where the tracking is activated when the finger contacts the slide area and the position of the cursor (the slide brick) is continuously tracked until it reached the end of the slide area (Fig. 2). The user can control the cursor either by his/her head, fingers, hand-arms, upper body or even the whole body.

The sensing type is the most advanced type of interaction in which a sensor is used to detect whether a target is present and whether the condition of the target meets the requirement for activation. Depending on the target, different types of sensors can be used for interaction. For presence or identification of a target, infrared (IR) sensor, electromagnetic sensor or video camera can detect the presence of various physical objects respectively such as a person with body temperature, a passive proximity card or a tag with Quick Response (QR) codes. The difference between presence detection and identification is that the former one needs no further confirmation of information or identity carried by the target, while the latter one requires recognition of identity or acquisition of information. If gestures, postures or motions performed by users are used to interact, depth camera

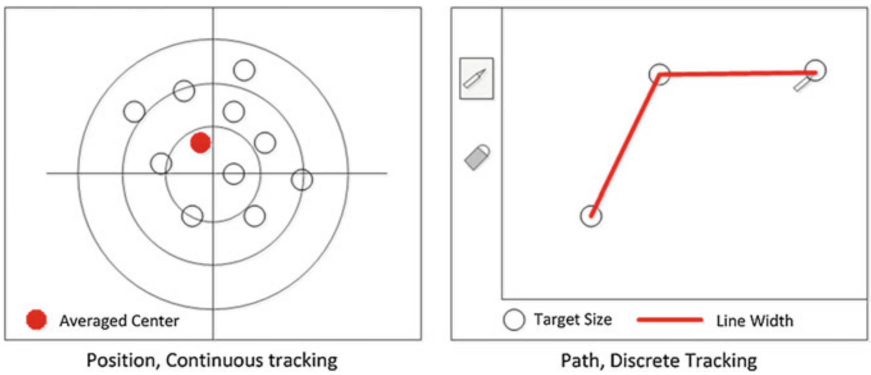
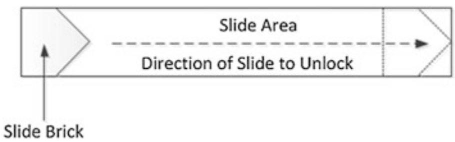


Fig. 1 Cursor interaction of different targets and tracking

Fig. 2 Slide to unlock



or gyro sensor should be used. The activation is thus based on recognition of spatial (e.g. distance or angle), geometrical (e.g. orientation or shape) or kinematic (speed or acceleration) features. To interact with sensors, different body parts may be used to move physical objects and perform gestures, postures or motions themselves.

Interaction can also take place without explicit motions from the user. The display type of interaction defined in Table 1 specifies such interaction. Information can be received through visual and/or auditory channels in various formats, including light, text, graphics (for visual channels only), sound, voice (for auditory channels only) and video (for both visual and auditory channels). The display interaction mainly provides instructions and feedback to users during the interaction so that the user may know the current status of the interaction and what to do next.

2.2 An Exemplified O2O Application in Proximity Commerce

"Make a Wish!"is one O2O application (Fig. 3) developed by Innovative Digitech-Enabled Applications & Services Institute (IDEAS) of the Institute for Information Industry (III), Taiwan. The application served as a promotion activity and was constructed on a system consisting of an intelligent-interactive digital signage, a smart phone and a user. Using the smart phone, the user firstly scanned a QR code appeared on the digital signage which automated a download of an application software (APP) designed specifically for the application. After installing and executing the APP, the user was asked to input his/her wish in text columns provided. Once a submit button was clicked, another QR code containing the user's wish would then appear on the screen of his/her smart phone. At the next

Fig. 3 Make a Wish application (the user is letting the camera installed beside the digital signage scan the QR code on his cell phone's screen)

step the user should move his/her mobile phone toward the digital signage and let another camera installed on the digital signage scan the second QR code on the smart phone's screen. Since the camera was camouflaged as a mailbox, the user's approaching his/her own smart phone simulated a mailing motion of a post card. Finally a greeting card would appear on the digital signage with the words of the user's best wishes.

2.3 Representing an Interaction Style in a Diagram

To define an interaction style specified above, an interaction diagram is used. Firstly, the user's entering texts into text columns were composed of two types: button interaction and cursor interaction. Once touched, the text column became active and a visible cursor indicated the current position for text entry. Therefore, this is cursor interaction by fingers based on positions, with discrete tracking and activation by contact. However, the typing of words should not be ignored. It was implemented by a software keyboard consisting of buttons. So the typing is an iteration of touch button interaction with single-click and lift-off activation. The buttons were operated by fingers also and sent out one letter a time, i.e. pulse signals. The end of the text entry was also a button interaction similar to those in typing. After the text message was transformed into a QR code, a sensing type interaction took place. The user moved the screen of his/her cell phone where the QR code was shown by hand and the QR code was identified by a video camera on the digital signage. The QR code contained the message the user just entered so that the digital signage was able to decode the wish and showed the message in the form of a Christmas card on its screen. The display interaction occurred here using visual channel in video format to provide the user enjoyable experience and feedback regarding information received by the digital signage. Afterward a product coupon was shown on the user's cell phone screen by which the user can redeem a free cup of coffee.

The interaction of Make a Wish can be therefore represented in a flowchart-like diagram (Fig. 4). In the Fig. 4 interaction points are defined (circled numbers): message entry, message submission, QR code scanning and message display. Beneath the interaction sequence there is a table defining interaction patterns and parameter used in each of the interaction points. Using this interaction diagram, a service provider can easily communicate with hardware and software engineers/designers regarding its needs of interaction patterns. Hardware and software engineers/designers are also benefitted from such a diagram where specifications for interfaces can be easily seen and extracted.

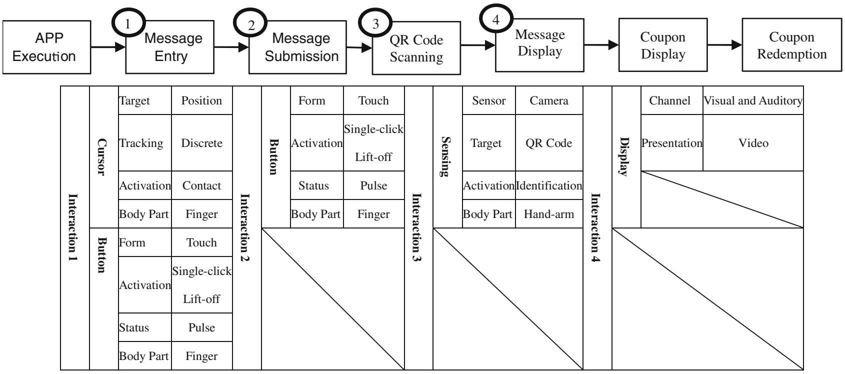


Fig. 4 The interaction diagram for Make a Wish

3 Conclusion and Future Directions

This study describes interaction specifications in terms of interaction styles represented by an interaction diagram consisting of 4 possible interaction types and their parameters which provide details in hardware selection, software implementation and criteria for interaction. The formal language used in the interaction specifications can be used for service provider and service implementer to communicate and develop a concrete prototype effectively because the process of interaction, the requirements for devices and how devices communicates with user are clearly and precisely defined. The specifications, however, are not comprehensive as technology advances and service pattern evolves. Future studies will focus on improving the specification to include innovative interaction design.

Acknowledgments This study is conducted under the "Digital Convergence Service Open Platform" of the Institute for Information Industry which is subsidized by the Ministry of Economy Affairs of the Republic of China.

References

Colle HA, Hiszem KJ (2004) Standing at a kiosk: effects of key size and spacing on touch screen numeric keypad performance and user preference. Ergonomics 47(13):1406–1423

Ehn P, Sjøgren D (1991) From system descriptions to scripts for action. In: Greenbaum JM, Kyng M (eds) Design work: cooperative design of computer systems. Routledge, London, pp 241–268

Nielsen L (2002) From user to character: an investigation into user-descriptions in scenarios. Paper presented at the proceedings of the 4th conference on designing interactive systems: processes, practices, methods, and techniques, London, England

Preece J, Carey T, Rogers Y, Holland S, Sharp H, Benyo D (1994) Interaction styles. In: Dix A (ed) Human-computer interaction. Addison-Wesley Publishing Company, Essex, pp 237–255

Sharp H, Rogers Y, Preece J (2002) Design, ptototyping and construction. In: Rogers Y et al (eds) Interaction design: beyond human-computer interaction. Wiley, NY, pp 239–275

Verplank B, Kim S (1987) Graphic invention for user interfaces: an experimental course in user-interface design. SIGCHI Bull 18(3):50–66. doi:10.1145/25281.25284

Investigation of Learning Remission in Manual Work Given that Similar Work is Performed During the Work Contract Break

Josefa Angelie D. Revilla and Iris Ann G. Martinez

Abstract According to literature, when a worker performs a task repeatedly, the time it takes to do the task decreases. This is based on the concept of learning curve. When the worker spends time away from work, there is usually an observed time decrement, as described by learning remission. A question may be "in case the worker does not completely stop working during the work break but performs 'similar work', how much remission can be expected?" Similar work may be work that share operations with the work prior to the break, but not completely the same. To investigate on learning remission, this research worked with a semiconductor and a hockey glove sewing business. The objective was to find the amount of similar work needed to be done during the work break to possibly reduce or avoid learning remission. The finding for the test case is, when at least 21 % of the supposed work break is spent doing the previous work, learning remission may not result. It is possible that for other industries, researchers may find similar results. This will help organizations transferring workers from one kind of work to another, not have increase in work time as a result of learning remission.

Keywords Learning curve · Learning remission · Similar work · Work break

J. A. D. Revilla (✉)
Assistant Professor of the Department of Industrial Engineering,
University of the Philippines, Los Baños, Laguna, Philippines
e-mail: angelie.revilla@gmail.com

I. A. G. Martinez
Associate Professor of the Department of Industrial Engineering and Operations Research,
University of the Philippines, Diliman, Quezon City, Philippines

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_136,

1 Introduction

Work interruption is commonly experienced by workers. Causes of work interruptions include:

1. Transfer to other lines within the organization because of seasonality of demand for the different lines;
2. Transfer to another organization because of end of contract with the previous one;
3. Complete stop while looking for employment because of end of contract with the previous employer.

Whichever the reason may be among the aforementioned, work interruption may cause learning loss or decline in work performance. This is known in literature as "forgetting" or "learning remission".

1.1 Learning Remission and Output

Learning remission describes decrement or decline in performance as a result of being away from work for some period of time. Learning remission a longer time to do the task or effectively, lower number of output for the same time period. This effect of lower output for the same time period is a concern of some manufacturing organizations. Specifically, for example, in manufacturing organizations that compensate their workers on piece-rate method, there is a minimum number of output required per worker per work day. The minimum number of output is set based on the performance of the standard worker. Typically, all workers are rated based on their performance compared with the standard. When workers take time away from work after a period of time, i.e., six-month contract period, it is often a question whether learning remission would really set in. In effect, a lower output should be expected from the worker from his resumption of work compared to his output prior to the work break.

1.2 Possibility of Avoiding Learning Remission

Extending the aforementioned question, a challenge can be stated as "would it be possible to avoid learning remission by performing related activities during the *supposed* work break?" Furthermore, if that will be possible, what related activities can be done? These questions are pressing concerns of countries where *contract work* is practiced.

1.3 *Definition of Work Break*

As mentioned above, in this research, the work break is "supposed". Strictly speaking, the work break should be complete stoppage from work. However, since most workers don't really stop working after they complete their work contract but instead work on an organization within the same or similar industry where their skills are required, work that is related to the work that they performed during Stint 1 may be done by the worker during the "supposed" work break.

2 The Objectives of This Research

It is the aim of this research to determine the level of output of a worker upon resumption from a work break. Furthermore, this research has the objective of identifying factors that affect the rate of output upon resumption. Knowledge of the factors will enable organizations institute programs and measures to ensure same or similar level of output upon resumption of work (i.e., Stint 2), as with the output prior to the work break (i.e., Stint 1). Please see Fig. 1 for an illustration of the objective of this research.

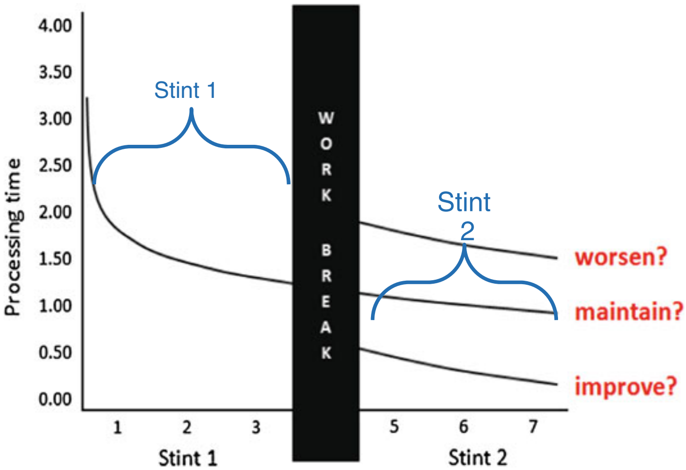


Fig. 1 The objective of this research

2.1 Specific Objectives

The specific objectives of this research are as follows:

1. To determine whether the output at the last point during Stint 1 varies significantly from the output at the first point during Stint 2 given work break of less than six (6) months.
2. To identify the work break-related factors that will significantly affect the level of output during Stint 2. Among the numerous work-break related factors, the following are considered in this paper:
   (a) Length of the work break (i.e., one day to six months)
   (b) Number of unique operations during the “supposed” work break
   (c) Frequency of performing during the “supposed” work break, the operations that are common with Stint 1.

3 Related Studies on Learning Curve and Forgetting

Learning curve traces its background from 1885 when Ebbinghaus first described it for memorizing syllables. Later, a mathematical model of the learning curve was proposed following work describing the effect of learning on production costs in the aircraft industry (Wright 1936). From then on, various research activities have been undertaken about the learning curve. Some of these are on the application of machine learning such as that of Principe and Euliano (2000).

While the concept of learning has been much explored, studies on forgetting, as a result of time away from work, have not been numerous. One of these few studies claims that an interruption in work (i.e., work break in this research) warrants the return of the worker to the top of the learning curve. Another study concluded with two findings: (1) Forgetting (i.e., defined as the excess of actual time over learning curve-predicted time) may be negligible for “continuous control” tasks but significant for procedural task and (2) Forgetting is a function of the amount learned and the passage of time, not of the learning rate or other variables. Similar to these conclusions, still another research stated that the degree of forgetting is a function of the work break length and the level of experience before the break.

4 The Problem and Hypothesis of This Research

The specific problem that this study seeks to address is “How can forgetting be minimized or avoided?”

The hypothesis of this research is as follows: "Given a 'time away' of six months or less from the work of Stint 1, forgetting can be avoided if similar operations as with those of Stint 1 are done during the supposed work break or time away from work." This research will consider "forgetting" to have been avoided if the output at the last data point in Stint 1 is at least equal to the output at the last data point of Stint 2.

5 Methodology: Case Study of a Semiconductor Company and a Hockey Glove Sewing Company

Figure 2 presents the methodology of this research:

As shown, the study initially took 15 samples of workers of a semiconductor company and compared the output rates for Stint 1 and Stint 2. To pursue the study further, this study took 79 samples of workers of a hockey glove manufacturing company again to compare the output rates for Stint 1 and Stint 2. Note that for each of the two companies, the observations made were done on workers who indeed have two stints. It was not difficult to perform the observations of Stint 1 and Stint of the same worker because it was typical for the organizations in the case study to re-hire workers after the workers have spent a work break of about six months after their contracts are completed.

Furthermore, Table 1 shows more detailed description of the observed workers and operations.

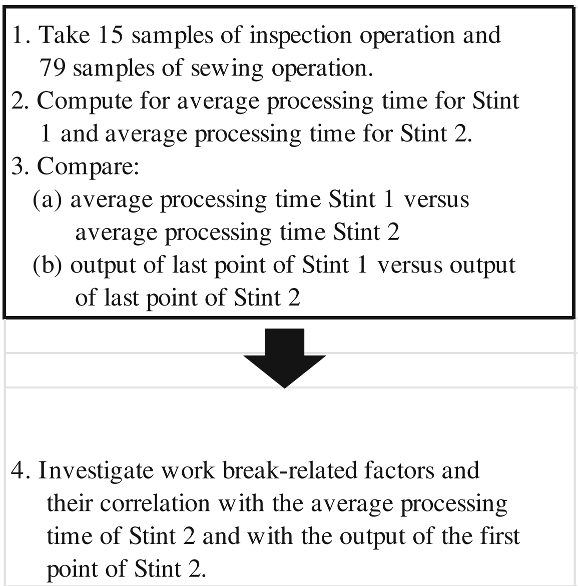


Fig. 2 Methodology of this research

Table 1 Description of the observed workers and operations

Case	Product	General process	Kind of work	Use of contractual operators
1	Actuator	1. Machining 2. Washing 3. Inspection 1 4. Plating 5. Inspection 2 6. Packing	Inspection process • 10 % machine-paced and 90 % worker-paced	70 % are contractual operators • Stint 1 = 15-16 days • Work break = 10 days • Stint 2 = 16-17 days
2	Baseball gloves	1. Cutting 2. Stamping 3. Skiving 4. Matching color 5. Inspection 1 6. Sewing (accessories) 7. Hot hand 8. Linings 9. Sewing (fingers) 10. Lacing 11. Inspection 2 12. Packing	Sewing process • 20 % machine-paced and 80 % worker-paced	80 % are contractual operators • Stint 1 = 2-3 months • Work break = 3 months • Stint 2 = 2-3 months

6 Results and Discussions

Both companies have partially machine-paced and partially operator-paced operations. Case study 1, done on a semiconductor company, considered 15 operators and a shorter work break duration. From this, as initial study, an interesting result is found. It shows that, aside from the work break length, the frequency of performing similar operation during the *supposed* work break seems to affect the average processing time on stint 2. It is seen that a 30 % increase in average processing time on stint 2 seems to be an effect of a work break wherein similar operations are performed. Thus, to further analyze the initial investigation, another case study is conducted.

In case study 2, a sufficient sample size and a longer work break length is considered. Furthermore, factors that might affect the output at Stint 2 were investigated.

The work break-related factors that were investigated included:

1. Length of the work break
2. Number of unique operations performed during the work break
3. Frequency of doing the same operations during the supposed work break as with those of Stint 1

Correlation analysis showed that among the factors considered, the frequency of performing similar operations during the supposed work break, i.e., common operations as those done during Stint 1, can significantly reduce or even eliminate forgetting. This study was not able to establish correlation between Stint 2 performance and the other work break-related factors investigated. This study found a negative moderate correlation between the output or processing time on Stint 1 and the frequency of doing similar operations during the supposed work break. This means that when the frequency of doing similar operations becomes higher, the processing time on Stint 2 becomes shorter. This finding coincides with the principle of the learning curve. However, the further question is "how frequent should the similar operations be done to not experience forgetting?"

This research has found that for the cases considered, the processing time at the start of Stint 2 is always higher than the processing time at the end of Stint 1 before the work break. However, even if the processing time at the start of Stint 2 is higher, the decline of processing time will be steeper if more than 40 % of the operations done in Stint 1 are continued during the supposed work break. This eventual steeper decline in processing time will result to a lower average processing time for Stint 2. Otherwise, when 40 % or less of the operations done in Stint 1 are continued during the supposed work break, not only will the processing time during the start of Stint 2 will be higher than the processing time at the end of Stint 1, but also the eventual decline of processing time during Stint 2 as a result of learning will not be enough to cause the average processing time of Stint 2 to be lower than the average processing time of Stint 1 (Fig. 3).

The finding about 40 % degree of similarity of operations between Stint 1 and the work during the supposed work break has been an interesting result for this study. The decrease in average processing time implies that forgetting may be avoided by making the worker perform similar tasks (i.e., at least 40 % similar) so

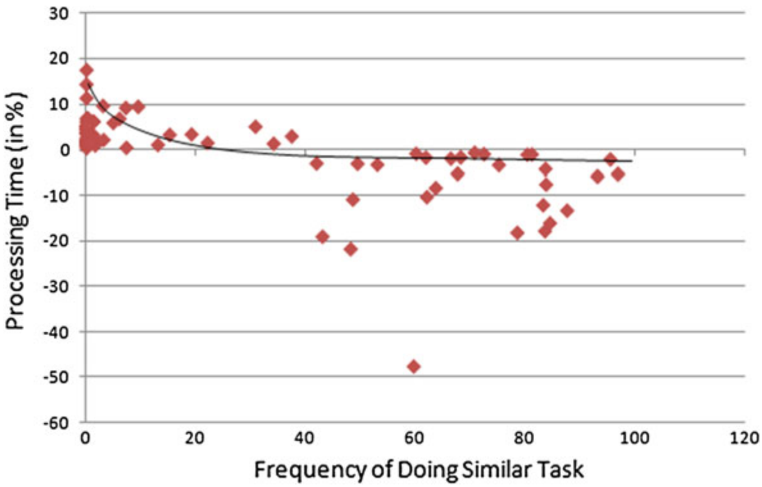


Fig. 3 Trend analysis between frequency of doing similar operation and average processing time on Stint 2

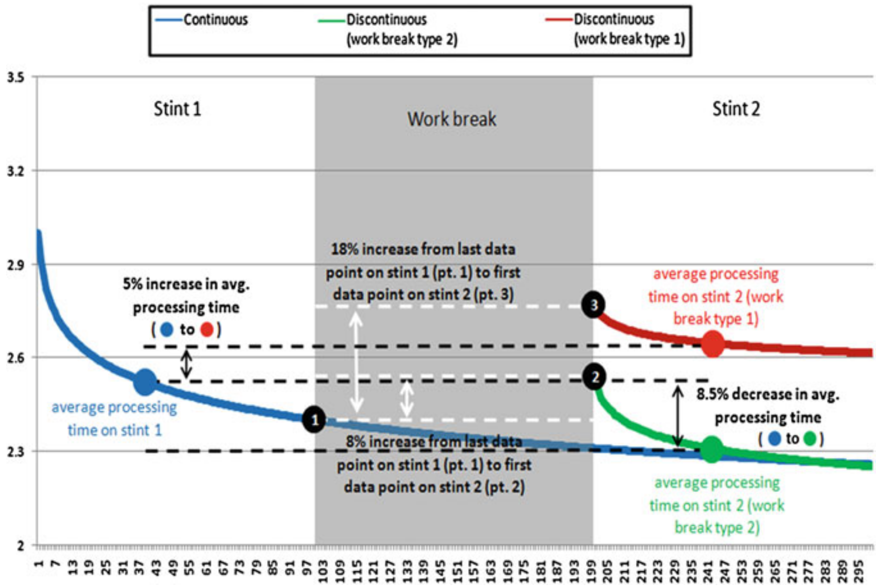


Fig. 4 Learning and forgetting when similar work is done during the supposed work break

that the same output can be expected on him when he goes back to the same work as performed during Stint 1. This finding may perhaps be also observed in other similar "procedural" work and may prove useful as a basis for computing production quotas, wage and productivity-related measures.

7 Conclusions

Work interruption is a typical occurrence. When work is interrupted, there is usually an associated forgetting by the worker. This causes a decline in performance that will be observed when the worker resumes the work on a future time. Several studies have been conducted on worker learning and forgetting. This study, in particular, was concerned with knowing if forgetting can be empirically observed for work breaks of less than six months and if forgetting can be avoided by instituting measures such as requiring the worker to perform similar work during the supposed work break. This study pursued the research by conducting two case studies: one on a semiconductor company and the other on a hockey glove manufacturing company (Fig. 4).

It was interesting for this study to find that forgetting could be observed for both case studies. An increase in the processing time was always observed between the end of Stint 1 and the start of Stint 2. However, when more than 40 % of operations were done similarly during the work break as with Stint 1, the learning during Stint 2 can be said to be better as shown by steeper decline in the eventual performance time of the task. In this case, the average processing time is observed to be smaller than the average processing time during Stint 1. This phenomenon was not observed when 40 % or less of the operations were common between those done in Stint 1 and during the supposed work break. The findings of this research can be helpful when organizations would like to hire and re-hire, assign and re-assign workers into tasks with work breaks in between "stints" and where forgetting needs to be minimized or avoided.

Acknowledgments This work is partially supported by the Engineering Research and Development for Technology program of the Department of Science and Technology of the Philippines.

References

Principe JC, Euliano NR, Lefebvre WC (2000) Neural and adaptive systems: fundamentals through simulations. Wiley, NY

Wright TP (1936) Factors affecting the cost of airplanes. J Aeronaut Sci 3(4):122–128

A Hidden Markov Model for Tool Wear Management

Chen-Ju Lin and Chun-Hung Chien

Abstract Determining the best time of tool replacement is critical to balancing production quality and tool utilization. A machining process would gradually produce defective parts as a tool wears out. To avoid additional production costs, replacing a tool before the yield drops below a minimum requirement is essential. On the other hand, frequent tool replacement would cause additional setup and tool costs. This paper proposes a hidden Markov model (HMM) to study the unknown nature of a tool wear progress by monitoring the quality characteristic of products. With the constructed model, the state of tool wear is diagnosed by using the Viterbi Algorithm. Then, a decision rule that evaluates the yield of the next machining part is proposed to determine the initiation of tool replacement. The simulation analysis shows that the proposed method could accurately estimate the model and the status of tool wear. The proposed decision rule can also make good use of tools whereas controlling yield.

Keywords Tool replacement · Tool wear · Yield

1 Introduction

Online monitoring of tool conditions is important to many machining processes. As tools wear out, machining processes would produce more and more defective workpieces. Tool replacement should be initiated once production yield drops

C.-J. Lin (✉) · C.-H. Chien
Department of Industrial Engineering and Management, Yuan Ze University,
No. 135 Yuan Tung Rd, Chung-Li, Taiwan
e-mail: chenju.lin@saturn.yzu.edu.tw

C.-H. Chien
e-mail: s995434@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_137,

below a minimal requirement to avoid additional production cost. On the other hand, premature tool replacement would incur extra tool costs and increase machine downtime. Accordingly, determining the best time of tool replacement is important to balance between production quality and tool utilization.

Recent advances in sensor technology and computational capabilities have facilitated in-process monitoring of tool conditions. Condition-based maintenance (CBM) that suggests maintenance decision depending on the information collected through condition monitoring is commonly applied in practice (Jardine et al. 2006). However, a critical challenge of CBM is high installation costs. Manufacturers may not be able to afford expensive monitoring equipment but afford general inspection instruments that measure outer appearance or features of the workpieces machined. Instead of determining the time of tool replacement based on the indicators like temperature, vibration data, X-ray images or others collected during condition monitoring, this paper directly focuses on the quality characteristic of workpieces.

2 Tool Wear Diagnostics Support

To diagnose tool wear, the time series approach was applied to analyze data variance to monitor tool condition (Kumar et al. 1997). The task of clustering tool condition becomes more difficult as the machining processes become more complicated. The collected data for analyzing tool wear condition are versatile. Cutting forces were investigated to monitor tool condition under the structure of neural network (Saglam and Unuvar 2003). However, neural network requires abundant training data which may not be available in practical problems. Fuzzy system was studied instead (Devillez and Dudzinski 2007). Other researchers completely reviewed the methods that diagnose tool condition by analyzing vibration and wavelet data (Heyns 2007; Zhu et al. 2009a, b).

Hidden Markov model (HMM) is appropriate to explain the tool wear problem. An HMM for tool condition consists of two stochastic processes: (1) A Markov chain with finite but unknown states describing an underlying process of tool wear. The number of states could be either known or unknown. (2) An observable process depending on the hidden state. The observations could be the condition monitoring data studied in the CBM domain or quality characteristics which will be introduced in the next section. When fixing number of states, the Baum-Welch algorithm (Baum 1972) was applied to estimate the parameters of HMM based on training data (Heck and Mcclellan 1991). The tool state of a drilling process is then determined by maximizing the conditional probability of state sequence given the estimated model and observation sequence. Similar approaches were applied to different machining process as follows, drilling: (Ertunc et al. 2001) and (Baruah and Chinnam 2005); rotating: (Wang et al. 2002) and (Li et al. 2005); computer numerical control (CNC): (Vallejo et al. 2005); milling: (Zhu et al. 2009a, b);

cutting: (Zhang and Yue 2009). The condition probabilities used for state diagnostics are slightly different in these papers.

When the number of states is unknown, a similarity index was used to determine the best number of states for a CNC machining process (Kumar et al. 2008). An adaptive process that increases the number of states by one whenever k consecutive observations cannot be categorized into the existing states was proposed for analyzing online data (Lee et al. 2010). The concept was close to statistical process control techniques.

3 Tool Wear Monitoring System

To effectively monitor tool condition and determine the time of tool replacement, this paper proposes a monitoring system containing three main phases: (1) model construction—estimating the HMM parameters and the number of states of tool wear, (2) state estimation—estimating tool wear status, and (3) tool replacement determination—an yield-based decision rule.

3.1 Modeling Tool Wear

Let the observation sequence $X = (x_1, x_2, \ldots, x_{T(h)})$ be the quality characteristic of workpieces collected from training data. A workpiece with the quality characteristic beyond its upper specification limit (USL) and lower specification limit (LSL) is considered as a defect. To construct the HMM of tool wear, a brand new tool is used in the machining process until producing h defective workpiece, $h > 1$. The collected quality characteristics of workpieces form a training data set for model construction.

After data acquisition, apply the Baum-Welch algorithm to estimate the parameter $\lambda = (\pi, A, B)$ of the HMM. π is the initial probabilities of the states, A is the transition probability matrix, and B is the distribution parameters of the quality characteristic under each tool wear state. Here we assume the distribution is Normal. Since the number of states is unknown, we applied the Bayesian information criterion (BIC) to determine the best model. The way of HMM construction is:

Step 1. Start the machinery process and collect the quality characteristic of each workpiece until the hth defect occurs, $X = (x_1, x_2, \ldots, x_{T(h)})$. $T(h)$ is the hth time such that $x_{T(h)} \notin$ [LSL, USL].

Step 2. Set the number of states $k = 2$. Apply the Baum-Welch algorithm to estimate $\hat{\lambda} = (\hat{\pi}, \hat{A}, \hat{B})$.

Step 3. Calculate BIC (Yu 2010) under the estimated HMM with k states.

$$\mathrm{BIC}(k) = -2\ln L + v(k)\ln T(h) \tag{1}$$

where L is the likelihood function, $L = f(o_1, o_2, \ldots, o_T \big| \hat{\lambda}) = \prod_{i=1}^{T} f(o_i \big| \hat{\lambda})$, and $v(k)$ is the degree of freedom, $v(k) = k^2 + 2k - 1$.

Step 4. Set $k = k + 1$. Estimate $\hat{\lambda} = (\hat{\pi}, \hat{A}, \hat{B})$ and calculated BIC(k) again.
Step 5. If BIC(k) < BIC($k - 1$), return to Step 4. Otherwise, stop. The final HMM has parameters $\hat{\lambda} = (\hat{\pi}, \hat{A}, \hat{B})$ estimated under k^* states, $k^* = k - 1$.

3.2 Diagnosing Tool Wear Conditions

Suppose that all of the tools have the same performance as the one used in model construction. To diagnose the tool condition of in-process data, sequentially apply the Viterbi algorithm (Viterbi 1967) as follows. T would increase as a machining process continues.

Initialization:

$$\delta_1(i) = \pi_i b_i(o_1), \quad 1 \le i \le k^* \tag{2}$$

$$\psi_1(i) = 0 \tag{3}$$

Recursive:

$$\delta_t(j) = \max_{1 \le i \le k^*} \{\delta_{t-1}(i) a_{ij}\} b_j(o_t), \quad 2 \le t \le T,\ 1 \le j \le k^* \tag{4}$$

$$\psi_t(j) = \arg\max_{1 \le i \le k*} \{\delta_{t-1}(i) a_{ij}\}, \quad 2 \le t \le T,\ 1 \le j \le k^* \tag{5}$$

Termination:

$$P^* = \max_{1 \le i \le k^*} \{\delta_T(i)\} \tag{6}$$

$$q_T^* = \arg\max_{1 \le i \le k^*} \{\delta_T(i)\} \tag{7}$$

Optimal path:

$$q_t^* = \psi_{t+1}(q_{t+1}^*), \quad t = T-1, T-2, \ldots, 1 \tag{8}$$

o_t is the quality characteristic of the workpiece at time t. $b_t(o_t)$ is the probability of observing o_t at state i. π_i is the initial probabilities of state i. a_{ij} is the transition probability from state i to state j. q_t^* is the best state of tool wear at time t.

3.3 Diagnosing Tool Wear Conditions

Severity level of tool wear directly affects the quality of workpieces machined. Effectively monitor and control machinery health is critical to produce qualified workpieces. We proposed a yield-based decision rule to initiate tool replacement. With the estimated HMM explained in Sect. 3.1, we are able to evaluate how likely the next workpiece will be qualified given the currently observed sequence O_t, $O_t = \{o_1, o_2, \ldots, o_t\}$. A tool is considered as capable if such probability is high. On the other hand, a tool is considered as worn out if such probability cannot meet a minimum requirement of yield. The proposed yield-based rule is as follows.

Decision rule:

Initiate tool replacement when $P(o_{t+1} \in [LSL, USL] \,|O_t) < R$, where R is the pre-specified minimum requirement of yield. Otherwise, continue machining.

$P(o_{t+1} \in [LSL, USL] \,|O_t)$ can be calculated as

$$\sum_{j=1}^{k^*} P\left(o_{t+1} \in [LSL, USL] \left| q_{t+1} = S_j \right) \times \left(\sum_{i=1}^{k^*} \hat{a}_{ij} \frac{\hat{\alpha}_t(i)}{P(O_t \big| \hat{\lambda})} \right) \right) \quad (9)$$

where

$$\hat{\alpha}_1(i) = \hat{\pi}_i \hat{b}_i(o_1), \quad 1 \le i \le k^* \quad (10)$$

$$\hat{\alpha}_{s+1}(j) = \hat{b}_j(o_{s+1}) \sum_{i=1}^{k^*} \hat{\alpha}_s(i) \hat{a}_{ij}, \quad 1 \le s \le t-1, 1 \le j \le k^* \quad (11)$$

$$P(O_t \big| \hat{\lambda}) = \sum_{i=1}^{k^*} \hat{\alpha}_t(i) \quad (12)$$

4 Simulation Analysis

In the following simulation, a drilling process is used to demonstrate the efficacy of the proposed system. The machining process drills one hole on each workpiece. The depth of a hole drilled is the quality characteristic measured in this example. As a tool wears out, the depth becomes shallow. The USL and LSL of the depth are set to 11 and 9 mm, respectively. Once there are three defects, the system stops collecting the training data, $h = 3$. As for the testing stage, the drilling process would stop and initiate tool replacement when the conditional yield of the next workpiece drops below 90 %, $R = 90$ %.

Assume that the tool wear condition of the drilling process is a three-state left to right Markov chain. From a brand new tool to worn out, the three states are the slight, moderate, and severe wear states. The distributions of the depths are normally distributed with N(10.4, 0.04), N(10, 0.04), and N(9.4, 0.09) under the slight, moderate, and severe wear states. The initial probabilities of the states are $\pi = [1\ 0\ 0]$. The transition probability matrix is

$$A = \begin{bmatrix} 0.97 & 0.03 & 0 \\ 0 & 0.97 & 0.03 \\ 0 & 0 & 1 \end{bmatrix} \quad (13)$$

In the simulation, the 81st, 82nd, and 84th workpieces are defective. Thus, the training phase stops collecting data at time $T(3) = 84$. The Baum-Welch algorithm is applied to estimate the parameters of the model. The minimum BIC value occurs when setting the number of states to three. The final estimated model is a three-state HMM with parameters $\pi = [1 0 0]$,

$$A = \begin{bmatrix} 0.973 & 0.027 & 0 \\ 0 & 0.972 & 0.028 \\ 0 & 0 & 1 \end{bmatrix} \quad (14)$$

N(10.4, 0.03), N(10, 0.11), and N(9.5, 0.23), which are highly close to the preset model. This estimated model is then applied to determine the time of tool replacement.

100 tools are then tested in the same drilling process to demonstrate the performance of the proposed system, including the accuracy in diagnosing tool condition and the efficiency in tool replacement. Suppose that all of the 100 tools start from brand new and have the same features as the one applied to construct the model of tool wear. The analysis shows promising performance of the Viterbi algorithm in evaluating the status of tool wear. For one tool, 93.02 % of tool condition can be accurately diagnosed before replacing the tool on average. The final state of tool condition is often considered as the worn out status when a tool must be immediately replaced. However, tool wear is a continuous progress. A tool may still be capable of machining a few more qualified workpieces at the beginning of the final state. Comparing to the naïve method that replaces a tool whenever the machining process enters the final state, Table 1 shows that the proposed system can prolong the usage of a tool whereas producing more qualified workpieces. The beneficial result is due to the proposed yield-based decision rule that is designed to balance between tool utilization and quality.

The stopping rule h of collecting training data would change the data set of training data and might influence model estimation. To further analyze the sensitivity of h to model estimation, we tested different rules that stop collecting

Table 1 Performance comparison between the proposed system and the naïve method

	Proposed system	Naïve method
Average time to replace tools	47.65	41.61
Average number of qualified products	47.36	41.50

training data when having 2–5 defects. The results suggests that parameter estimation of HMM is rather robust to h. The stopping rule has more influence on the parameters of the final state than the other states. The phenomenon may due to the number of observations taken in each state.

5 Conclusions

Monitoring the status of tool wear and scheduling tool replacement are critical tasks to many machining process due to high requirement in quality and cost control. This paper proposes a HMM to diagnose tool conditions and a yield index to determine tool replacement. The simulation results show that applying Baum-Welch algorithm along with BIC can effectively model the status of tool wear. The Viterbi algorithm also performs well in estimating the condition of tool wear with accuracy rates higher than 90 %. Comparing to the naïve policy that replaces tools when a machining process enters the final state of tool life, the proposed policy based on the yield index can lead to a few more qualified workpieces whereas maintaining yield requirement. The promising results suggest a rather balance between quality and tool utilization.

The analysis in this paper shows that the estimated HMM depends on the training data. It would be worthwhile to investigate the optimum stopping rule h of collecting the training data in the future. We are also working on building the HMM for tool wear based on the tool life of multiple tools rather than one, which could be biased. With a better estimated model, the proposed system could even better estimate the condition of tool wear and justify the time of tool replacement.

References

Baruah P, Chinnam RB (2005) HMMs for diagnostics and prognostics in machining processes. Int J Prod Res 43(6):1275–1293

Baum LE (1972) An inequality and associated maximization technique in statistical estimation for probabilistic functions of markov processes. Inequalities 3:1–8

Devillez A, Dudzinski D (2007) Tool vibration detection with eddy current sensors in machining process and computation of stability lobes using fuzzy classifiers. Mech Syst Signal Pr 21(1):441–456

Ertunc HM, Loparo KA, Ocak H (2001) Tool wear condition monitoring in drilling operations using hidden markov models (HMMs). Int J Mach Tool Manu 41(9):1363–1384

Heck LP, McClellan JH (1991) Mechanical system monitoring using hidden markov models. Paper presented at the IEEE international conference on acoustics, speech and signal processing 3, Toronto, Canada, pp 697–1700, 14–17 Apr 1991

Heyns PS (2007) Tool condition monitoring using vibration measurements a review. Insight 49(8):447–450

Jardine A, Lin D, Banjevic D (2006) A review on machinery diagnostics and prognostics implementing condition-based maintenance. Mech Syst Signal Pr 20(7):1483–1510

Kumar SA, Ravindra HV, Srinivasa YG (1997) In-process tool wear monitoring through time series modeling and pattern recognition. Int J Prod Res 35(3):739–751

Kumar A, Tseng F, Guo Y, Chinnam RB (2008) Hidden-markov model based sequential clustering for autonomous diagnostics. Proceedings of the International Joint Conference on Neural Networks, Hong Kong, China, 3345-3351, 1-8 June 2008

Lee S, Li L, Ni J (2010) Online degradation assessment and adaptive fault detection using modified hidden markov model. J Manuf Sci E-T ASME 132(2):021010-1–021010-11

Li Z, Wu Z, He Y, Chu F (2005) Hidden Markov model-based fault diagnostics method in speed-up and speed-down process for rotating machinery. Mech Syst Signal Pr 19(2):329–339

Saglam H, Unuvar A (2003) Tool condition monitoring in milling based on cutting forces by a neural network. Int J Prod Res 41(7):1519–1532

Vallejo AJ, Nolazco-Flores JA, Morales-Menendez R, Sucar LE, Rodrıguez CA (2005) Tool-wear monitoring based on continuous hidden markov models. Lect Notes Comput Sc 3773:880–890

Viterbi J (1967) Error bounds for convolutional codes and an asymptotically optimal decoding algorithm. IEEE T Inform Theory 13(2):260–269

Wang L, Mehrabi MG, Kannatey-Asibu E (2002) Hidden markov model-based tool wear monitoring in turning. J Manuf Sci E-T ASME 124(3):651–658

Yu J (2010) Hidden markov models combining local and global information for nonlinear and multimodal process monitoring. J Process Contr 20(3):344–359

Zhang C, Yue X, Zhang X (2009) Cutting chatter monitoring using hidden markov models. Paper presented at the international conference on control, automation and systems engineering, Zhangjiajie, China, pp 504–507, 11–12 July 2009

Zhu K, Wong YS, Hong GS (2009a) Multi-category micro-milling tool wear monitoring with continuos hidden markov models. Mech Syst Signal Pr 23(2):547–560

Zhu K, Wong YS, Hong GS (2009b) Wavelet analysis of sensor signals for tool condition monitoring: a review and some new results. Int J Mach Tool Manu 49(7):537–553

Energy Management Using Storage Batteries in Large Commercial Facilities Based on Projection of Power Demand

Kentaro Kaji, Jing Zhang and Kenji Tanaka

Abstract This study provides three methods for projection of power demand of large commercial facilities planned for construction, for the operation algorithm of storage batteries to manage energy and minimize power costs, and for derivation of optimal storage battery size for different amounts of power demand and building use. The projection of power demand is derived based on statistics of building power demand and floor area. The algorithm for operating storage batteries determines the amount of purchased electricity on an hourly timescale. The algorithm aims to minimize the cost of power through two approaches: first by reducing the basic rate determined by the peak of power demand, and second by utilizing the power purchased and charged at nighttime when the price of power is lower. Optimization of storage battery size is determined by calculating internal rate of return, which is derived by considering the profit from energy management, cost, and storage battery lifetime. The authors applied these methods to commercial facilities in Tokyo. The methods successfully helped the facility owners to determine appropriate storage battery size and to quantify the profit from their energy management system.

Keywords Energy management · Storage battery · Power demand projection

K. Kaji (✉) · J. Zhang
Department of Technology Management for Innovation, Graduate School of Engineering, The University of Tokyo, Tokyo, Japan
e-mail: kaji@triton.naoe.t.u-tokyo.ac.jp

J. Zhang
e-mail: chou@sys.t.u-tokyo.ac.jp

K. Tanaka
Department of System Innovation, Graduate School of Engineering, The University of Tokyo, Tokyo, Japan
e-mail: tanaka@triton.naoe.t.u-tokyo.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_138,

1 Introduction

After the Great East Japan Earthquake on March 11, 2011, utilization of stationary batteries for demand-side electricity management has gathered social interest, and many companies such as real estate and electronics companies have been developing energy management services for offices, commercial buildings, and condominiums using energy storage systems (NEC press release 2012). Behind this trend are two energy-related anxieties shared among companies. The first is securing electricity in the event of blackout, and the second is energy cost, which has been rising because power companies cannot run their nuclear power plants since safety guidelines have not yet been established following the accident at the Fukushima Daiichi Nuclear Power Plant (Tokyo Electric Power Co. 2011).

Breakthroughs in large-scale storage batteries are also enabling utilization of storage batteries for stationary use. Batteries with capacities of 50 kWh to 2 MWh are being used in demonstration experiments conducted by the Japanese government and some electronics companies in communities in Japan.

By introducing stationary batteries, four effects can be expected:

1. Reduction of the basic rate, which is determined by the peak of power demand
2. Utilization of the power purchased and charged at nighttime when the price of power is cheaper than daytime
3. Enhancement of energy durability in the event of blackout
4. Energy supply service for adjacent buildings

However, methodologies have not yet been established for specification design of storage batteries optimized for energy consumption patterns, for the amount of power demand, or for operation of storage batteries to minimize energy cost.

There are some studies on the optimization of storage batteries and renewable power generators (Borowy and Salameh 1995; Protogeropoulos et al. 1998; Koutroulis et al. 2006; Yang et al. 2007); however, those studies do not consider the optimization of storage battery size from both technical and economical aspects. There are no studies that consider algorithms to decide the amount of purchased electricity on an hourly timescale while minimizing energy cost and pursuing the above effects. The authors have therefore developed an algorithm to pursue two objectives: minimizing energy cost and deriving appropriate storage battery size. A method to project power demand was also developed, because the proposed models are intended for planning building construction.

2 Model

In this section, methods for projection of power demand and a storage battery operation algorithm are discussed. To derive optimized storage batteries and evaluate the effect, power demand on hourly scale is projected, and then the appropriate storage battery size is decided by a time-marching energy management simulation using the algorithm. An evaluation method for the simulation results is also discussed in this section.

2.1 Projection of Power Demand

In this part, the method of power demand projection is discussed. The projection method consists of two essentials: "daily fluctuation," which means the fluctuation of the amount of power demand per day during the year, and "hourly fluctuation," which means the fluctuation of the amount of power demand per 30 min during the day.

Figure 1 shows the process of power demand projection. A daily fluctuation pattern is first derived by the process shown in Fig. 2.

First, the floor size of each target building usage is obtained. Usage is defined in this study as commercial, office, hotel, or other use. Second, power demand by floor size of each usage is obtained from statistics data or other existing data. Third, derive the amount of average daily power demand of each floor usage by multiplying the floor size with the power demand of each floor usage. Fourth, the average daily power demand of the whole building is derived by adding the amount of power demand of each usage and multiplying by a weighting factor *k*, as shown in Eq. (1). Fifth, the daily fluctuation pattern is derived by multiplying average power demand with a daily fluctuation coefficient, which is defined as a weighting factor on each day of the year, derived by dividing the amount of each

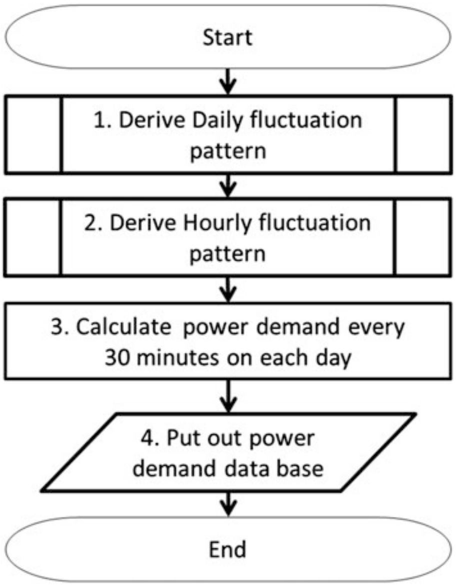


Fig. 1 Flow of power demand projection

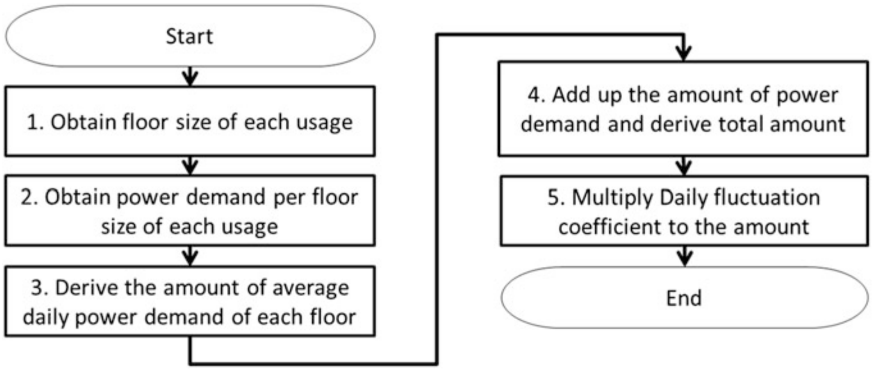


Fig. 2 Flow of deriving daily fluctuation pattern

daily power demand by the average amount of power demand of existing statistics data. The computation of the fifth step is shown as Eq. (2).

$$Average\,Power\,Demand = k * \sum Floor\,Size * Power\,Demand\,of\,Each\,Usage \tag{1}$$

$$\begin{aligned} &Daily\,Fluctuation\,Pattern\ (n) = DFC(n) * Average\,Power\,Demand \\ &DFC(n) : Daily\,Fluctuation\,Coefficient\,of\,the\,"n"th\,day\,(n = 1, 2, \ldots, 365) \end{aligned} \tag{2}$$

The second step of the process of power demand projection in Fig. 1 is shown in detail in Fig. 3.

The first step in deriving the hourly fluctuation pattern is to obtain power demand at 5:00 and 17:00 of an existing building whose usage is the same as the target building. This aims to obtain the maximum and minimum power demand of an existing building. According to our previous case studies of existing buildings,

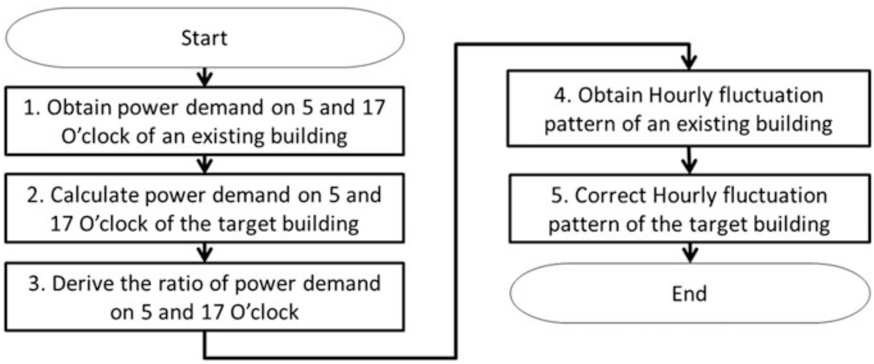


Fig. 3 Flow of deriving hourly fluctuation pattern

power demand is minimal at 5:00 and maximal at 17:00. Second, calculate power demand at 5:00 and 17:00 for the target building by adding up power demand of each floor in use at 5:00 or 17:00. The approach to deriving power demand of each usage floor is the same as in Eq. (1). The process of the second step is shown as Eq. (3). Third, derive the ratio of power demand by dividing power demand at 17:00 by that at 5:00. Fourth, obtain the hourly fluctuation pattern of the building whose power demand at 5:00 and 17:00 is obtained in the first step. Fifth, the hourly fluctuation pattern of the target building is derived by correcting the pattern of the existing building according to Eq. (4).

$$\begin{aligned}&Power\ Demand(t) = \sum PDEUF(t)\\&Power\ Demand(t) : Power\ demand\ at\ t : 00\\&PDEUF(t) : Power\ demand\ of\ each\ usage\ floor\ on\ t : 00\ (t = 5, 17)\end{aligned} \tag{3}$$

$$\begin{aligned}&D(k) = E(5) + 0.5 * \frac{\alpha_{target} - 1}{\alpha_{existing} - 1} * \{E(17) - E(5)\} * \left[1 - \cos\left\{\frac{E(k) - E(5)}{E(17) - E(5)} * \pi\right\}\right]\\&D(k) : Power\ demand\ at\ k : 00\ of\ the\ target\ building\ (normalized\ form)\\&E(k) : Power\ demand\ at\ k : 00\ of\ the\ existing\ building\ (normalized\ form)\\&\alpha_{target} : Ratio\ of\ power\ demand\ at\ 5 : 00\ and\ 17 : 00\ of\ the\ target\ building\\&\alpha_{existing} : Ratio\ of\ power\ demand\ at\ 5 : 00\ and\ 17 : 00\ of\ the\ existing\ building\end{aligned} \tag{4}$$

The third step of the process of power demand projection in Fig. 1 is to calculate power demand every 30 min by dividing the amount of daily power demand into 48 steps according to hourly fluctuation pattern. Then in the fourth step, a database of projected power demand of the target building is attained in 48 steps a day, over 365 days.

2.2 Algorithm for Operating Storage Batteries

The purpose of the algorithm is to decide the minimum value of the maximum amount of power per 30 min, purchased from the grid. By deciding an appropriate minimum peak, the amount of power charged in the storage battery can be discharged effectively during the peak time, so the basic electricity fee ratio can be minimized.

Another purpose is to minimize the minimum amount of power purchased from the grid, to prevent excessive charging of the storage battery. By deciding the minimum amount of power purchased, ill effects on purchase planning such as a sudden increase of power purchasing at the beginning of nighttime can be prevented. Figure 4 shows the flow of the algorithm. After obtaining and sorting projected power demand data in the first and second steps, the maximum amount of purchased power is decided in the third and fourth steps. In the fourth step the maximum amount of power is derived in between line [$i - 1$] and line [i], using the bisection method. The minimum amount of purchased power is decided in the fifth and sixth steps in the same way as deciding maximum purchased power.

2.3 Evaluation Method for the Result of Energy Management Simulation

The feasibility of introducing storage batteries is evaluated based on the unit price of storage batteries and maintenance cost, and on the profit considering the amount of reduced basic electricity fees and commodity electricity fees. In calculating the profit and the cost, device lifetimes and profit discount ratios are also considered, as are the price of electricity and storage batteries.

3 Case Study

3.1 Projection of Power Demand

We applied the model to commercial buildings planned for construction in Tokyo, Japan. Table 1 shows an example of statistical data on power demand and the result for the projected amount of power demand in the target building.

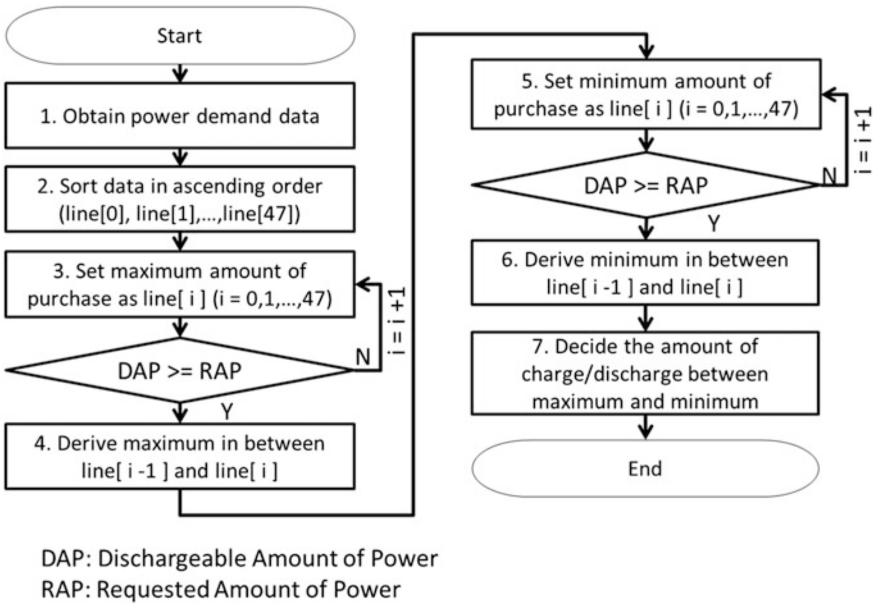


Fig. 4 Algorithm for operating storage battery

Table 1 Projected power demand for the target building

Statistics data		Target building		
Purpose	Power demand (kWh/day/m^2)	Purpose	Floor size (m^2)	Power demand (MWh/day)
Office	1.4	Office	69,000	72.5
Commerce	2.6	Commerce	29,000	56.6
Other	0.38	Other	72,000	20.5
–		Total	170,000	149.5

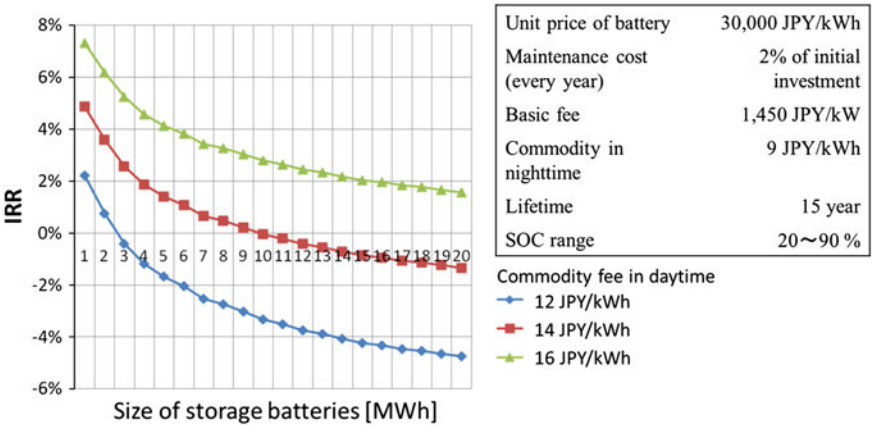


Fig. 5 Internal rate of return versus battery size for three daytime commodity fees

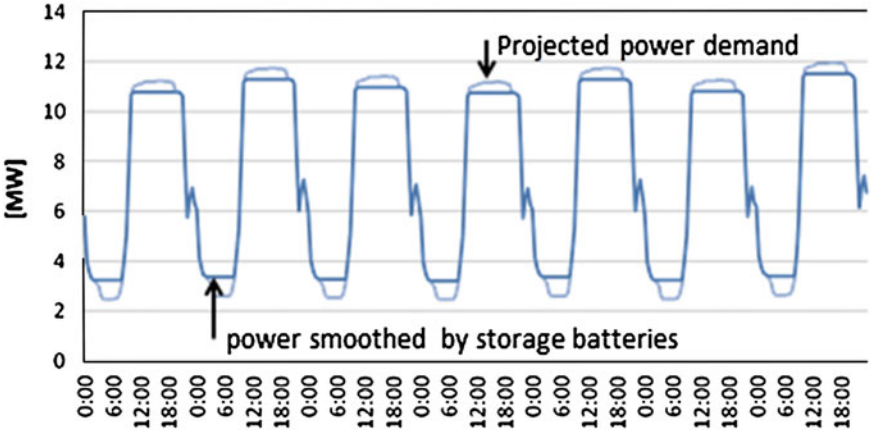


Fig. 6 Change in power purchased from the grid (July 3–9)

3.2 Evaluation of Simulation Result

We simulated energy management based on the projection, changing the storage battery size; then the internal rate of return of each case was calculated as shown in Fig. 5. Calculating the commodity fee in daytime as 16 JPY/kWh, the internal rate of return for all storage battery sizes up to 20 MWh is positive during the battery lifetimes. The size is limited when the commodity fee in daytime is 12 or 14 JPY/kWh. When deciding the storage battery size, the effect of energy durability in the event of blackout, and battery space limitations are also considered, as is profitability. We confirmed that the algorithm reduced projected peak by the storage batteries shown in Fig. 6, which shows change in purchased power after introducing 5 MWh storage batteries.

4 Conclusions

This study developed a projection method for power demand of buildings planned for construction and an algorithm for operating storage batteries, which can pursue profit by reducing the basic electricity fee and by utilizing cheaper power purchased in nighttime. As a case study, the models were applied to commercial buildings planned for construction, and the effect of the models and the profit brought by storage batteries were verified.

Acknowledgments This work was partially supported by Social System Design, Co. and its president Hideaki Miyata, to whom we express our gratitude. The authors would also like to express our deep appreciation for the reviewers' helpful comments and advice, which greatly improved this paper.

References

Borowy B, Salameh Z (1995) Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system. IEEE Trans Energy Conver 11:367–375

NEC press release (2012) Tokyo Electric Power Co. press release. http://www.tepco.co.jp/e-rates/individual/kaitei2012/

Protogeropoulos C, Brinkworth BJ, Marshall RH (1998) Sizing and techno-economical optimization for hybrid solar photovoltaic/wind power systems with battery storage. Int J Energy Res 21:465–479

Koutroulis E, Kolokotsa D, Potirakis A, Kalaitzakis K (2006) Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms. Sol Energy 80:1072–1088

Yang H, Lu L, Zhou W (2007) A novel optimization sizing model for hybrid solar-wind power generation system. Sol Energy 81:76–84

The Optimal Parameters Design of Multiple Quality Characteristics for the Welding Thick Plate of Aerospace Aluminum Alloy

Jhy-Ping Jhang

Abstract The welding of different metal materials such as aerospace aluminum alloy has superior mechanical characteristics, but the feasible setting for the welding parameters of the TIG has many difficulties due to some hard and crisp inter-metallic compounds created within the weld line. Normally, the setting for welding parameters does not have a formula to follow; it usually depends on experts' past knowledge and experiences. Once exceeding the rule of thumb, it becomes impossible to set up feasibly the optimal parameters, and the past researches focus on thin 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 aerospace aluminum alloy thick plate. It uses TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and Artificial Neural Network (ANN) to train the optimal function framework of parameter design for the thick plate weldment of aerospace aluminum alloy. To improve previous experimental methods for multiple characteristics, this research method employs ANN and all combinations to search the optimal parameter such that the potential parameter can be evaluated more completely and objectively. Additionally, the model can learn the relationship between the welding parameters and the quality responses of different aluminum alloy materials to facilitate the future applications in the decision-making of parameter settings for automatic welding equipment. The research results can be presented to the industries as a reference, and improve the product quality and welding efficiency to relevant welding industries.

Keywords TIG · TOPSIS · ANN · Aerospace aluminum alloy · Taguchi method

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

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_139,

1 Introduction

The welding of different metal materials has superior mechanical characteristics, but the feasible setting for the welding parameters of the TIG has many difficulties due to some hard and crisp inter-metallic compounds created within the weld line. Normally, the setting for welding parameters does not have a formula to follow; it usually depends on experts' past knowledge and experiences. Once exceeding the rule of thumb, it becomes impossible to set up feasibly the optimal parameters, and the past researches focus on thin 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 method. The search algorithm is easy to fall into local optimal but not global optimal.

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) propose the algorithm of Grey relational analysis and TOPSIS for multiple quality characteristics.

Tong and Su (1997a, b; Tong and Wang 2000) propose multi-response robust design by principal component analysis and by Fuzzy multiple attribute decision making.

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

Juang and Tarng (2002) find that the factors of welding current and welding torch drift speed are 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 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.

In order to be efficient for solving optimal parameters problems, our research uses TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and ANN to find the global optimal function framework of parameter design for the thick plate weldment of aerospace aluminum alloy.

2 Methodologies

2.1 Structure

This research collects the data of 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 compute *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. We use TOPSIS method to integrate all *S*/*N* ratios of multiple quality characteristics into C_i. The factors level and C_i values are training by ANN to find the optimal frame which associates all combinations to find global optimal solution. Finally, the global optimal is obtained by the confirmation experiment of different optimal solutions with respect to different methods.

2.2 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:

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

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^-).

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad \text{where, } v_j^+ = \max_i [v_{ij}], \tag{2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad \text{where, } v_j^- = \min_i [v_{ij}], \tag{3}$$

Step 5. Arrange the priorities of the programs.

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{4}$$

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

Figure captions should be below the figures; table names and table captions should be above the tables. Use the abbreviation "Fig." even at the beginning of a sentence.

3 Experimental Planning

3.1 Experimental Allocation

In this study, we use the welding material is the aerospace aluminum alloy (7075) thick plate(8 mm), size is 80 × 60 × 8 mm, the welding diagram is showed in Fig. 1', 5 sets of control factors are considered; each control factor has 3 levels.

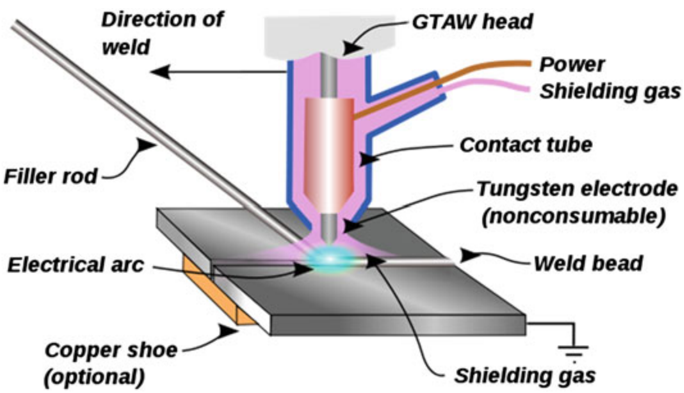


Fig. 1 The welding graph

Table 1 Experimental factors and levels

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

Please refer to Table 1 for the experimental factor and its level. The noise factor is 3 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, 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 2112 G2014, and in accordance with the specimen 13B. Shock test is the specimen compliance CNS 3033 G2022, and in accordance with V-concave regulations.The formula of energy shock is

$$E = Wh_1 - Wh_2 = WR(COS\beta - COS\alpha) \tag{5}$$

where, α: initial angle, 143°; β: shocking angle;
W: weight, 26.63 kgf; R: radius, 0.635 m

3.2 Analysis of Individual Quality Characteristic

In this study, 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.

$$\text{Nominal-the-best } S/N = 10 \times \log\left[\frac{S_m - V_e}{n \times V_e}\right] \text{ where, } S_m = \frac{(\sum y_i)^2}{n},\ V_e = \frac{1}{n-1}\left(\sum y_i^2 - S_m\right) \tag{6}$$

$$\text{Larger-the-better } S/N = -10 \times \log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \tag{7}$$

3.3 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. The value of the five levels of control factors as input, the *Ci* value of TOPSIS as output, use BNN to build models. In this study, we select the marginal value (the maximum and minimum) and the median value of 27 groups of samples as the test samples, and the remaining samples for training, the criteria of decision-making is according to the MSE values of ANN, the MSE of training samples and test samples are the more smaller the more better. The optimal frame which associates all combinations finds global optimal solution.

4 Results Analysis

4.1 The Optimal Combinations of Cross Table

We compute the *S*/*N* ratios, the combination of factor levels, ANOVA, contribution rate of multiple quality characteristics, which are compiled into a Cross Table to find the optimal combinations, as shown in Table 2.

4.2 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 3.

4.3 Confirmation Experiment

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

4.4 Results and Discussions

From Table 4, the *Ci* of ANN and all combinations 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 ANN and all combinations is the total optimal welding parameters design of aerospace Aluminum alloy thick plate.

The significant factors are welding gap and striking Tungsten length.

Table 2 Cross table

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

Table 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			*	*		

Table 4 The comparison *Ci* of confirmation experiment

Optimal combinations	Cross table A2B2C3D2E3	TOPSIS A2B2C3D3E2	ANN and all combinations
Ci value	0.77	0.90	0.93

5 Conclusions

The conclusions are summarized in the following:

1. The ANN and all combinations method used in this case are better than others. So the optimal combination of ANN and all combinations is the total optimal welding parameters design of aerospace Aluminum alloy thick plate.
2. The significant factors are welding gap and striking Tungsten length in this case.
3. In the future, we can consider using 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.

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 Logistics Manag 2(1):27–34

Chang HH (2006) Dynamic multi-response experiments by back propagation 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'l 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, Wang CH (2000) Optimizing multi-response problems in a dynamic system by grey relational analysis. J Chin Inst Ind Eng 17(2):147–156

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

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

Synergizing Both Universal Design Principles and Su-Field Analysis to an Innovative Product Design Process

Chun-Ming Yang, Ching-Han Kao, Thu-Hua Liu, Ting Lin and Yi-Wun Chen

Abstract To promote developing more usable and accessed, daily-used products that could meet the rigorous requirements from diverse consumers at the present time, this research proposed an innovative product design process by synergizing both universal design (UD) principles and TRIZ tools. This newly developed process started with stating the design problems via a UD evaluation, followed by PDMT analysis to develop the preliminary design directions. The directions were then analyzed by using Su-Field models in order to locate the potential resolutions from TRIZ's 76 Standard Solutions. Finally, a case study was conducted to demonstrate how this innovative design process works. Study result shows that this approach can help identify the core of the problem and locate the improved product concepts effectively, resulting in generating more creative and usable product design.

Keywords TRIZ · Su-field analysis · Universal design · PDMT

C.-M. Yang (✉) · C.-H. Kao · T.-H. Liu · T. Lin · Y.-W. Chen
Department of Industrial Design, Ming Chi University of Technology, 84 Gungjuan Road, Taishan Distric, New Taipei City, Taiwan
e-mail: cmyang@mail.mcut.edu.tw

C.-H. Kao
e-mail: kaoch@mail.mcut.edu.tw

T.-H. Liu
e-mail: thliu@mail.mcut.edu.tw

T. Lin
e-mail: linting20@gmail.com

Y.-W. Chen
e-mail: lisa60832@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_140,

1 Introduction

Declining birth rates are leading to an increase in the proportion of aged people in the population. For this reason, more emphasis is being placed on universal design. However, difficulties often occur in the design of universally applicable products because the principles offered are too general. Effectively using the principles of universal design requires a tool to provide direction in the design process. TRIZ is an instrument capable of dealing with a lack of inspiration and provides solutions to creativity-related problems. This study integrated universal design with TRIZ to establish a process for the systematic development of products, capable of guiding designers toward innovative solutions.

2 Literature Review

2.1 Universal Design

After World War II, the medical treatment for the injured soldiers and social turbulence led to the concern over the issue of "Barrier-free Design". During the implementation of this concept, related issues were expanded to a broader scope, not only covering individuals with physical and mental disabilities, but also the broad user population. Thus, it evolves into the concept of universal design in modern time (Duncan 2007). In 1990, the U.S. approved ADA. Although laws are passed to protect the individuals with disabilities, they still face much inconvenience in use of space or products. Therefore, The Center of Universal Design led by Ronald L. Mace, based on ADA, treated universal design as "all products and the built environment to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability, or status in life", and advocated "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Duncan 2007; The Center for universal design 1997).

Scholars have presented a variety of definition for the principles of universal design. The Center for Universal Design (1997) proposed seven principles: (1) equitable use, (2) flexibility in use, (3) simplicity and intuitive operation, (4) perceptible information, (5) tolerance for error, (6) low physical effort, and (7) size and space for approach and use. These can be used to evaluate whether the design of a product is universal and direct the actions of designers accordingly. Nakagawa (2006) pointed out the shortcomings of the seven universal design principles and outlined three additional attributes: durability and production economics, quality and aesthetics, and health and natural environment. These were combined with 37 sub-principles to create an evaluation form for universal design, known as the Product Performance Program (PPP).

Universal design principles have been widely mentioned and applied by researchers. According to Preiser and Ostroff (2001), universal design refers to the planning and design regardless of the user. They also claimed that universal design involves a sense of space, which means that knowledge databases related to ergonomics can also be used in universal design. Preiser (2008) categorized the literature dealing with universal design as relating to industrial design, product design, fashion design, interior design, architecture, urban design and planning, information technology, health facility planners, administration, facility managers, and environmental psychologists. He also suggested that PPPs be designed to fit the domain. Muller (1997) provided background descriptions, definitions, and case analysis based on the seven principles outlined by the Center for Universal Design.

2.2 TRIZ

The Theory of Inventive Problem Solving (TRIZ) was created by Genrich Altshuller (1926–1998), who began investigating solutions to the problems of invention in 1946. During his patent research, Altshuller found that among hundreds of thousands of patents, only approximately 40,000 (2 %) were actual pioneering inventions (Altshuller et al. 1997). Altshuller (1999) observed three types of obstacles to thought processes during the evolution of innovation and invention: psychological inertia, limited domain knowledge, and trial and error method. Overcoming these obstacles and avoiding being led astray require a theory of innovation and invention and TRIZ is an instrument capable of dealing with multiple obstacles to thought processes.

TRIZ provides systematic solutions to problems, including scenario analysis, contradiction analysis, substance-field (su-field) analysis, the ARIZ problem-solving system, 40 inventive principles, and 76 standard solutions (Terninko et al. 1998). Despite the many techniques in TRIZ, the primary goal and problem-solving techniques still focus on identifying contradictions and ideal solutions (Ideation International Inc. 2006), and in the event that a system requires improvements, su-field analysis can be used for prediction.

2.3 Substance-Field Analysis

Su-Field Analysis was proposed by Altshuller in 1979. He developed models that described structural problems within systems and used symbolic language to clearly express the functions of technical systems (subsystems), thereby accurately describing the constituent elements of these systems and the relationships among them (Altshuller 1984). The elements necessary to construct and define the technical model of a system include two substances (S) and a field (F) (Fig. 1). A triangular model presents the design relationships among them. The substances can

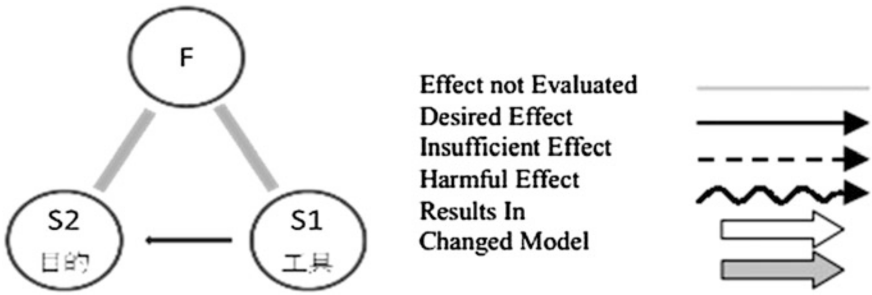


Fig. 1 Triangular model of substance-field analysis and legend of triangular model

be any objects. The symbol for substance is S, and S1 generally represents a passive role, S2 denotes an active role, and S3 indicates the introduced substance. The field displays the manner in which the substances interact. In physics, there are only four types of fields: gravity, electromagnetism, the nuclear force field, and the particle field (Savransky 2000; Mann 2007). The type of field determines the process of actions, and different relationships between the substances and the field correspond to different standard solutions. In the constructed model, the structure of the interactions among the three often demonstrates the following effects: the desired effect, harmful effects, and insufficient effects. These effects are displayed using different lines (Fig. 1) (Mann 2007). These symbols clearly show how the problem is structured, thereby enabling users to clarify the problem.

In the framework of the su-field analysis model, a system generally includes a variety of functions, each of which requires a model. TRIZ divides functions into the following four categories (Terninko et al. 1998):

1. Effective complete system: This function possesses all three components, which are all effective and display the effects desired by the designers.
2. Incomplete system: A portion of the three components does not exist and therefore requires additional components to achieve the effective complete function or a whole new function as a replacement.
3. Ineffective complete system: All of the components that provide the function exist, but the effects desired by the designers are incomplete.
4. Harmful complete system: All of the components that provide the function exist, but the effects produced conflict with the ones that the designers desire. During the process of innovation, harmful functions must be eliminated.

With the exception of (a), all of the models have problems that require improvement. 76 Standard Solutions, developed by Altshuller in conjunction with substance-field, can be used to find solutions to problems in any given model. 76 Standard Solutions can be divided into five classes (Table 1) (Savransky 2000). Although su-field analysis and the 76 Standard Solutions can be adopted independently, combining them is generally more effective in deriving elegant solutions.

Table 1 76 standard solutions

Class	Description	Number of standard solutions
Class 1	Improving the system with no or little change	13 Standard solutions
Class 2	Improving the system by changing the system	23 Standard solutions
Class 3	System transitions	6 Standard solutions
Class 4	Detection and measurement	17 Standard solutions
Class 5	Strategies for simplification and improvement	17 Standard solutions

2.4 Development of Systematic Universal Design Procedure Based on Substance-Field Analysis

Striving to follow all the principles of universal design can easily result in products that lack creativity. Thus, this study integrated universal design to detect problems and evaluate products, and then used the problem-solving techniques of TRIZ to derive solutions. This approach results in design concepts featuring the best of both worlds. This study utilized universal design principles as the main framework and integrated TRIZ theory with su-field analysis models to establish an innovative procedure for the implementation of universal design. We first investigated problems that did not conform to universal design principles using the PPP questionnaire. We then defined the preliminary direction for problem-solving using the PDMT approach before analyzing the problem using a su-field analysis model. Adopting a suitable solution from the 76 Standard Solutions of TRIZ enabled the generation of innovative solutions based on universal design.

Participants were required to actually operate the existing product before answering the 37 question items in the PPP questionnaire regarding their satisfaction towards the design of the product. Scoring was based on a Likert 5-point Scale, ranging from “very satisfied” (40) to “very dissatisfied” (0). We categorized and calculated the mean scores from problems originating from the same principles and selected the universal design principle with the lowest score as the defect that was most in need of improvement. We assumed an optimal solution method based on the objective and used PDMT (Chen 2008) to analyze the primary problem. This study derived the purpose, directions, methods, and tools for PDMT analysis. The universal design principle with the lowest score in the PPP scale was set as the problem. Concept development was then based on the optimal solution method, and the solution was extended from the direction of concept development.

Using su-field analysis, we then constructed a triangular model for the preliminary direction of problem-solving. We substituted the action of the component or product into the triangular model as *F*, the solution field (solution), and the medium of the object as S2, the improvement tool; S1 denoted the product or component to be improved. Once completed, the triangular model clearly identifies the part of the system requiring improvement using the 76 Standard Solutions. We then analyzed the problem (Table 2) and determined whether the problem was

Table 2 Problem analysis using 76 standard solutions

Problem analysis using 76 standard solutions	YES/NO
1. Does the system possess two substances and one field?	
2. Is the problem related to measurement?	
3. Do harmful relationships exist in the system?	

related to measurement. If this were the case, Class 4 (detection and measurement) would be taken into consideration. If the problem was not related to measurement, we would seek principle solutions from the other four classes and develop concepts to derive the final solution for the designers.

3 Results

This study adopted the common pen as a case study. According to the questionnaire results, Principle 6 (low physical effort) was identified as the primary issue in the use of pens. We therefore set "no fatigue after long-term use" as the ultimate objective of our ideal solution. This objective provided a suitable problem-solving direction and feasible solutions as well as direction analysis. We then derived the characteristics of weight, shape, reminder, and method of use, from which we extended eight improvement methods: material, ergonomics, time reminder, sound, vibration, other external forces, cease in pen use, and contact with more than paper. Using su-field analysis, we constructed a model and selected a solution from those derived using PDMT to create a substance-field model.

Case 1: In this instance, weight function was considered. Once the su-field model was constructed (Fig. 2), we defined the system accordingly and considered the sequence of events in using the pen. In accordance with the answers in the table above, we had to consider all five classes. For the sake of conciseness, we simply outline the results of our search and comparison, 5.1.1.1 of introducing substances, which involves the use of "nothing", such as vacuum, air, bubbles, foam, voids, and gaps. These suggestions led us to produce a pen with a skeletal structure to reduce the weight of the pen and prevent fatigue after long-term use (Fig. 2).

Case 2: In this case, cease using the pen was considered. With constructing the substance-field model, we incorporated an unknown *F*, in the hopes of changing the way pens are generally used (Fig. 3). For this, we employed 2.4.1 of detection and measurement in the 76 Standard Solutions, adding ferromagnetic materials. We magnetized the ink and placed a magnetic pad before the fingers of the participants so that they could write effortlessly (Fig. 3).

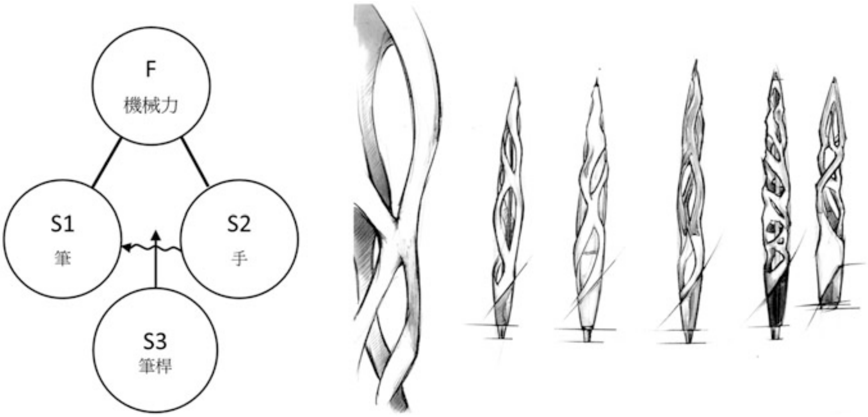


Fig. 2 Triangular model and concept development for case 1

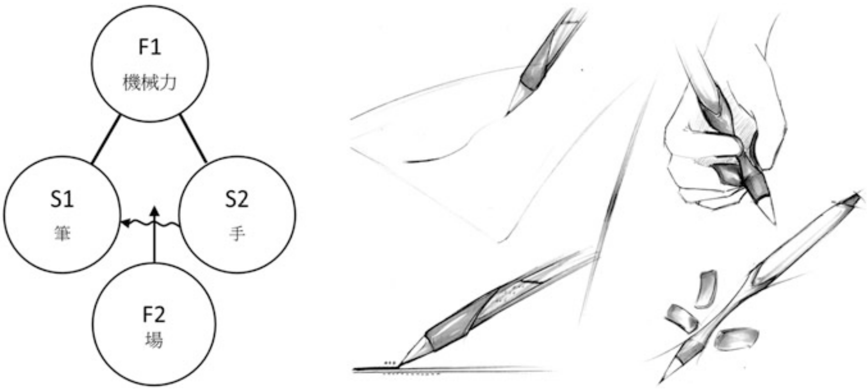


Fig. 3 Triangular model and concept development for case 2

4 Conclusion

Universal design is meant to satisfy the needs of the greater majority rather than a perspective of user issues from social concern. Universal design principles can provide reasonable suggestions for the development and design of products; however, designers often fail to make breakthroughs or are unsure of how to proceed. This study used TRIZ tools to provide innovative design procedure applicable to all domains. We also adopted su-field analysis to depict problems graphically in order to enable users to clarify and identify problems. Our results indicate that the integration of universal design principles and TRIZ tools provides a logical procedure for designers to follow to ensure that the resulting products are creatively realized and in line with the principles of universal design.

Acknowledgments The authors are grateful for support of the National Science Council, Taiwan under grant NSC101-2221-E-131-002-MY2.

References

Altshuller G (1984) Creativity as an exact science. Gordon and Breach, New York
Altshuller G, Shulyak L, Rodman S (1997). 40 principles: TRIZ keys to innovation (Vol. 1). Technical Innovation Center Inc
Altshuller G (1999) The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical innovation center, Worcester
Chen CH (2008) Introduction to TRIZ and CREAX. Workshop (Pitotech Co Ltd). 2 Oct 2008
Duncan R (2007) Universal design-clarification and development. A Report for the Ministry
Ideation International (2006) History of TRIZ and I-TRIZ. http://www.ideationtriz.com/history.asp. Accessed 21 Nov 2012
Mann D (2007) Hands-on systematic innovation. Tingmao, Taipei
Mueller J (1997) Case studies on universal design. Des Res Methods J 1(1)
Nakagawa S (2006) Textbook for universal design. Longsea press, Taipei
Preiser WFE (2008) Universal design: from policy to assessment research and practice. Archnet-IJAR, 2
Preiser W, Ostroff E (2001) Universal design handbook. New York
Savransky SD (2000) Engineering of creativity: introduction to TRIZ methodology of inventive problem solving. CRC Press, Boca Raton
Terninko J, Zusman A, Zoltin B (1998) Systematic innovation-introduction to TRIZ. CRC Press, Boca Raton
The Center of Universal Design (1997) http://www.ncsu.edu/project/design-projects/udi/. Accessed 3 Nov 2012

The Joint Determination of Optimum Process Mean, Economic Order Quantity, and Production Run Length

Chung-Ho Chen

Abstract In this study, the author proposes a modified Chen and Liu's model with quality loss and single sampling rectifying inspection plan. Assume that the retailer's order quantity is concerned with the manufacturer's product quality and the quality characteristic of product is normally distributed. Taguchi's symmetric quadratic quality loss function will be applied in evaluating the product quality. The optimal retailer's order quantity and the manufacturer's process mean and production run length will be jointly determined by maximizing the expected total profit of society including the manufacturer and the retailer.

Keywords Economic order quantity · Process mean · Production run length · Taguchi's quadratic quality loss function

1 Introduction

The supply chain system is a major topic for the manufacturing industries in order to obtain the maximum expected total profit of society including the manufacturer and the retailer. The manufacturer's objective needs to consider the sale revenue, the manufacturing cost, the inspection cost, and the inventory cost for having the maximum expected profit. The retailer's objective needs to consider the order quantity, the holding cost, the goodwill loss of cost, and the used cost of customer for having the maximum expected profit. How to get a trade-off between them should be available for further study. Chen and Liu (2007) presented the optimum profit model between the producers and the purchasers for the supply chain system with pure procurement policy from the regular supplier and mixed procurement

C.-H. Chen (✉)
Department of Management and Information Technology, Southern Taiwan University of Science and Technology, Tainan, Taiwan
e-mail: chench@mail.stust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_141,

policy from the regular supplier and the spot market. Chen and Liu (2008) further proposed an optimal consignment policy considering a fixed fee and a per-unit commission. Their model determines a higher manufacturer's profit than the traditional production system and coordinates the retailer to obtain a large supply chain profit.

In Chen and Liu's (2008) model with traditional production system, they neglected the effect of product quality on the retailer's order quantity and only considered the order quantity obeying the uniform distribution. In fact, the retailer's order quantity is concerned with product quality. Chen and Liu's (2008) model with simple manufacturing cost did not consider the used cost of customers in traditional production system. Hence, the modified Chen and Liu's (2008) model needs to be addressed for determining the optimum process parameters. Chen (2010) proposed a modified Chen and Liu's (2008) model with quality loss and single sampling plan based on the dependent assumption of the retailer's order quantity and manufacturer's product quality. However, Chen (2010) neglected manufacturer's inventory cost and the cost for the non-conforming products in the sample of accepted lot.

Hanna and Jobe (1996) discussed the quality characteristic of product and quality cost on the effect of lot size. They determine the optimal order quantity lot when the model with quality cost evaluation based on 100 % inspection, sampling inspection, and no inspection for products. Jaber et al. (2009) considered entropic order quantity model when product characteristic is not perfect. Their results suggested that larger quantities should be ordered than those of the classical economic order quantity model. Economic selection of process mean is an important problem for modern statistical process control. It will affect the expected profit/cost per item. Recently, many researchers have addressed this work. Both 100 % inspection and sampling inspection are considered for different models. Taguchi (1986) presented the quadratic quality loss function for redefining the product quality. Hence, the optimum product quality should be the quality characteristic with minimum bias and variance. Recently, his quality loss function has been successfully applied in the problem of optimum process mean setting.

In this paper, the work will propose a modified Chen and Liu's (2008) model with quality loss, manufacturer's inventory cost, and single sampling rectifying inspection plan. Assume that the retailer's order quantity is concerned with the manufacturer's product quality and the quality characteristic of product is normally distributed. The non-conforming products in the sample of accepted lot are replaced by conforming ones. If the lot is rejected, then all of the products are rectified and sold at the same price as the products of accepted lot. Taguchi's (1986) symmetric quadratic quality loss function will be applied in evaluating the product quality. The optimal retailer's order quantity and the manufacturer's process mean and production run length will be jointly determined by maximizing the expected total profit of society including the manufacturer and the retailer. The motivation behind this work stems from the fact that the neglect of the quality loss within the specification limits and manufacturer's inventory cost should have the overestimated expected total profit of society.

2 Modified Chen and Liu's (2008) Traditional System Model

Taguchi (1986) redefined the product quality as the loss of society when the product is sold to the customer for use. The used product for customer maybe occur a lot of costs including maintenance, safety, pollution, and sale service. Chen and Liu's (2008) model also did not consider the used cost of customers. The neglect of the quality loss within the specification limits should have the overestimated expected profit per item for the retailer.

Assume that the quality characteristic of Y is normally distributed with unknown mean $\mu_y$and known standard deviation σ_y, i.e., $Y \sim N\left(\mu_y, \sigma_y^2\right)$ and $X|Y \sim N(\lambda_1 + \lambda_2 y, \sigma^2)$, where λ_1, λ_2, and σ^2 are constants. Hence, we have $X \sim N\left(\lambda_1 + \lambda_2\mu_y, \lambda_2^2\sigma_y^2 + \sigma^2\right)$ and $Y|X \sim N\left(\frac{\lambda_2\sigma_y^2(x-\lambda_1)+\mu_y\sigma^2}{\lambda_2^2\sigma_y^2+\sigma^2}, \frac{\sigma_y^2\sigma^2}{\lambda_2^2\sigma_y^2+\sigma^2}\right)$.

Taguchi (1986) proposed the quadratic quality loss function for evaluating the product quality. If the product quality characteristic is on the target value, then it has the optimum output value. However, we need to input some different resource in the production process. Hence, the process control needs to obtain minimum bias and variance for output product. According to Taguchi's (1986) definition for product quality, the retailer's expected profit should subtract the used cost of customer for product in order to avoid overestimating retailer's expected profit. Hence, the author proposes the following modified Chen and Liu's (2008) model.

The retailer's profit is given by

$$\pi_{PS}^R = \begin{cases} RX - WQ - H(Q - X) - X \cdot Loss(Y), & X <; Q,\ -\infty <; Y <; \infty \\ RQ - WQ - S(X - Q) \cdot Loss(Y), & X \geq Q,\ -\infty <; Y <; \infty \end{cases} \tag{1}$$

where X is the consumer demand which is an uniform distribution, $X \sim U[\mu_x - (\sigma_x/2), \mu_x + (\sigma_x/2)]$, μ_x is the mean of X, σ_x is the variability of X, and $f(x)$ is the probability distribution of X; R is a retailer purchasing a finished product from a regular supplier and reselling it at this price to the end customer; C is the regular manufacturer produces each unit at this cost; W is the regular manufacturer and the retailer entering into a contract at this wholesale price; Q is the regular manufacturer setting the wholesale price to maximize his expected profit while offering the buyer this specific order quantity; S is a goodwill loss for the retailer when realized demand exceeds procurement quantity; H is a carrying cost for the retailer when realized demand is less than procurement quantity; Y is the normal quality characteristic of product, $Y \sim N\left(\mu_y, \sigma_y^2\right)$; μ_y is the unknown mean of Y; σ_y is the known standard deviation of Y; $Loss(Y)$ is Taguchi's (1986) quadratic quality loss function per unit, $Loss(Y) = k(Y - y_0)^2$; k is the quality loss coefficient; y_0 is the target value of product.

The retailer's expected profit includes the sale profit when the demand quantity of customer is less than order quantity, the sale profit when the demand quantity of customer is greater than order quantity, the carrying cost when the demand quantity of customer is less than order quantity, and the goodwill loss when the demand quantity of customer is greater than order quantity. From Chen (2010), we have the expected profit of retailer as follows:

$$E\left(\pi_{PS}^{R}\right) = E(\pi_1) + E(\pi_2) - E(\pi_3) - E(\pi_4) \tag{2}$$

where

$$E(\pi_1) = (R+H)\left\{\mu_k \Phi\left(\frac{Q-\mu_k}{\sigma_k}\right) - \sigma_k \phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} - (W+H)Q\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right) \tag{3}$$

$$\begin{aligned} E(\pi_2) =& (R-W+S)Q\left[1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] \\ & - S\left\{\mu_k[1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)] + \sigma_k \phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} \end{aligned} \tag{4}$$

$$\begin{aligned} E(\pi_3) = & kA^2\left\{\mu_k^3 \Phi\left(\frac{Q-\mu_k}{\sigma_k}\right) + 3\mu_k^2\sigma_k\left[-\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right]\right. \\ & + 3\mu_k\sigma_k^2\left[-\frac{Q-\mu_k}{\sigma_k}\cdot\phi\left(\frac{Q-\mu_k}{\sigma_k}\right) + \Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] + \sigma_k^3\left[-\left(\frac{Q-\mu_k}{\sigma_k}\right)^2\cdot\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right. \\ & \left. -2\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} + 2kAB\left\{\mu_k^2\left[\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] - 2\mu_k\sigma_k\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right. \\ & + \sigma_k^2\{-\frac{Q-\mu_k}{\sigma_k}\phi(\frac{Q-\mu_k}{\sigma_k})\} + k\left(B^2+C_0\right)\left\{\mu_k\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right) - \sigma_k\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} \end{aligned} \tag{5}$$

$$\begin{aligned} E(\pi_4) =& kA^2Q\left\{\mu_k^2\left[1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] + 2\mu_k\sigma_k\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right. \\ & \left. + \sigma_k^2\left\{\left[\left(\frac{Q-\mu_k}{\sigma_k}\right)\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] + \left[1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right]\right\}\right\} \\ & + 2kQAB\left\{\mu_k\left[1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right] + \sigma_k\phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} \\ & + kQ\left(B^2+C_0\right)\left\{1-\Phi\left(\frac{Q-\mu_k}{\sigma_k}\right)\right\} \end{aligned} \tag{6}$$

where $\mu_k = \lambda_1 + \lambda_2 \cdot \mu_y$; $\sigma_k = \sqrt{\lambda_2^2\sigma_y^2 + \sigma^2}$; $A = \frac{\lambda_2^2\sigma_y^2}{\lambda_2^2\sigma_y^2+\sigma^2}$; $B = \frac{\mu_y\sigma^2-\lambda_1\lambda_2^2\sigma_y^2}{\lambda_2^2\sigma_y^2+\sigma^2} - y_0$; $C_0 = \frac{\sigma_y^2\sigma^2}{\lambda_2^2\sigma_y^2+\sigma^2}$; $\Phi(\cdot)$ is the cumulative distribution function of standard normal random variable; $\phi(\cdot)$ is the probability density function of standard normal random variable.

Assume that the retailer's order quantity is equal to the lot size of single sampling rectifying inspection plan. If the lot is accepted, then the selling price of product per unit is W. The non-conforming products in the sample of accepted lot are replaced by conforming ones. Let R_I denote the cost of replacing a defective item by an acceptable item in the accepted lot. If the lot is rejected, then all of the products are rectified and sold at a price W. Let R_L denote the expected cost of replacing all rejected items found in a rejected lot. Hence, the manufacturer's profit under adopting single rectifying inspection plan for determining the quality of product lot is given by

$$\pi_{PS}^{S} = \begin{cases} WQ - ni - DR_I - Qc\mu_y, & D \leq d_0 \\ WQ - Qi - R_L - Qc\mu_y, & D > d_0 \end{cases} \tag{7}$$

where n is the sample size; c is the variable production cost per unit; i is the inspection cost per unit; d_0 is the acceptance number; D is the number of non-conformance in the sample; c is the cost of processing per unit; i is the inspection cost per unit; $R_L = R_I \cdot d_{rl}; d_{rl}$ is the expected number of defective items in a rejected lot (= the expected number of defectives found in the sample, given that the lot was rejected + the expected number of defectives in the non-sample portion of the lot),

$d_{rl} = E(D|D > d_0) + p(Q - n) \quad E(D|D > d_0) = \dfrac{np\left[1 - \sum_{x=0}^{d_0-1} \frac{e^{-np}(np)^x}{x!}\right]}{1 - \sum_{x=0}^{d_0} \frac{e^{-np}(np)^x}{x!}}$; p is the probability of a defective item$\left(= 1 - \left[\Phi\left(\frac{U-\mu_y}{\sigma_y}\right) - \Phi\left(\frac{L-\mu_y}{\sigma_y}\right)\right]\right)$; L is the lower specification limit of product; U is the upper specification limit of product; $\Phi(\cdot)$is the cumulative distribution function of the standard normal random variable.

The manufacturer's expected profit for the product lot is

$$\begin{aligned} E_1\left(\pi_{PS}^{S}\right) &= \left(WQ - ni - DR_I - Qc\mu_y\right)P_1 + \left(WQ - Qi - R_L - Qc\mu_y\right)(1 - P_1) \\ &= [R_L + (Q - n)i]P_1 - R_I npP_0 + \left(WQ - R_L - Qi - Qc\mu_y\right) \end{aligned} \tag{8}$$

where

$$P_1 = \sum_{d=0}^{d_0} \frac{e^{-np} \cdot (np)^d}{d!} \tag{9}$$

$$P_0 = \sum_{d=0}^{d_0-1} \frac{e^{-np} \cdot (np)^d}{d!} \tag{10}$$

The manufacturer should consider the inventory cost if the product is produced and unsold before the retailer's order. Hence, the expected total profit for the manufacturer with imperfect quality of product is that the expected total profit for the product lot subtracts the total inventory cost including the set-up cost and the holding cost as follows:

$$E\left(\pi_{PS}^{S}\right) = E_1\left(\pi_{PS}^{S}\right) - S_1 \cdot \frac{Q}{I_1 T} - \frac{B_1(I_1 - O_1)T}{2} \tag{11}$$

where Q is the order quantity from the retailer; O_1 is the demand quantity in units per unit time; S_1 is the set-up cost for each production run; I_1 is the production quantity in units per unit time; B_1 is the holding cost per unit item per unit time; T is the production run length per unit time.

The expected total profit of society including the retailer and the manufacturer is

$$ETP\left(Q,\ \mu_y, T\right) = E\left(\pi_{PS}^{R}\right) + E\left(\pi_{PS}^{S}\right) \tag{12}$$

In Chen and Liu's (2008) model, the retailer determines the order quantity and the manufacturer sequentially determine the wholesale price for maximizing respective objective function. Their solution is based on independence between order quantity and wholesale price. However, the dependence exists in the modified Chen and Liu's (2008) model because the order quantity is related with the manufacturer's product quality characteristic. Hence, we need to solve Eq. (13) to simultaneously obtain the optimal retailer's order quantity (Q^*), the optimal manufacturer's process mean $\left(\mu_y^*\right)$, and the optimal production run length (T^*) with the maximum expected profit for the retailer and the manufacturer.

It is difficult to show that Hessian's matrix is a negative definite matrix for Eq. (13). One cannot obtain a closed-form solution. To decrease decision variables in solving the optimization problem, we consider maximizing the expected total profit of society, partially differentiating Eq. (13) with respect to T and equaling to zero:

$$\frac{\partial ETP\left(Q, \mu_y, T\right)}{\partial T} = \frac{S_1 Q}{I_1 T^2} - \frac{B_1(I_1 - O_1)}{2} = 0 \tag{13}$$

From Eq. (13), we get an explicit expression of T in terms of order quantity Q:

$$T = \sqrt{\frac{2S_1 Q}{I_1(I_1 - O_1)B_1}} \tag{14}$$

The heuristic solution procedure for the above model (13) is as follows:

Step 1. Set maximum $Q = Q_{\max}$.
Step 2. Let $Q = 1$
Step 3. Compute $T = \sqrt{\frac{2S_1 Q}{I_1(I_1 - O_1)B_1}}$.
Step 4. Let $L < \mu_y < U$. One can adopt direct search method for obtaining the optimal μ_y^* with the maximum expected total profit of society for Eq. (13) with the given order quantity Q and production run length T.

Step 5. Let $Q = Q + 1$. Repeat Steps 3–4 until $Q = Q_{\max}$. The combination $\left(Q^*,\ \mu_y^*, T^*\right)$ with maximum expected total profit of society is the optimal solution.

3 Numerical Example and Sensitivity Analysis

Assume that some parameters are as follows: $R = 100$, $W = 40$, $S = 3$, $H = 2$, $\lambda_1 = 100$, $\lambda_2 = 0.8$, $n = 16$, $d_0 = 1, \sigma = 2$, $y_0 = 10$, $\sigma_y = 0.5$, $i = 0.05$, $k = 50$, $c = 0.5$, $L = 8$, $U = 12$, $R_I = 1, I_1 = 10, O_1 = 8, S_1 = 2$, and $B_1 = 4$. By solving Eq. (13), one obtains the optimal process mean $\mu_y^* = 10.08$, the optimal order quantity $Q^* = 112$, and the optimal production run length $T^* = 2.37$with retailer's expected profit $E\left(\pi_{PS}^R\right) = 5029.82$, manufacturer's expected profit $E\left(\pi_{PS}^S\right) = 3895.79$, and expected total profit of society $ETP\left(Q,\ \mu_y\right) = 8925.61$.

We do the sensitivity analysis of some parameters. From Table 1, we have the following observations:

1. The order quantity, the process mean, and the production run length almost is constant as the sale price per unit (R) increases. The retailer's expected profit, the manufacturer's expected profit, and the expected total profit of society increase as the sale price per unit increases. The sale price per unit has a have a major effect on the retailers' expected profit and the expected total profit of society.
2. The order quantity increases, the process mean is constant, and the production run length increases as the intercept of mean demand of customer (λ_1) increases. The retailer's expected profit, the manufacturer's expected profit, and the expected total profit of society increase as the intercept of mean demand of customer increases. The intercept of mean demand of customer has a have a major effect on the retailers' expected profit, manufacturer's expected profit, and the expected total profit of society.

Table 1 The effect of parameters for optimal solution

R	Q	μ_y	T	$E\left(\pi_{PS}^R\right)$	$E\left(\pi_{PS}^S\right)$	$ETP\left(Q,\ \mu_y, T\right)$	Per
80	111	10.08	2.36	2904.38	3860.91	6765.29	−24.20
120	112	10.08	2.37	7190.67	3895.79	11086.47	24.21
λ_1	Q	μ_y	T	$E\left(\pi_{PS}^R\right)$	$E\left(\pi_{PS}^S\right)$	$ETP\left(Q,\ \mu_y, T\right)$	Per
80	92	10.08	2.14	4067.35	3198.36	7265.71	−18.60
120	132	10.08	2.57	5992.24	4593.37	10585.60	18.60

Note Per $= \frac{ETP\left(Q, \mu_y, T\right) - 8925.61}{8925.61} \cdot 100\,\%$

4 Conclusions

In this paper, the author has presented a modified Chen and Liu's (2008) traditional system model with quality loss of product. Assume that the retailer's order quantity is concerned with the manufacturer's product quality and the quality characteristic of product is normally distributed. The quality of lot for manufacturer is decided by adopting a single sampling rectifying inspection plan. The process mean of quality characteristic, the production run length of product, and the order quantity of retailer are simultaneously determined in the modified model. From the above numerical results, one has the following conclusion: The sale price per unit has a have a major effect on the retailers' expected profit and the expected total profit of society and the intercept of mean demand of customer has a have a major effect on the retailers' expected profit, manufacturer's expected profit, and the expected total profit of society. Hence, one needs to have an exact estimation on these two parameters in order to obtain the exact decision values. The extension to integrated model with 100 % inspection may be left for further study.

References

Chen CH (2010) The joint determination of optimum process mean and economic order quantity. Paper presented at the 2010 international conference in management sciences and decision making, Tamsui, Taiwan, pp 285–292

Chen SL, Liu CL (2007) Procurement strategies in the presence of the spot market-an analytical framework. Prod Plann Control 18:297–309

Chen SL, Liu CL (2008) The optimal consignment policy for the manufacturer under supply chain coordination. Int J Prod Res 46:5121–5143

Hanna MD, Jobe JM (1996) Including quality costs in the lot-sizing decision. Int J Qual Reliab Manag 13:8–17

Jaber MY, Bonney M, Rosen MA, Moualek I (2009) Entropic order quantity (EnOQ) model for deteriorating items. Appl Math Model 33:564–578

Taguchi G (1986) Introduction to quality engineering. Asian Productivity Organization, Tokyo

Developing Customer Information System Using Fuzzy Query and Cluster Analysis

Chui-Yu Chiu, Ho-Chun Ku, I-Ting Kuo and Po-Chou Shih

Abstract Customer information is critical to customer relationship management. The goal of this research is to improve the efficiency of customer relationship management through developing a customer information system. Fuzzy terms with linguistic variables can help specific queries to be more versatile and user friendly for customer data mining. In this paper, we propose a method integrating cluster analysis with linguistic variables in the context of fuzzy query logistics. Based on the proposed method, we constructed a customer information system that can offer the user useful information as regards with strategy, decision making, and better resource allocation methods. We expect to decrease total execution time and to increase the practicability with the feature of customer information cluster analysis.

Keywords Fuzzy query · Cluster analysis · Linguistic variable · Relational database

1 Introduction

Along with the rapid development within and peripheral to the information industry, database systems are increasingly being utilized. However, information is often vague and ambiguous to the user. We can divide problematically imprecise

C.-Y. Chiu (✉) · H.-C. Ku · I.-T. Kuo · P.-C. Shih
Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei 106, Taiwan, Republic of China
e-mail: cychiu@ntut.edu.tw

H.-C. Ku
e-mail: ruokku@yahoo.com.tw

I.-T. Kuo
e-mail: 298177@gmail.com

P.-C. Shih
e-mail: pojo0701@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_142,

information into two types in this context: the first considers the possibility or similarity of imprecise queries within the classic database; the second concerns the storage problem as regards the imprecise information and the database system. However, no matter what type the imprecise information, it is important to acquire various types of information for making optimal decisions.

The fuzzy theory (Zadeh 1965), which has been developed for many years has been applied to indefinite data with regard to a diverse range of applications in a diverse range of industries and has been integral to the effective solutions to numerous problems. The applications in fuzzy theory can mainly divide into two categories within relational database systems: the translation of fuzzy queries and fuzzy relational databases.

However, user demand is also changeable and often simultaneous. Many have attempted to further improve the effect of processing uncertainties and the field of research has been developing over many years. Fuzzy sets were first used for querying conventional databases firstly in 1977 (Tahani 1977) where there were imprecise conditions inside queries. SQLf was a fuzzy extension to SQL (Bosc and Pivert 1995). This was proposed to represent a synthesis method among flexible queries in relational databases. FSQL, developed in 2005, is an extension of the SQL language. It contains Data Manipulation Language (DML) of FSQL, including SELEC, INSERT, DELETE, and UPDATE instructions.

Cluster analysis is one of the more useful methods/techniques used to glean knowledge from a dataset. Cluster analysis is based on the similarity of clusters and it can detect high heterogeneity among clusters and high homogeneity within a cluster.

We will use fuzzy theory to translate the uncertain demand in the context of clear query language. We are able to use the result of cluster analysis to create a new relational table within the relational database and divide the data set into several sub sets. According to the query, the search will select the subset according to a non-global search. A decrease in the sizes of searches will improve the efficiency (Chen and Lin 2002). Furthermore, the query based on the integration with the features of cluster analysis and linguistic variables are expected to be more practical.

2 Literature Review

2.1 Development of Relational Database

Databases are used in numerous business contexts, i.e., banking, airlines, universities, sales, online retailers, manufacturing, human resources, etc. Notably, the relational database, which is based on a relational model, is one of the more commonly used databases in business. The relational model was first proposed by Dr. E.F. Codd of IBM in 1970.

2.2 Fuzzy Query

Fuzzy theory was proposed by Zaden (1965); the method involves processing something uncertain in order to estimate the value exactly. In the past, we have received some information which has been well approximated as regards value but not is precise. This has yielded, in some cases, incorrect information causing executors to make poor decisions more often. Hence, fuzzy set theory is applied to problems in engineering, business, medicine, and natural sciences (Guiffrida and Nagi 1998).

Applying fuzzy set theory to relational databases has matured and diversified. However, there are two main directions of this type of research. The first direction is fuzzy query translation for relational database systems. Users who search for information from databases can input conditions and the system checks the data to satisfy the query conditions of the user. Sometimes the value of fuzzy terms is not as same as the conditions but this data is still relevant to the user. In order to improve upon this, we might translate the common nature language into SQL first and then process it through relational databases. The other direction involves fuzzy relational databases (Qiang et al. 2008). To improve the restrictions within the traditional relational databases, one can construct the database model so that it has an extended type of data.

2.3 Cluster Analysis

Clustering is an exploratory method used to help solve classification problems and is a useful technique for the elucidation of knowledge from a dataset. Its use is germane when little or nothing is known about the category structure within a body of data. The objective of clustering is to sort a sample of cases under consideration into groups such that the degree of association is high between members of the same group and low between members of different groups. A cluster is comprised of set of entities which are alike, while entities from different clusters are not alike. Clustering is also called unsupervised classification, where no predefined classes are assigned. Some general applications of clustering includes pattern recognition, spatial data analysis, imaging processing, multimedia computing, bioinformatics, biometrics, economics, WWW, and so on.

Aldenderfer and Blashfield decided on five basic steps that characterized all clustering studies (Aldenderfer and Blashfield 1984).

Clustering of data is broadly based on two approaches: hierarchy and partition (Jain and Dubes 1988). Over the last several decades, due to the development of artificial intelligence and soft computing, clustering methods based on other theories or techniques has advanced.

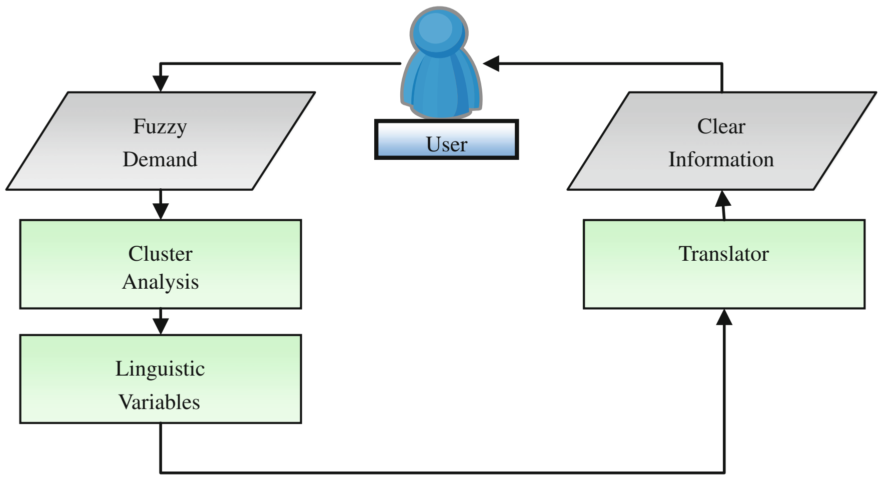


Fig. 1 The research architecture

3 Methodology

3.1 Framework

In this study, we propose a method for integrating cluster analysis and fuzzy terms in linguistic variables to improve the effect of fuzzy queries and, as such, this is expected to shorten the execution time for the query. Further, the practicability of the query could advance according to the feature of cluster analysis simultaneously. Finally, our method translates the results of the process into clear query language within the relational database and, in doing so, assists queries using an RFM analysis. We discuss how this could benefit an enterprise or firm in making decisions or allocating resources as regards different customers. The research architecture is shown as Fig. 1. However, we design the query systems architecture as shown in Figs. 2 and 3.

3.2 Cluster Analysis

This study uses the results of cluster analysis from the former experiment (Chiu et al. 2008). The steps of the method are:

- Step 1: build the relational table to record the cluster analysis. This is called the table of cluster analysis. There are records of information about features of each cluster such as measures of central tendency, measures of dispersion tendency, and measures of shape tendency.

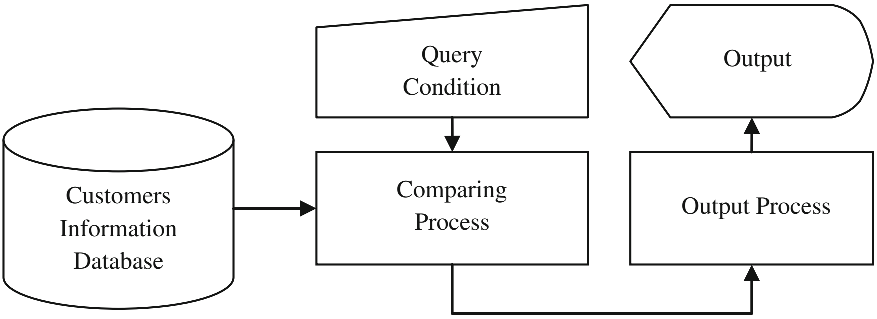


Fig. 2 Architecture of query system in global search

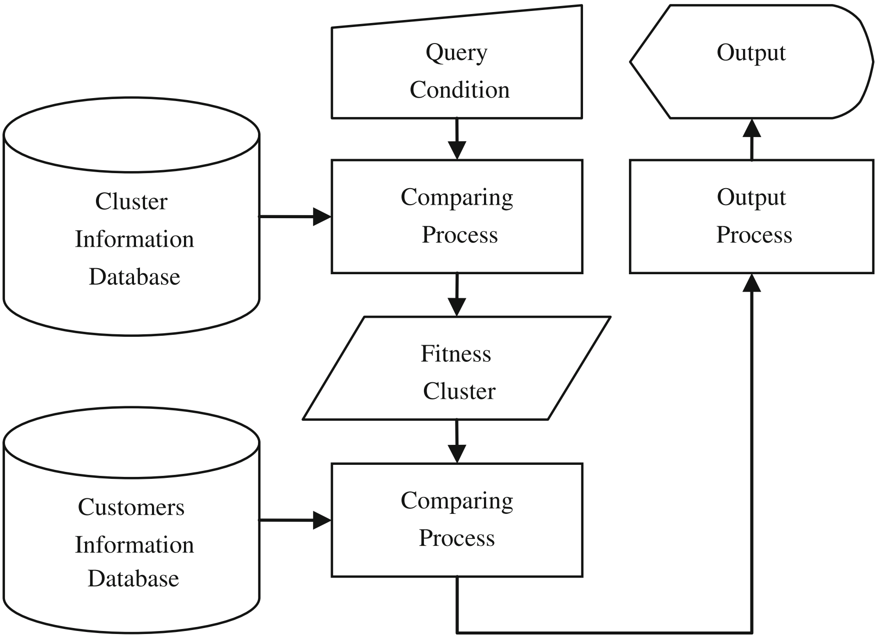


Fig. 3 Architecture of query system integrating the features of cluster analysis

- Step 2: divide the source database into several classes by its clusters. This will help to reduce the size of larger data sets and the execution times; this is amenable for administering the data at the same time.
- Step 3: according to the query conditions set by the user, count the distance to each centroid of clusters. When the distance is the minimum among these, its cluster will be the data set to compare with the query conditions.
- Step 4: adjust the parameter of function or the factor of query by its features of cluster analysis.

Table 1 The relational table of cluster analysis

G_index	RMean	FMean	MMean	Intra	Number
1	0.547866	0.556169	0.594098	0.216385	21
2	0.639573	0.205863	0.367448	0.268222	13
3	0.844350	0.680196	0.719214	0.293066	14
4	0.209397	0.278638	0.435888	0.239071	33
5	0.150691	0.073703	0.222419	0.208986	29
6	0.232697	0.662472	0.817353	0.310540	10

- Step 5: compare with the data in the above cluster whose centroid has the minimum distance to the query conditions and count the membership value to see if it satisfies as regards the threshold.

After these steps, the system can adjust the process of querying by the features of cluster analysis easily. This makes it more efficient to retrieve the data from database.

4 Experiment Process and Result Analysis

4.1 System Platform

- The programming language: PHP 4.3.11
- The database management system: MySQL 4.0.24:

The relational table of cluster analysis is shown in Table 1. It records the cluster information including the measurement of central tendency, measures of dispersion, measures of dispersion tendency, and so on.

The relational table of each cluster is shown in Table 2. This is used to count the membership value. Therefore, the value of tuples in the records is in relation to normalization, not the true value in reality.

Table 2 The relational table of cluster1

Index	NormalR	NormalF	NormalM
1	0.536763	0.581925	0.784784
7	0.568915	0.441738	0.440312
11	0.587959	0.691451	0.786775
31	0.703922	0.404430	0.636108

Table 3 The feature of simulation

	Mean			Standard Deviation		
	R	F	M	R	F	M
Cluster 1	19.80	139.47	1986197.0	8.77	114.54	2486626.0
Cluster 2	12.20	10.03	179139.0	9.51	8.99	270543.0
Cluster 3	2.37	552.40	10437012.0	2.62	719.80	12171818.0
Cluster 4	237.87	17.87	246326.2	172.96	14.18	306763.4
Cluster 5	326.30	2.73	15977.0	197.19	1.78	14074.0
Cluster 6	174.13	538.33	28255299.4	98.65	713.78	34120605.8

Table 4 The result of efficiency in both query systems

	Global	Cluster analysis
Cluster 1	0.022102	0.006931
Cluster 2	0.022723	0.005465
Cluster 3	0.021669	0.005613
Cluster 4	0.022655	0.007806
Cluster 5	0.022462	0.007514
Cluster 6	0.021418	0.005054

4.2 The Improvement of Query

4.2.1 System Simulation

In order to evaluate the performance of system, we construct the set of test data to simulate the query. The set of test data is generated by random numbers in normal distribution. There are 30 queries in each cluster. Table 3 summarizes the set of test data in each cluster. Each query will get all membership values which correspond to the total data in the same cluster.

4.2.2 The Evaluation of Efficiency

As regards the experiment in the set of test data, the results of efficiency with both query system architectures are shown in Table 4. We found that the efficiency of query system integrating cluster analysis is better than that of query system in a global search. However, in the query system integrating cluster analysis, the size of each cluster still affects the execution time within each cluster.

5 Conclusion

According to the above research and experiments, the effect of querying has undergone improvements. Not only has there been shown to be a decrease in execution time but the practicality of queries has also been improved by the integration of cluster analysis.

The query system offers accurate customer information. Therefore, this method can further help to track customers with the pertinent customer information including individual experiences and purchasing records. The market feature helps enterprises segment customers to decide upon the degrees of importance regarding demographics. We conclude that either of these benefits will optimize an enterprise's ability to glean important types of quality information to better allow them to assess and improve their own market strategy.

References

Aldenderfer MS, Blashfield RK (1984) Cluster analysis: quatitative applications in the social sciences. Sage Publication, Beverly Hills

Bosc P, Pivert O (1995) SQLf: a relational database language for fuzzy querying. IEEE Trans Fuzzy Syst 3(1):1–17

Chen SM, Lin YS (2002) A new method for fuzzy query processing inrelational database systems. Cybern Sys Int J 33:447–482

Chiu CY, Chen YF, Kuo IT, Ku HC (2008) An intelligent market segmentation system using k-means and particle swarm optimization. Expert Systems with Applications

Guiffrida AL, Nagi R (1998) Fuzzy set theory application in production management research: a literature survey. J Intell Manuf 9(1):39–56

Jain AK, Dubes RC (1988) Algorithms for clustering data. Prentice-Hall, Englewood Cliffs

Qiang L, Yang W, Yi D (2008) Kernel shapes of fuzzy sets in fuzzy systems for function approximation. Inf Sci 178:836–857

Tahani V (1977) A conceptual framework for fuzzy querying processing: a step toward very intelligent databases systems. Inf Process Manage 13:289–303

Zadeh LA (1965) Fuzzy sets. Inf Control 8:338–353

Automatic Clustering Combining Differential Evolution Algorithm and *k*-Means Algorithm

R. J. Kuo, Erma Suryani and Achmad Yasid

Abstract One of the most challenging problems in data clustering is to determine the number of clusters. This study intends to propose an improved differential evolution algorithm which integrates automatic clustering based differential evolution (ACDE) algorithm and *k*-means (ACDE-*k-means*) algorithm. It requires no prior knowledge about number of clusters. *k*-means algorithm is employed to tune cluster centroids in order to improve the performance of DE algorithm. To validate the performance of the proposed algorithm, two well-known data sets, Iris and Wine, are employed. The computational results indicate that the proposed ACDE-*k*-means algorithm is superior to classical DE algorithm.

Keywords Automatic clustering · Differential evolution · *k*-means

1 Introduction

Clustering is an unsupervised data classification for observations, data items, or features vectors based on similarity (Jain et al. 1999). There are numerous scientific fields and applications utilized clustering techniques such as data mining, image segmentation (Frigui and krishnapuram 1999), bioinformatics (Yeung et al. 2001), documents clustering (Cai et al. 2005), market segmentation (Kuo et al. 2012a, b).

R. J. Kuo (✉) · A. Yasid
Department of Industrial Management, National Taiwan University of Science and Technology, 43 Keelung Road, Section 4, Taipei 106, Taiwan, Republic of China
e-mail: rjkuo@mail.ntust.edu.tw

E. Suryani
Department of Information Systems, Institut Teknologi Sepuluh Nopember, Jl. Raya ITS, Surabaya 60111, Indonesia
e-mail: erma@is.its.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_143,

Clustering algorithms can be broadly divided into two groups: *hierarchical* and *partitional*. Hierarchical algorithm finds nested cluster either in agglomerative mode (begin with treat each data point as a cluster and merge the nearest two clusters iteratively until stopping criterion met) or divisive mode (begin with all data points grouped in one cluster and recursively dividing each cluster into smaller clusters until stopping criterion met). *Partitional* algorithm, on the other hand, attempts to find all clusters simultaneously. The most well-known hierarchical clustering algorithms are single-link and complete link; while in the *partitional* clustering, *k*-means algorithm is the most popular and simplest algorithm.

Clustering algorithm can also divided in two categories: crisp (hard) and fuzzy (soft) algorithm. In crisp clustering, any data point may only belong to one cluster. While in fuzzy clustering, data point may belong to all clusters with a specific degree of membership. The work described in this study is concerned crisp clustering algorithms.

However, most of these methods require the user to subjectively define number of clusters. Thus, one of the most challenging problems in clustering is how to find the *k* cluster number automatically. Recently, using the evolutionary computation to get cluster number has been widely applied such as genetic algorithm (Bandyopadhyay and Maulik 2002), particle swarm optimization (Paterlini and Krink 2006), and differential evolution (Das et al. 2008).

Differential evolution algorithm (Storn and Price 1997) is a novel evolutionary algorithm (EA) for global optimization. It uses floating point to encode for its population and has been successfully applied in clustering problem. Compared with PSO algorithm and GA, DE algorithm outperforms PSO algorithm and GA over *partitional* clustering (Paterlini and Krink 2006). In order to improve DE algorithm, Kwedlo (2011) combined DE algorithm with *k*-means algorithm. Das et al. (2008) also proposed automatic clustering based DE (ACDE) algorithm. The ACDE algorithm modifies scale factor *F* in original DE algorithm with random manner in the range [1, 0.5] and linearly decreases the crossover rate along with iterations. Therefore, this study will propose a novel automatic clustering approach based on DE algorithm combining with *k*-means algorithm for crisp clustering (ACDE-*k-means*). Combination of DE algorithm and *k*-means algorithm can balance exploration and exploitation processes.

The rest of this paper is organized as follows. Section 2 briefly discusses literature study about data clustering and DE algorithm, while the proposed method is described in Sect. 3. Section 4 presents the computational results. Finally, the concluding remakes are made in Sect. 5.

2 Literature Study

2.1 Clustering

Given a data set X = $\{x_1, x_2, \ldots, x_N\}$ contains N data points in d dimension. The dataset can be grouped into K number of clusters $C = \{C_1, C_2, \ldots, C_K\}$. Hard clustering problems have three properties that should maintain, i.e., (1) each cluster should have at least one data point assigned; (2) no data point common in two different clusters; and (3) each pattern must be attached into a cluster. The related equations are illustrated as follows.

$$C_i \neq \emptyset, \quad \forall_i \in \{1, 2, \ldots, K\} \tag{1}$$

$$C_i \cap C_j = \emptyset, \quad \forall i \neq j \text{ and } i, j \in \{1, 2, \ldots, K\} \tag{2}$$

$$\cup_{i=1}^{K} C_i = X \tag{3}$$

2.1.1 *k*-Means

k-means algorithm is a well-known clustering algorithm. The basic step of *k*-means algorithm (MacQueen 1967) is as follows:

1. Randomly select k initial data points as cluster centroids,
2. Assign each data point to the closest centroid,
3. Recalculate the centroid of each cluster using average method,
4. Repeat steps 2 and 3 until stopping criterion is met.

2.1.2 Cluster Validity Index

The clustering result is evaluated using cluster validity index on a quantitative basis. Cluster validity index serves two purposes: determining number of clusters and finding the best partition. Thus, two aspects of partitioning namely *cohesion* and *separation* should be considered. There are many validity measurements proposed previously, yet this study will only discusses two validity measurements which will be employed in the proposed automatic clustering algorithm.

1. *VI Index*

This index calculates ratio between *intra* and *inter* dissimilarity (Kuo et al. 2012a, b). Let *VI* be the fitness function to minimize the value. The formula is shown as follows:

$$VI = (c \times N(0,\ 1) + 1) \times \frac{intra}{inter}, \tag{4}$$

where $(c \times N(0,\ 1) + 1)$ is a punishment value to avoid having too few clusters, c is a constant value and set to 30. The $N(0,1)$ is Gaussian function of cluster numbers. In this experiment, $N(0,1)$ is adopted for Iris and Wine datasets since the numbers of clusters for these data sets are small.

Intra is the average distance between centroid m_k to the data point x in a cluster. Calculate the Euclidian distance of data point to the centroid of cluster, sum up all the shortest distance of each data point to the centroid of cluster, and then divide it by the total number of data tuples, N_p. The formula of *intra* is as follows:

$$intra = \frac{1}{N_p} \sum_{k=1}^{K} \sum_{x \in C_k} \|x - m_k\|^2 \tag{5}$$

Inter as illustrated in Eq. (6) is a minimum centroid distance among clusters. The distance from each cluster centroid to another cluster centroid is calculated to get the minimum value.

$$\begin{aligned} &inter = \min\{d(\vec{m}_k,\ \vec{m}_{kk})\} \\ &\quad \forall k = 1,\ 2, \ldots, K - 1 \ \text{ and } \ kk = k + 1, \ldots,\ K. \end{aligned} \tag{6}$$

2. *CS Measure*

CS measure is a simple clustering measurement index that can assign more cluster centroids to the area with low-density data than conventional clustering algorithms (Chou et al. 2004). First, the cluster centroid is average of all the data points in the cluster as shown in Eq. (7). Then, the CS measure can be formulated by Eq. (8), where $d(\vec{x}_i,\ \vec{x}_q)$ is distance metric between two data points, $\vec{x}_i$ and $\vec{x}_q$.

$$\vec{m}_i = \frac{1}{N_i} \sum_{x_j \in C_i} \vec{x}_j \tag{7}$$

$$\begin{aligned} CS(K) &= \frac{\frac{1}{K}\sum_{i=1}^{K}\left[\frac{1}{N_i}\sum_{\vec{x}_i \in C_i} \max_{\vec{x}_q \in C_i}\left\{d(\vec{x}_i, \vec{x}_q)\right\}\right]}{\frac{1}{K}\sum_{i=1}^{K}\left[\min_{j \in K, j \neq i}\left\{d(\vec{m}_i, \vec{m}_j)\right\}\right]} \\ &= \frac{\sum_{i=1}^{K}\left[\frac{1}{N_i}\sum_{\vec{x}_i \in C_i} \max_{\vec{x}_q \in C_i}\left\{d(\vec{x}_i, \vec{x}_q)\right\}\right]}{\sum_{i=1}^{K}\left[\min_{j \in K, j \neq i}\left\{d(\vec{m}_i, \vec{m}_j)\right\}\right]} \end{aligned} \tag{8}$$

2.2 Differential Evolution Algorithm

DE algorithm is an evolution-based algorithm proposed by Storn and Price. Like other evolutionary algorithms, the initial population $V_{i,d}(t)$, is randomly generated. The ith individual vector (chromosome) of population at time step (generation) t has d components (dimensions) as shown in Eq. (9). Then, it will evolve using mutation and crossover.

$$V_{i,d}(t) = v_{i,1}(t), v_{i,2}(t), \ldots, v_{i,d}(t) \quad (9)$$

Mutation is a process to generate new parameter by adding weighted difference between two population vectors to a third vector. Mutant vector $Z_{i,\mathrm{d}}(t+1)$ as illustrated in Eq. (10) is generated by three random vectors, i.e., $V_{j,d}(t)$, $V_{k,d}(t)$, and $V_{l,d}(t)$, from the same generation (for distinct i, j, k, and l) according to scale factor F.

$$Z_{i,d}(t+1) = V_{j,d}(t) + F(V_{k,d}(t) - V_{l,d}(t)) \quad (10)$$

In order to increase the diversity of perturbed parameters vectors, trial vector $U_{ji,d}(t+1)$ as shown in Eq. (11) is created using crossover operator.

$$U_{ji,d}(t+1) = \begin{cases} Z_{i,d}(t+1) & \mathit{if}\ rand_j(0,1) \le CR\ or\ j = rand(d) \\ V_{i,d}(t), & \mathit{if}\ rand_j(0,1) > CR\ or\ j \ne rand(d) \end{cases} \quad (11)$$

Furthermore, selection process is executed. In order to decide whether offspring can become a member of new generation, the trial vector is compared to the fitness function. If the new offspring $U_i(t+1)$ yields a better value (minimum) of the objective function $f(V_i(t))$, it replaces its parent in the next generation. Otherwise the parent $V_i(t)$ is retained to be parent for the next generation $V_i(t+1)$. The decision rule is as follows:

$$V_i(t+1) = \begin{cases} U_i(t+1), & \mathit{if}\ f(U_i(t+1)) > f(V_i(t)) \\ V_i(t), & \mathit{if}\ f(U_i(t+1)) \le f(V_i(t)) \end{cases} \quad (12)$$

3 Automatic Clustering Based DE Algorithm

The algorithm of the proposed ACDE-*k-means* is as follows:

step 1. Initialize each chromosome to contain k (randomly generate) number of randomly selected cluster centers and k randomly activation threshold [0,1].

step 2. Find out the active centorids $v_{i,k}T_k$ in each chromosome using rule as shown in Eq. (13).

step 3. For $t = 1$ to t_{max} do

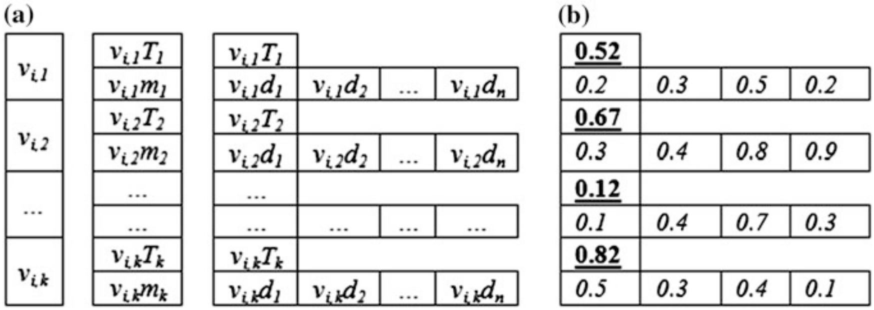


Fig. 1 **a** Detail of chromosome schema, **b** An individual vector with four threshold (*bold underlined*) and four centroid of each cluster (*italic*)

a. Calculate distance of each data vector to all actives centroids of the *i*th chromosome.
b. Assign each data vector to a cluster with shortest distance.
c. Change the population member based on DE algorithm. Use fitness function to select better population
d. Check whether the vector chromosome is met hard clustering properties.
e. Apply *k*-means algorithm to adjust centroids of *i*th active chromosome. Use the active cluster number as input of *k*-means algorithm.

step 4. Output the global best chromosome (the minimum fitness) as final result.

In this proposed method, the chromosome representation is based on (Das et al. 2008). Every chromosome $v_i(t)$ is a real number vector. It comprises of activation threshold $v_{i,k}T_k + (v_{i,k} \times d_n)$ dimensions. Each of activation threshold $v_{i,k}T_k$ is random number in the range of [0,1] that act as control parameter to determine whether the cluster is active or inactive. The rule to specify the cluster is active or inactive is as follows:

$$\begin{aligned} \text{IF}\, v_{i,k}T_k > 0.5,\ \text{THEN}\, \textit{the kth cluster center}\, v_{i,k}m_k\, \textit{is}\ \text{ACTIVE} \\ \text{ELSE}\, v_{i,k}m_k\, \textit{is}\ \text{INACTIVE} \end{aligned} \tag{13}$$

As an example, (0.52), (0.67), (0.12) and (0.82) are activation threshold, while (0.2, 0.3, 0.5, 0.2), (0.3, 0.4, 0.8, 0.9), (0.1, 0.4, 0.7, 0.3) and (0.5, 0.3, 0.4, 0.1) are centroid of vector chromosome $v_{i,k,}m_k$ (Fig. 1).

4 Computational Results

The proposed ACDE-*k-means* algorithm is validated using two data sets namely iris and wine. To judge the accuracy of ACDE-*k*-means, we let each algorithm to run for 30 times. Two fitness functions, CS measure and VI measure are applied. Simulations were executed using C++ on a PC Intel Core2 Quad at 2.4 GHz with

Table 1 Real life datasets

Data set	N	Number of dimensions	Number of clusters	Composition of each cluster
Iris	150	4	3	50, 50, 50
Wine	178	13	3	59, 71, 48

Note better result is printed in bold

Table 2 Tunning parameters

Parameter	Value
Population size	10x dimension
CR_{min}; CR_{max}	0.5; 1
F (ACDE-k-means)	[0.5,1.0]
F (Classical DE)	0.5
k_{min}; k_{max}	2; $\sqrt{Npop}$

Note better result is printed in bold

Table 3 Number of clusters

Dataset	Algorithm	Number of clusters (average ± st. dev)		CS value	VI value
		CS	VI		
Iris	ACDE-k-means	**2.8 ± 0.407**	**3.2 ± 0.4068**	**0.605 ± 0.013**	**0.238 ± 0.013**
	Classical DE	2.83 ± 0.531	2.5 ± 0.7768	0.6791 ± 0.013	0.117 ± 0.101
Wine	ACDE-k-means	**3.2 ± 0.761**	**3.77 ± 0.504**	**0.947 ± 0.052**	**0.525 ± 0.036**
	Classical DE	3.4 ± 0.724	2.33 ± 0.547	0.852 ± 0.054	0.135 ± 0.123

Table 4 Accuracy

Dataset	Algorithm	Accuracy (average ± st. dev)	
		CS	VI
Iris	ACDE-k-means	**0.8267 ± 0.0813**	**0.756 ± 0.0153**
	Classical DE	0.6791 ± 0.0033	0.4391 ± 0.1242
Wine	ACDE-k-mean	**0.8484 ± 0.1175**	**0.8291 ± 0.0654**
	Classical DE	0.4071 ± 0.0619	0.4721 ± 0.1097

2 GB of RAM environment. The tuning parameters are set based on Das et al. (2008). The only difference is that the initial number of clusters (k_{max}) is determined by using $\sqrt{Npop}$. The results are compared with those of classical DE algorithm (Tables 1 and 2).

Table 3 gives number of clusters obtained from 30-time independence runs where each run uses 100 iterations. The result shows that average cluster number found by ACDE-k-means is more similar to the actual value than classical DE algorithm both in CS and VI measures. For Iris data set, the average cluster numbers obtained from ACDE-k-means for CS and VI are 2.8 and 3.2, respectively. Table 4 summarizes accuracy obtained by both algorithms. It reveals that ACDE-*k*-means algorithm has better accuracy than classical DE algorithm for both data sets. Basically, no matter CS or VI, ACDE-*k*-means algorithm outperforms classical DE algorithm.

5 Conclusions

In this paper, a differential evolution algorithm based for automatic clustering has been proposed. ACDE algorithm is combined with *k*-means algorithm to improve the performance of DE algorithm. ACDE-*k*-means algorithm owns the ability to find the number of clusters automatically. Moreover, the proposed method is also able to balance the evolution process of DE algorithm so that it can achieve a better partition compared with classical DE algorithm. Results from different fitness measures (CS and VI) and two different data sets (Iris and Wine) indicate that ACDE-*k*-means performs well in terms of both number of clusters and clustering results.

References

Bandyopadhyay S, Maulik U (2002) Genetic clustering for automatic evolution of cluster and application to image classification. Pattern Recogn 35:1197–1208

Cai D, Xiaofei H, Han J (2005) Documents clustering using locality preserving indexing. Knowl Data Eng IEEE Tran 17(12):1624–1637

Chou C-H, Su M-C, Lai E (2004) A new cluster validity measure and its application to image compression. Patter Anal Applic 7:205–220

Das S, Abraham A, Komar A (2008) Automatic clustering using improved differential evolution algorithm. IEEE Trans Syst Man Cybern Part A 38:218–237

Frigui H, Krishnapuram R (1999) A robust competitive clustering algorithm with applications in computer vision. IEEE Trans Pattern Anal Mach Intell 21:450–465

Jain AK, Murty MN, Flynn PJ (1999) Data clustering: a review. ACM Comput Surv (CSUR) 31(3):264–323

Kuo RJ, Akbaria K, Subroto B (2012a) Application of particle swarm optimization and perceptual map to tourist market segmentation. Expert Syst App 39:8726–8735

Kuo RJ, Syu YJ, Chen ZY, Tien FC (2012b) Integration of particle swarm optimization and genetic algorithm for dynamic clustering. Inf Sci 195:124–140

Kwedlo W (2011) A clustering method combining differential evolution with the k-means algorithms. Pattern Recognit Lett 32:1613–1621

Macqueen J (1967) Some methods for classification and analysis of multivariate observations. In: Proceedings of the fifth Berkeley Symposium on mathematical statistics and probability, vol 1, pp 281–297

Paterlini S, Krink T (2006) Differential evolution and particle swarm optimization in partitional clustering. Comput Stat Data Anal 50:1220–1247

Storn R, Price K (1997) Differential evolution—a simple and efficient heuristic for global optimization over continuous spaces. J Global Optim 11:341–359

Yeung KY, Fraley C, Murua A, Raftery AE, Ruzzo WL (2001) Model-based clustering and data transformations for gene expression data. Bioinformatics 17:977–987

Application of Two-Stage Clustering on the Attitude and Behavioral of the Nursing Staff: A Case Study of Medical Center in Taiwan

Farn-Shing Chen, Shih-Wei Hsu, Chia-An Tu and Wen-Tsann Lin

Abstract The purpose of this study was to probe into and organizing personnel representing attitude and behavior that the function should possess, a case study of medical center nursing categories of employees for the study, due to the professionalism of nursing staff for the establishment of a good nurse-patient relationship as well as to demonstrated the attitude of an important condition, in this study was with Situational judgment test the collect a nursing staff in the true working situational, the view on the function importance. Testing the materials is obtained by the database of this case hospital, carry on Two-stage clustering method hiving off laws (Self-Organizing Maps and K-means) secondary analysis, will be importance of "situational judgment test functions questionnaire" that the information collected, analyze attitude and behavior that nursing staff should possess. According the analysis results found that personnel in different posts and ranks between two groups of 'staff' and 'executive', to the attitude and behavioral cognition, think 'responsible for seriously' with 'quality leading' the most important, cultivation of the future nursing staff, should strengthen the cultivation of professional attitude, and implement the rigorous of standard operation procedure, period of to reduce the gap between of health professional education and clinical/nursing practice.

Keywords Attitude and behavior · Competency · Situational judgment test · Two-step cluster method

F.-S. Chen · S.-W. Hsu (✉) · C.-A. Tu
Department of Industrial Education and Technology, National Changhua University of Education, Changhua 500, Taiwan, Republic of China
e-mail: kb80284@gmail.com

F.-S. Chen
e-mail: iefchen@cc.ncue.edu.tw

W.-T. Lin
Department of Industrial Engineering and Management, National Chin-Yi University of Technology, Taichung 411, Taiwan, Republic of China
e-mail: lin505@ncut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_144,

1 Introduction

Spencer and Spencer (1993) proposed the iceberg model theory, which divides competency into explicit components, such as knowledge, skills, and abilities, and implicit components including traits and values. They also indicated that competency is the integration of explicit and implicit employee abilities required for a specific position in a business or organization. In this study, nurses were selected as the primary subjects because they are a group who constitutes the majority of employees in health care institutions and who are closest to patients. More than 80 % of health care treatment behavior and care activities are conducted by nurses. This indicates that nurses occupy an important role in ensuring patient safety. Therefore, the professionalism and behavior of nurses must be cultivated to establish excellent nurse-patient relationships and patient service attitudes. Consequently, the objectives of this study are as follows:

1. Explore the problem-solving and coping measures related to health care services that are adopted by nurses in the case hospital, as well as their attitudes and behaviors in the work environment, using the situational judgment test (SJT) model.
2. To examines the nursing professionalism exhibited by nurses delivering health care services, and recommends attitude and behavior.

2 Literature Review

2.1 Attitude and Behavior

Regarding the relationship between attitude and behavior, most early studies that examined the factors influencing individual behavior investigated the influence that attitudes toward a specific item had on behavior. Therefore, Thomas and Znaniecki (1918) were the first scholars to use attitude to explain social behavior. They contended that attitude is a psychological process in which individual people determine their real behaviors and latent reactions. After the 1960s, the concept of attitude shifted toward being a type of behavioral tendency (Taylor et al. 1997), and with appropriate or accurate knowledge, resulting attitudes could influence behaviors (Ben-Ari 1996). Chien et al. (2006) indicated that the more positive people's attitudes toward a given behavior are, the higher their level of cognition and tendency to adopt a certain type of behavior becomes. Consequently, Askariana et al. (2004) explored the relationship between knowledge (i.e., cognition), attitude, and practice (i.e., behavior) and reported that a significant correlation existed between increasing knowledge and expected behavioral changes. However, Lin et al. (2009) indicated that merely increasing knowledge does not necessarily induce behavioral changes directly, and attitude can serve as a media that provides a continuous emotional input or investment. Based on this concept, this study explores the influence that nurses' attitudes have on their health care service provision behavior.

2.2 Competency

Competency refers to the ability and willingness to employ existing knowledge and skills to perform work tasks. In other words, competency is a general term for behavior, motivation, and knowledge related to work success (Burgoyne 1993; Byham and Moyer 1996; Fletcher 2001). According to the description provided by the American Society for Training and Development, competency is the crucial ability required to perform a specific task. Furthermore, the European Centre for the Development of Vocational Training defined competency as the unique knowledge, skills, attitude, and motivations required to complete a specific task. Spencer and Spencer (1993) contended that competency represents the underlying characteristics of a person, which not only relate to the person's work position, but also facilitate understanding the person's expected or real reactions and expressions influencing behavior and performance.

2.3 Situational Judgment Tests

Health care behavior involves high complexity and uncertainty, when nurses perform health care behavior-based work, they must possess highly professional nursing knowledge and skills to ensure the provision of safe patient care services. Furthermore, nurses primarily and directly participate in health care behaviors that occur during the treatment of patients by physicians. Therefore, using the SJT method, this study collected nurses' opinions regarding the importance of competency for real work situations in the case hospital. McDaniel et al. (2007) divided the answering models for SJT into the knowledge format (What is the best answer?) and the behavioral tendency format (What is the action you are most likely to adopt?).

3 Methods

3.1 Validation of Sources for Secondary Analysis

The objective of this study was to explore the influence that nurses' attitudes and behaviors had on expressions or demonstrations of competency in the case hospital. To acquire expected results more appropriately, this study used the database established through the case hospital's Competency Importance Questionnaire to conduct secondary analysis. The case hospital distributed the questionnaires to understand the self-expectations of employees and supervisors and their cognitions or perceptions regarding the attitudes and behaviors they should possess for their positions. Therefore, by conducting in-depth analysis of existing data, novel conclusions and explanations could be derived. Furthermore, only by screening and accessing adequate data from the database could this study achieve its research goals.

3.2 Participant Descriptions

The case hospital examined in this study was selected from 144 health care institutions accredited on the "2009–2012 list of contracted National Health Insurance teaching hospitals or institutions at higher levels" by the Department of Health, Executive Yuan, R.O.C. (Taiwan). The selected case hospital also attained accreditation as a medical center of excellent rank in 2011 (valid from January 1, 2012, to December 31, 2015). Thus, this medical center was selected for the case study, and nurses employed at the center were recruited as participants.

3.3 Explanations Regarding Administration and Completion of the Questionnaire

To select participants from the case hospital to complete the Competency Importance Questionnaire, hospital personnel were grouped according to profession type using professional and work attributes. Because the greater complexity of the physician profession hinders profession-based grouping, non-physician personnel of the case hospital were recruited as participants for this type of grouping. Subsequently, after the Human Resources Department of the case hospital met with the supervisors of each hospital unit and reached a consensus, the various professions in the case hospital were divided into 21 categories. Because this study only adopted nurses of the case hospital as participants.

3.4 Analysis and Implementation

This study used two-stage clustering to conduct a confirmatory comparison. This process was performed to classify data into numerous clusters and ensure high similarity among data in a cluster to understand nurses' perceptions regarding the various profession categories in the case hospital. The consistencies and differences between the participants were compared, and the results of the two-stage clustering analysis were organized in sequential order. We employed the 80/20 theory to extract the attitude and behavior items that influence the case hospital nurses' displays of competency. Chang et al. (2011) examined medical unit cost analyses and medical service procedural problems using quality control circle activities. They also applied the 80/20 theory to identify the primary reasons or factors requiring imperative improvement, allowing for enhancement of unit costs and medical procedures and enabling the hospital to increase income, reduce expenses, and achieve sustainable development. Consequently, this study determined that 80 % of the medical services delivered by nurses were influenced by 20 % of the attitude and behavior items affecting competency displays.

4 Data Analysis and Discussion

4.1 Cluster Comparison and Analysis of Two-Stage Clustering

Employing the SPSS Clementine 10.1 software package for two-stage clustering analysis, this study found an initial solution using the unsupervised self-organizing map (SOM) network in the first stage.

Subsequently, using the two-stage clustering analysis results of SOM and K-means, we obtained the distribution of each cluster composition. To facilitate clear examination of the distribution, we observed every cluster when all contained 100 data rows, using color normalization to explore the proportion of each cluster in relation to all clusters. Thus, normalization was used to further clarify and observe the relevance between each cluster and the percentage of each cluster in relation to the whole, as shown in Fig. 1a, b.

Figure 1a, b show the cluster distribution, where the relevance between the cluster size and personnel cognition of attitude and behavior in each profession category is clear and specific. Therefore, all nurses serving in the case hospital

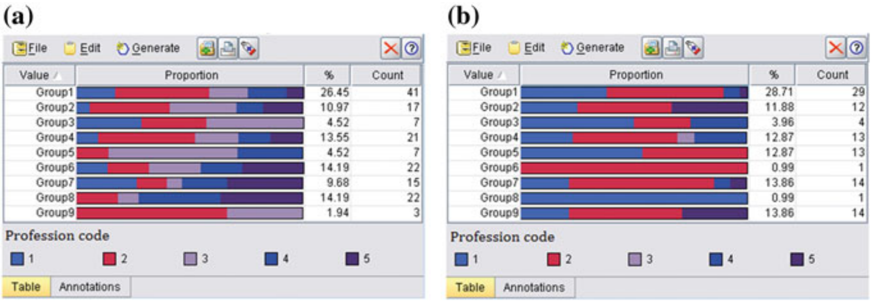


Fig. 1 **a** Employee self-evaluations. **b** Supervisor evaluations

possess a consensus that attitude and behavior can affect representations or demonstrations of competency. Regarding employee self-evaluations, the percentage sum of Clusters 1, 2, 4, 6, and 7 was 74.84 %, comprising all categories of nurse professions. Regarding supervisor evaluations, the percentage sum of Clusters 1, 2, 4, 7, and 9 was 81.18 %, which shows a similar level to that for employee self-evaluations. However, the cluster distribution graph only demonstrates the percentages of each cluster. To further examine the attitude and behavior items that influence the case hospital nurses' competency displays, we extracted the attitude and behavior items that influence competency based on the 80/20 rule. The extracted attitude and behavior items can provide a reference for nurses of the case hospital for improving medical services offered by the hospital.

4.2 Extracting the Attitude and Behavior Items that Influence Displays of Competency Based on the 80/20 Rule

This study divided case-hospital nursing respondents into employees and supervisors according to their position rank. For the questionnaire administration methods mentioned previously, multiple-response items were designed. Consequently, this study used the SPSS Statistics 17.0 software package to conduct multiple-response item analysis and rank the attitude and behavior items extracted from corresponding clusters of the employee self-evaluations and supervisor evaluations using the 80/20 rule. The results showed that in different clusters, the cognitive or perceived importance of various attitude and behavior items differed between employees and supervisors. Thus, to further understand importance rankings for attitude and behavior items in employee self-evaluations and supervisor evaluations, we organized the overall importance rankings into Table 1.

4.3 Discussion

In summation, the two-stage clustering analysis results were first used to divide employee self-evaluations and supervisor evaluations into nine clusters, and clustering analysis results were then adopted to plot a distribution map or diagram to explore the composition and relationship between each profession category. The objective of this study was to explore the influence of attitude and behavior items. Therefore, clusters comprising all categories of nurses were screened to conduct in-depth analysis and comparisons of the relationship between employee self-evaluations and supervisor evaluations. The 80/20 rule was used to extract the attitude and behavior items that influence competency displays. Because the Competency Importance Questionnaire comprised 35 items, the initial 20 %

Table 1 Importance rankings of the various attitude and behavior items

Employee self-evaluations			Supervisor evaluations		
Ranking	Attitude and behavior items	%	Ranking	Attitude and behavior items	%
1	04_Earnest and responsible	15.71	1	02_Quality-oriented	17.14
2	07_Teamwork	12.86	2	04_Earnest and responsible	16.43
3	08_Communication and coordination	12.86	3	10_Customer service	15.00
4	35_Crisis management	12.86	4	07_Teamwork	12.86
5	06_Proactive	8.57	5	03_Work management	8.57
6	03_Work management	7.86	6	30_Ability to bear stress	8.57
7	02_Quality-oriented	7.14	7	06_Proactive	7.86
8	31_Care and empathy	5.71	8	08_Communication and coordination	5.00
9	13_Adaptability	5.00	9	13_Adaptability	4.29
10	30_Ability to bear stress	3.57	10	11_Integrity	1.43
11	10_Customer service	2.14	11	12_Self-development	1.43
12	05_Work vitality	1.43	12	01_Pursuit of excellence	0.71
13	11_Integrity	1.43	13	17_Customer-oriented	0.71
14	24_Work guidance	1.43			
15	29_Problem-solving	1.43			

(i.e., the first seven items in the sequential order or ranking of each cluster) were extracted. Furthermore, to understand the importance rankings of attitude and behavior items obtained from employee self-evaluations and supervisor evaluations, we organized the overall importance rankings to concentrate and consolidate the results. According to the ranking results, this study can propose perceptions found in employee self-evaluations and supervisor evaluations regarding commonalities and differences for attitude and behavior items and can identify the critical attitude and behavior items included in these evaluations.

5 Conclusions

The primary conclusions for the research objectives of this study were below:

Through the SJT model, we determined that 10 common cognitive items considered to influence workplace situations existed between employees and supervisors in the case hospital. Based on this result, employees believed that they must work earnestly to validly complete their tasks and demonstrate responsibility. By contrast, supervisors believed that quality must be ensured before completing tasks to implement safe medical services.

Regarding the notion that attitude and behavior affect demonstrations of competency, we aim to enhance health care institutions' emphasis on developing attitudes and behaviors that can influence competency displays. The percentage of common cognition between employees and supervisors was 77.14 and 97.14 %, respectively. This result shows that supervisors already sufficiently comprehend the attitude and behavior items that influence competency displays, whereas employees should enhance this cognition.

Regarding the provision of vocational nursing education that cultivates and inspires appropriate attitudes, behaviors, and nursing concepts among students, we examined the current situation of case hospital nurses using the attitude and behavior perceptions of nursing personnel who perform practical health care services and by applying scientific methods for analysis. We anticipate that by adopting a combination of methodology, theory, and practice using existing data, the study results can balance theory and practice and provide referential value for schools and the industry when training competent and adequate nurses for health care institutions.

References

Askariana M, Honarvara B, Tabatabaeeb HR, Assadianc O (2004) Knowledge, practice and attitude towards standard isolation precautions in Iranian medical students. J Hosp Infect 58:292–296

Ben-Ari A (1996) Israeli professionals' knowledge of attitudes towards AIDS. Soc Work Health Care 22(4):35–52

Burgoyne JG (1993) The competence movement: issues, stakeholders and prospects. Pers Rev 22(6):6–13

Byham WC, Moyer RP (1996) Using competencies to build a successful organization. Development Dimensions International Inc, USA

Chang WD, Lai PT, Tsai CT, Chan HC (2011) Using quality control circle to dispose of the cost problems in a medical unit: an experience of rehabilitation center. J Health Manage 9(1):17–27

Chien CW, Lee YC, Lee CK, Lin YC, An BY (2006) The influence of inpatients' attitude on recognition of patient safety: a theory of planned behavior perspective. Cheng Vhing Med J 2(4):18–25

Fletcher S (2001) NVQS, standards and competence: a practical guide for employers, managers and trainers. Kogan Page Ltd, London

Lin CC, Huang ST, Chuang CM, Lee HM (2009) A study of knowledge attitude and behavior of infection control of nurses. Bull Hungkuang Inst Technol 55:1–16

McDaniel MA, Hartman NS, Whetzel DL, Grubb WL (2007) Situational judgment tests, response instructions, and validity: a meta-analysis. Pers Psychol 60:63–91

Spencer LM, Spencer SM (1993) Competence at work: models for superior performance. Wiley, New Jersey

Taylor SE, Peplau LA, Sears DO (1997) Social psychology. Prentice Hall, New Jersey

Thomas WI, Znaniecki F (1918) The polish peasant in Europe and America. Badger, Boston

The Effects of Music Training on the Cognitive Ability and Auditory Memory

Min-Sheng Chen, Chan-Ming Hsu and Tien-Ju Chiang

Abstract Previous research indicated a link between music training and cognitive ability. Despite some positive evidence, there is a different point about which abilities are improved. In this study, one experiment was conducted to investigate the effect of music training on memory retention. Two input modalities (visual and auditory) and delay time (0, 4, 6, 8, and 10 s) were manipulated. Participants were asked to finish prime task (memory retention) and distraction task (press the direction key to match the word or arrow). The result showed that music trained group performed better than the non-music trained one. For music trained group, their performance showed no significant difference between visual and auditory modalities. Participants without music training performed much better on visual than on auditory modality. This result of this experiment may support the idea that the music training influences participant's performance on memory retention. This research shows that music training is an important part of adolescent education and can help improve children's cognitive abilities.

Keywords Music training · Retention ability · Auditory memory · Cognitive ability · Children

M.-S. Chen (✉) · C.-M. Hsu · T.-J. Chiang
Department of Industrial Engineering and Management, National Yunlin University of Science and Technology, Douliu, Taiwan, Republic of China
e-mail: chens@yuntech.edu.tw

C.-M. Hsu
e-mail: k21973@hotmail.com

T.-J. Chiang
e-mail: g9921801@yuntech.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_145,

1 Introduction

There is a cultural belief in Taiwan that children who play music will not misbehave, and many Taiwanese families provide their children with music training. Yet, we know little about the impact the experience of learning a musical instrument has on children's cognitive behaviors. This paper investigates the relationship between cognition and musical training among young children in Taiwan.

Previous research has shown that music training not only provides learners with more experience and background knowledge, but also improves the cognitive ability of the brain to process musical information. There is some evidence, hypothesized that non-music learners would distinguish lyrics according to their surface features, such as tone and rhythm, while music learners would use structural features, such as keys and chords (Gabriel et al. 1995). Study categorized participants into two groups according to their musical abilities in order to understand the correlation between music ability and phonological awareness. The results showed that children with better music abilities also displayed better phonological awareness. The authors concluded that both language and music experiences aided children's auditory development and were beneficial to their auditory cognitive behavior (Zehra et al. 2002), and explores the impacts of music experience on intervals and melody outlines (Dowling 1978).

Baddeley and Hitch's (1974) propose a working memory model, which includes an attention controller, the central executive, which is assisted by two subsidiary systems, the phonological loop, and the visual-spatial sketchpad. Baddeley et al. (1998) tested children with a non-word span task, which was more accurate than the digit span task for measuring phonological loop span. Children relied completely on the operation of the phonological loop store when asked to pronounce an unfamiliar word during this test.

Korenman and Peynircioglu (2007) explored the effect of different learning methods, including visual and audio styles, on music learning and memory. The study experiment tested participants' memories of written words and a melody. Results showed that the visual style learner performed better when words or tunes were presented visually. Likewise, Moore's (1990) result showed that visual style learners demonstrated a higher learning efficiency and precision in music notation learning experiments. Ho et al. (2003) also explored the effect of music training on children's memory. This study also showed that the group with music training had better auditory memory and memory retention.

Comparisons of music training and non-music training participants represent experiments that have spatial–temporal (Rauscher et al. 1997; Gromko and Poorman 1998), spatial abilities (Husain et al. 2002), memory (Chan et al. 1998; Jakobson et al. 2003, 2008; Lee et al. 2007), mental abilities (Brandler and Rammsayer 2003; Helmbold et al. 2005), modularity (Peretz and Coltheart 2003) and transfer (Schellenberg 2005; Schellenberg and Peretz 2008).

The goal is to investigate whether differences in learning styles and preferences play a role in this relationship, and determine the impact of music training on children's working memory and memory retention capability.

2 Experiment

2.1 Participants and Design

At the stage 1, seventy one participants joined this experiment. They were asked to finish Barsch learning style inventory (BLSI) test were further divided into two equal groups according to the learning preference (visual or auditory).

At the stage 2, forty eight participants were selected from the BLSI test. There were 24 participants who had music training (7 males and 17 females), with a mean age of 11.67 years (SD = 0.87), and had an average music learning time of 4.17 years (SD = 1.84, longest was 7). In this group, there were 12 visual learners (3 males and 9 females) with an average age of 12 years (SD = 1.04) and 12 auditory learners (4 males and 8 females) with an average age of 11.33 years (SD = 0.49). Additionally, there were 24 participants who did not have music training (14 males and 10 females), with a mean age of 11.88 years (SD = 0.85), and had an average music learning time of 0.46 years (SD = 0.57 year). Eleven participants had brief music training experience, with longest of 1.5 years, and the rest had no experience. In this group, there were 12 visual learners (6 males and 6 females), with an average age of 11.92 years (SD = 1.08), and 12 auditory learners (8 males and 4 females), with an average age of 11.83 years (SD = 0.58). See Table 1 for a description of these participants.

The design of this study had two between-subject variables: music training group (music vs. non-music) and learning preference (visual vs. auditory), and two within-subject variables: modality (visual vs. auditory presentation) and delay time (0, 2, 4, 6, 8, and 10 s). Delay time = 0 refers to an immediate repetition with no intervening items. The dependent variable was accuracy.

2.2 Materials and Procedure

Tasks were completed with E-Prime 2.0, using a 17-inch LCD screen and 2.1 channel speakers. Numbers between one and nine were used in this digit memory task. No single digit was repeated and digits were not in consecutive order. For the

Table 1 Sample descriptions of participants in experiment

Group	Average music learning time	Learning preferences	Number	Average age
Music	4.167 (max = 7)	Visual/auditory	12/12	12.000/11.333
Non-music	0.458 (max = 1.5)	Visual/auditory	12/12	11.917/11.833

visual tasks, images were drawn using Photoshop 6.0 and presented at the size of 17 by 17 cm. For the auditory tasks, audio files were recorded with male voice at one second per digit. Participants sat approximately 50 cm from the computer screen.

This experiment involved a visual and auditory memory retention task. At the beginning of the experiment, participants were given a practical trial to ensure that they could understand and be familiar with the procedure. Two presentation conditions were manipulated including visual presentation and auditory presentation. Participants were instructed that they would see or hear two to nine digits for a visual or auditory presentation test, participants was requested to answer immediately or later. The tasks were repeated twice with random arrangement. Participants were presented with 198 trials (six practice trials and 192 test trials).

The word "start" was displayed at the center of the screen for the duration of the initially trial appear for a second and then a blank screen would appear for a second. Stimuli were presented in either visual or auditory presentation and the set size of digits ranged from two to nine. Amount of time required depended on the number of digits tested. Each digit appeared for 1000 ms.

When participants chose to answer questions immediately, 'please answer' would first appear on the screen and participants were required to press the space key to proceed to the next question (upper part of Fig. 1). Delay tie between prime task and distraction task with different time period. Distraction task when the sign '←' was presented or the word 'left' was spoken, participants needed to press the left key on the keyboard and vice versa. Participants were asked to write down the digits in the order presented, and a break of 5 min during the task (without feedback) was given.

2.3 Results

A repeated measures analysis of variance (ANOVA), the independent variables were music training group, learning preference, modality and delay time. The results revealed significant main effects for between and within variables: for groups ($p < 0.001$), for modality ($p < 0.001$) and for delay time ($p = 0.019$), but no significant for learning preference ($p = 0.469$). These analyses indicated that the mean accuracy was greater in music trained ($m = 0.88$, $SD = 0.14$) than in non-music trained ($m = 0.73$, $SD = 0.19$), and that the mean accuracy was better in visual presentation ($m = 0.88$, $SD = 0.13$) than in auditory presentation ($m = 0.73$, $SD = 0.20$). The results revealed significant two-factor interactions: for group × modality ($p = 0.002$), and for modality × delay time ($p = 0.000$). There was no significant difference in three-factor interactions.

A Tukey-HSD post hoc test revealed that participants performed better on visual tasks compared to auditory tasks for both the music trained ($p = 0.033$) and non-music trained ($p = 0.000$) groups. For music trained participants, they showed better performance on visual and auditory tasks, and visual task greater

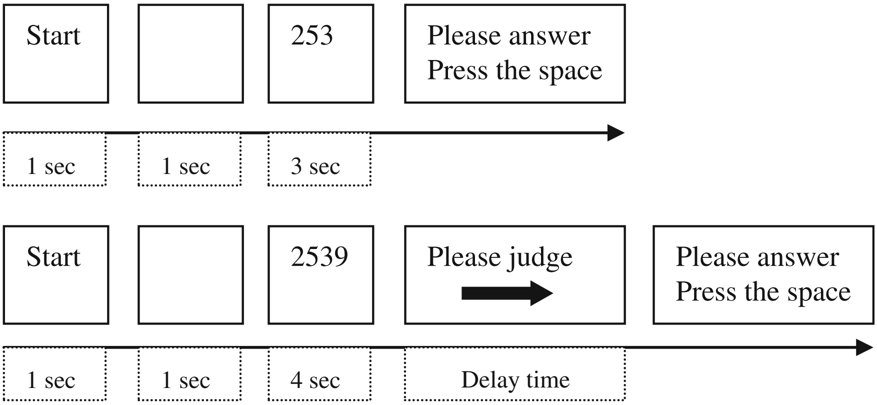


Fig. 1 Example display of experimental procedure for two presentation conditions

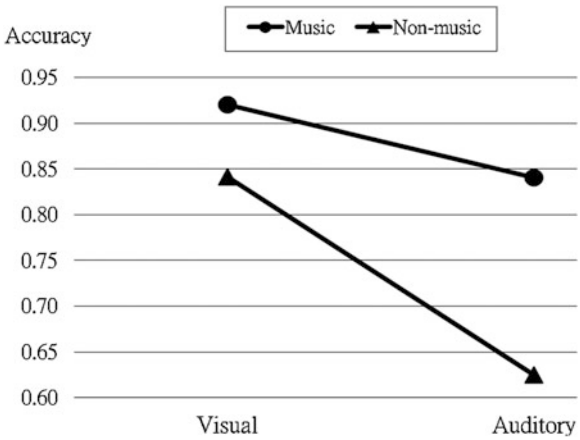
than auditory task. However, no obvious difference was found with visual task in the non-music trained group and auditory task in the music trained group ($p = 0.991$), see Fig. 2.

A Tukey-HSD post hoc test, with delay time an advantage for visual task was observed ($p < 0.016$), see Fig. 2. The visual task had no significantly response to changes in delay time ($p > 0.05$). Participants performed better on auditory task in 0 s delay than in 4, 8, and 10 s delay time ($p < 0.013$), see Fig. 3.

3 Discussion

Results of the experiment showed that the music trained group performed better than the non-music trained one on memory retention tasks. These results are similar to the findings reported in Ho et al. (2003). The difference between learning

Fig. 2 Accuracy for two groups on visual and auditory task music training demonstrated overall higher accuracy ($p = 0.002$) by the presence of two tasks



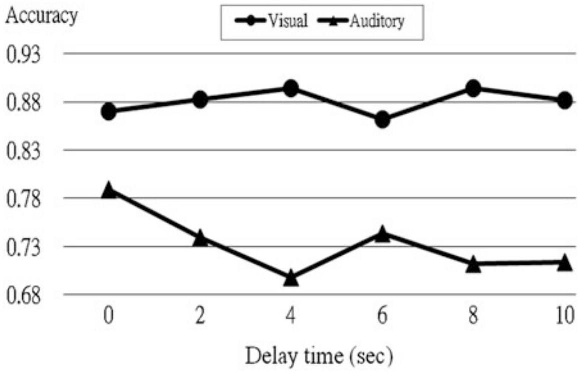


Fig. 3 Accuracy for different delay period on visual and auditory task, the interaction between modality presentation and delay time was significant ($p < 0.016$). The accuracy at each delay period was expected to be better for the visual presentation than for the auditory one

styles was not obvious, therefore we speculated that learning preference does not have an effect on memory retention.

Performance was better overall for visual tasks compared to auditory ones. Similar results were reported by Moore et al. Additionally, greater learning efficiency was observed among the non-music trained group for visual tasks. That is, in the music trained group, accuracy was 92.06 % for auditory tasks and 84.07 % for visual tasks, with difference of 7.99 %. In the non-music trained group, accuracy was 84.12 % for visual tasks and 62.46 % for auditory tasks, with difference of 21.66 %. Thus, a greater difference was observed in non-music trained group. The reason for this finding likely has to do with the constant flow of auditory information during music training. As a result, the music trained group might perceive less of a difference between visual and auditory cognition during memory retention tasks. On the other hand, children without music training likely rely mainly on visual perception. As a result, these children perceive a greater difference between the visual and auditory memory retention tasks.

Results also showed differences between the two modalities in terms of the time delay tasks. In this case, participants performed better with the visual tasks compared to the auditory tasks. The presence of a time delay did not affect performance on visual tasks, which had an accuracy of memory retention of 88.09 %. However, for auditory tasks, the accuracy decreased from 78.91 % with a 0 s time delay to 69.79 % with a 4 s delay time.

The results from this experiment were inconsistent with Jensen (1971). In our case, memory retention was greater for visual tasks. The inconsistency is likely different experimental methods and approaches in this experiment.

Participants with music training performed better than the group without music training. In terms of memory retention, the music trained group retained memory better than the non-music trained group. Overall, both groups performed better on visual tasks. A great study demonstrating this modality effect was reported by Mayer and Moreno (1998). The authors also conducted the experimental procedure for the two presentation conditions (visual text condition and auditory text condition). The results demonstrated that learning outcomes text presentation was higher for auditory. Given the results of our study, in terms of learning styles, auditory learners out-performed visual learners on the visual memory tasks.

Given the results of our study, participants' ability on memory retention was influenced by music training on visual and auditory memory retention. These findings suggest that children's visual-spatial abilities could be improved through music training. More curriculums should be included such as general music training and musical instrument lessons. This study shows that increased engagement in music and other interactive activities could improve children's overall cognitive abilities and enhance their learning experiences.

4 Conclusions

Our findings suggest that general associations between music training and modalities cognitive abilities from individual differences in memory retention. In terms of memory retention, music training retained memory better than the non-music training group. Both groups performed better when tasks were visually presented. No significant difference between difference style learners was found in memory retention task.

References

Baddeley AD, Hitch GJ (1974) Working memory. In: Broadbent DE (ed) Functional aspects of human memory. The Royal Society, London, pp 73–86

Baddeley A, Gathercole S, Papagno C (1998) The phonological loop as a language learning device. Psychol Rev 105:158–173

Brandler S, Rammsayer TH (2003) Differences in mental abilities between musicians and non-musicians. Psychol Music 31:123–138

Chan AS, Ho YC, Cheung MC (1998) Music training improves verbal memory. Nature 396(6707):128

Dowling WJ (1978) Scale and contour: two components of a theory of memory for melodies. Psychol Rev 85:341–354

Gabriel AR, Kevin JF, Julie AS (1995) Timbre reliance in nonmusicans' and musicans' memory for melodies. Music Perception 13:127–140

Gromko JE, Poorman AS (1998) The effect of music training on preschoolers' spatial-temporal task performance. J Res Music Educ 46:173–181

Helmbold N, Rammsayer T, Altenmüller E (2005) Differences in primary mental abilities between musicians and nonmusicians. J Individ Differ 26:74–85

Ho YC, Cheung MC, Chan AS (2003) Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children. Neuropsychology 17(3):439–450

Husain G, Thompson WF, Schellenberg EG (2002) Effects of musical tempo and mode on arousal, mood, and spatial abilities. Music Perception 20:151–171

Jakobson LS, Cuddy LL, Kilgour AR (2003) Time tagging: a key to musicians' superior memory. Music Perception 20:307–313

Jakobson LS, Lewycky ST, Kilgour AR, Stoesz BM (2008) Memory for verbal and visual material in highly trained musicians. Music Perception 26:41–55

Jensen AR (1971) Individual differences in visual and auditory memory. J Educ Psychol 62:123–131

Korenman LM, Peynircioglu ZF (2007) Individual differences in learning and remembering music: auditory versus visual presentation. J Res Music Educ 55(1):48–64

Lee Y-S, Lu M-J, Ko H-P (2007) Effects of skill training on working memory capacity. Learn Instr 17:336–344

Mayer RE, Moreno R (1998) A split-attention effect in multimedia learning: evidence for dual processing systems in working memory. J Educ Psychol 90:312–320

Moore BR (1990) The relationship between curriculum and learner: music composition and learning style. J Res Music Educ 38:24–38

Peretz I, Coltheart M (2003) Modularity of music processing. Nat Neurosci 6:688–691

Rauscher FH, Shaw GL, Levine LJ, Wright EL, Dennis WR, Newcomb RL (1997) Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. Neurol Res 19:2–8

Schellenberg EG (2005) Music and cognitive abilities. Curr Dir Psychol Sci 14:317–320

Schellenberg EG, Peretz I (2008) Music, language, and cognition: unresolved issues. Trends Cogn Sci 12:45–46

Zehra FP, Aydyn YD, Banu ÖK (2002) Phonological awareness and musical aptitude. J Res Reading 25(1):68–80

Control Scheme for the Service Quality

Ling Yang

Abstract This research constructs a novel quality control scheme for monitoring the service quality. Providing high-quality services can enhance company's productivity and strengthen its competitiveness. Due to the diversity of service operation, measuring and monitoring the service quality becomes very difficult. PZB's SERVQUAL is a commonly used scale to measure the service quality. The SERVQUAL scale has been shown to measure five underlying dimensions with 22 quality elements. After a questionnaire investigation, the collected information of service quality is often not monitored continually. If the service quality has variation, there will be no way for immediate correction. Precise instruments for measuring quality and accomplishing quality control have been developed and widely used in the manufacturing sector. The quality control chart is one of the commonly used tools of statistical process control for on-line control. Applying the control chart in the service quality can improve the control effect. In this work, the Ridit analysis is used to transform the collected data, which are mostly in Likert-scale, and to find the priority of quality elements. Some more important elements can be selected for the construction of control chart.

Keywords Control chart · Service quality · PZB quality model · SERVQUAL · Ridit analysis

1 Introduction

Facing global competition, the company should provide high-quality services and products to meet customers' needs. The diversity of service operation makes the measurement of service quality challenging. After many studies about service

L. Yang (✉)
Department of Marketing and Logistics Management, St. John's University, 499, Sec. 4, Tamking Road, Tamsui District, New Taipei City 25135, Taiwan, Republic of China
e-mail: lgyang@mail.sju.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_146,

quality, Parasuraman et al. (called PZB for short) (1985) provided the famous PZB service quality model. PZB's SERVQUAL scale and their various extensions (Parasuraman et al. 1988, 1991, 1993, 1994; Zeithaml et al. 1993) indicated the factors that influence customer expectations and customer perceptions, and tried to quantify customer satisfaction using service performance gaps. The main gaps with SERVQUAL scale are: the knowledge gap, the standards gap, the delivery gap, the communications gap, and the overall gap. In SERVQUAL, the service quality is divided into five dimensions with 22 quality items. After SERVQUAL, there are a lot of studies for service quality scales proposed. SERVQUAL is still the most widely used.

SERVQUAL scale is based on the gap theory of service quality. In SERVQUAL's questionnaire, the twenty-two items of service quality are asked in "expected quality" sector and "perceived quality" sector, respectively. For each quality item, the service quality (SQ) is computed as the gap score of the perceived quality (P) and the expected quality (E), i.e.,

$$SQ = P - E \tag{1}$$

If $SQ > 0$, it means that the customer is satisfied, and the higher the positive number, the more satisfaction. If $SQ < 0$, it means that the customer is not satisfied, and the higher the negative number, the more dissatisfaction.

Most of the service quality studies conduct a questionnaire survey in a specific period of time, but little research had been carried out for the monitoring of usual service quality. There are some firms engaged in regular surveys. Due to lack of appropriate quality control tool, the collected data of regular surveys cannot be used in a continuous quality monitoring. In order to ensure the product or service is in control, the application of on-line quality control is essential. The aim of this study is to construct a novel control scheme for monitoring the service quality in a firm's daily services.

2 Previous Research

2.1 Ordered Samples Control Chart

Franceschini et al. (2005) proposed an ordered samples control chart for ordinal scale sample data. Their study was based on the process sampling of manufacturing sector, and only one quality characteristic was considered. Such a quality control scheme cannot display all of the information of a firm's service quality.

2.2 *Expectation-Perception Control Chart*

Donthu (1991) constructed an expectation-perception control chart which used the SERVQUAL scales to generate quantitative data. Based on five dimensions of service quality, their collected data were analyzed in expectation analysis and perception analysis, respectively. And, the control limits of the expectation-perception control chart were computed by all respondent data. Unlike the concept of online control, the samples of the expectation-perception control scheme were selected randomly from the respondent data in the same survey. Their sampling method did not comply with the spirit of process control.

3 The Proposed Service Quality Control Scheme

The purpose of this study is to provide a control scheme for monitoring the service quality. Quality control chart is one of the commonly used tools in on-line quality control. The control chart is a graph used to study how a process changes over time with data plotted in time order. The construction of control chart includes the control center line, the upper control limit, and the lower control limit.

Most of the general service quality scales have about 20 items, or even more. If all of the quality items are put to control individually, it seems difficult to interpret these data. If the quality items can be sorted by the degree of importance, and select the more important items to control, the work of service quality control can be more focused. In questionnaire surveys, most of the answers of respondents are measured with Likert-scale. Likert-scale assumes that each quality item has the same value, i.e., each answer is considered as an interval scale. However, Schwarz et al. (1991) found that the respondents tended to the center-right options.

For many respondents, a Likert-scale from 1 (meaning "strongly disagree") to 5 (meaning "strongly agree") is not equidistant between 1 and 5 of each option, but more like ordinal scale to express their views. Using the average of interval scale to determine the importance sequence of the quality items seems inappropriate. Therefore, the collected data should be converted appropriately before construct a service quality control chart.

Some studies (Yager 1993; Wu 2007) tried to convert Likert scale. Ridit (Relative to an Identified Distribution Unit) analysis (Fielding 1993) is one of the commonly used methods in the context of ordered categorical data. Chatterjee and Chatterjee (2005) proposed a prioritization methodology of the service quality items with Ridit analysis (Bross 1958; Agresti 2010). In this study, Ridit analysis is invoked to transform the collected data of the survey questionnaire, and prioritize the quality items according to the increasing order of service gap (as shown in 1). Then some mean control charts, such as the Shewhart-$\overline{X}$ control chart (Montgomery 2009) and the exponentially weighted moving average (EWMA)-$\overline{X}$ control chart (Roberts 1959) can be used to construct the service quality control chart.

4 Conclusions

The proposed service quality control scheme allows the firms of service sector to sustain the quality control. The use of Ridit analysis makes data conversion more reasonable and identifies the priority of quality items. The design of the control charts for more important items allows the quality control more focused. The proposed service quality control scheme has practical value.

Acknowledgments This work is partially supported by the National Science Council, Taiwan, ROC, under Contract no. NSC 101-2221- E-129-011.

References

Agresti A (2010) Analysis of ordinal categorical data. Wiley, New York

Bross ID (1958) How to use ridit analysis. Biometrics 14:18–38

Chatterjee S, Chatterjee A (2005) Prioritization of service quality parameters based on ordinal responses. Total Quali Manag 16:477–489

Donthu N (1991) Quality control in services industry. J Profl Serv Market 7:31–55

Fielding A (1993) Scoring functions for ordered classifications in statistical analysis. Qual Quant 27:1–17

Franceschini F, Galetto M, Varetto M (2005) Ordered samples control charts for ordinal variables. Qual Relia Engi Intl 21:177–195

Montgomery D (2009) Statistical quality control: a modern introduction, 6th edn. Wiley, New York

Parasuraman A, Zeithaml VA, Berry LL (1985) A conceptual model of service quality and its implications for future research. J Market 49:41–50

Parasuraman A, Zeithaml VA, Berry LL (1988) SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. J Retail 64:12–40

Parasuraman A, Berry LL, Zeithaml VA (1991) Refinement and reassessment of the SERVQUAL scale. J Retail 67:420–450

Parasuraman A, Berry LL, Zeithaml VA (1993) More on improving service quality measurement. J Retail 69:140–147

Parasuraman A, Zeithaml VA, Berry LL (1994) Alternative scales for measuring service quality: a comparative assessment based on psychometric and diagnostic criteria. J Retail 70:201–230

Roberts SW (1959) Control chart tests based on geometric moving averages. Technometrics 1:239–250

Schwarz N, Knauper B, Hippler HJ et al (1991) Rating scales: numeric values may change the meaning of scale labels. Pub Opin Quart 55:570–582

Wu CH (2007) An empirical study on the transformation of Likert-scale data to numerical scores. Appl Math Sci 1:2851–2862

Yager R (1993) Non-numeric multi-criteria multi-person decision making. Group Deci Negot 2:81–93

Zeithaml V, Berry L, Parasuraman A (1993) The nature and determinant of customer expectation of service quality. J Acad Market Sci 21:1–12

Particle Swam Optimization for Multi-level Location Allocation Problem Under Supplier Evaluation

Anurak Chaiwichian and Rapeepan Pitakaso

Abstract The aim of this paper is to propose the method for solving multi-level location allocation problems under supplier evaluation. The proposed problem is solved by particle swarm optimization (PSO). Generally, the multi-level location allocation problem considers the suitable locations to service customers or to store inventory from the suppliers. The proposed problem is to determine the suitable location to store and produce the product from the selected suppliers and then delivers product to the customers. The selected suppliers are determined by the capability of them. The capability of the suppliers means the quality of the material delivered and the reliability of delivery date which gather from their past statistics. The problem solving can be divided into two steps: the first step is to evaluate each potential supplier using fuzzy approach and second step is to selects the locations in order to serve the customer demand with minimum cost using PSO by calculating the amount of material shipped to location by a specified supplier closeness coefficient (CC_h). As the results, the percentage error is between 0.89 and 16.90 % and the average runtime is 4.2 s.

Keywords Capacitated p-median problem · Fuzzy · Closeness coefficient (CC_h) · Particle swarm optimization (PSO)

A. Chaiwichian (✉) · R. Pitakaso
Department of Industrial Engineering, Ubonratchathani University, Ubonratchathani 34190, Thailand
e-mail: anuak.aun@gmail.com

R. Pitakaso
e-mail: enrapepi@mail2.UBU.AC.TH

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_147,

1 Introduction

The capacitated p-median problem (CPMP) was a well-known discrete location problem. We have to partition a set of customers, with a known demand, in p-facilities and consider between capacities that enough supply to a set of customers and minimized total distance. This problem has many researchers to create various new heuristic algorithms. Such Lorena and Senne (2003) used Lagrangean/surrogate relaxation which improves upper bounds applying local search heuristics to solutions. Similar problem, Mulvey and Beck (1984) examined the Lagrangean relaxation of assignment constraints in a 0–1 linear integer programming problem formulation. Diaz and Fernandez (2006) proposed heuristic algorithms for capacitated p-median problem. They used 3 methods for solving including Scatter Search, Path Relinking, and combining Scatter Search and Relinking together.

Various heuristic algorithms were applied to determine CPMP. This was modified for complicated problem, which was known to be NP-hard (Garey and Johnsoh 1979). Among the more recent works on application heuristics was that of Ahmadi and Osman (2005) propose a greedy random adaptive memory search method and later offer a guided construction search heuristic. Fleszar and Hindi (2008) presented Variable Neighbour hood Search for solving CPMP.

For the recent problem, CPMP was mixed with customer and matching routing supplier or probability customer in order to minimize total cost or minimize distance. Corresponding to this, it has many researches try to solve this. Albareda-Sambola et al. (2009) introduced a new problem called the Capacity and Distance Constrained Plant Location Problem which constraints include capacity of plants and total distance between plant and customers. Zhu et al. (2010) offers a new problem called the capacitated plant location problem with customer and supplier matching (CLSM). They merge a distribution trip and a supply trip into one triangular trip for saving allocation cost. In same line, Kuban Altinel et al. (2009) considered constraints under capacity with probabilistic customer locations. A review of previous works indicates that the methods for solving problems are pointed to the discrete optimization with minimization cost under capacitated constrain but it could not consider the supplier evaluation together. So, in this paper we present an approach for capacitated p-median problem under supplier evaluation with mixed discrete-continuous optimization. To determine this problem, we present the fuzzy algorithms for evaluating supplier and we use Lingo software and PSO method to solve problem.

In this paper, the next section presents the mathematical models and Fuzzy method. In Sect. 3, we propose methodology of this research. Section 4 describes the method of PSO and Sect. 5 explains the methodology. Finally, the experiments are illustrated by a table which is a result of testing in 3 cases.

2 Mathematical Models

2.1 Mathematics

We have divided problem into 3 cases and defined the meaning of supplier in each case.

For the case 1, the plants receive products only from the suppliers which are passed and all customer demands are enough to serve. Objective function and constrains are as below

$$\mathrm{Min} = \sum_{i=1}^{m}\sum_{j=1}^{n} A_i C_{ij} X_{ij} + \sum_{h=1}^{k}\sum_{j=1}^{n} U_h Y_h W_{hj} Z_{hj} - \sum_{j=1}^{n}\sum_{h=1}^{k} \frac{U_h}{(1+U_h)} Y_h W_{hj} Z_{hj} \quad (1)$$

Subject to

$$\sum_{h=1}^{k} U_h Y_h Z_{hj} \le P_j, \ \forall j \quad (2)$$

$$\sum_{h=1}^{k} U_h Y_h Z_{hj} \ge \sum_{i=1}^{m} A_i X_{ij}, \ \forall j \quad (3)$$

$$\sum_{i=1}^{m} X_{ij} \ge 1, \ \forall j \quad (4)$$

$$\sum_{j=1}^{n} X_{ij} = 1, \ \forall i \quad (5)$$

$$\sum_{h=1}^{k} Z_{hj} \ge 1, \ \forall j \quad (6)$$

$$\sum_{j=1}^{n} Z_{hj} \le 1, \ \forall h \quad (7)$$

$$X_{ij} \in \{0,1\} \quad (8)$$

$$Z_{hj} \in [0,1] \quad (9)$$

$$U_h > 0 \quad (10)$$

where,

i Customer

j Plant

h Supplier
A_i Customer demand at i
C_{ij} Cost per piece for delivering products from plant j to customer i
U_h Percentage for ordering products from supplier h
Y_h Capacity of supplier h
X_{ij} $\begin{cases} \text{if customer i is served by plant j.} \\ \text{0 otherwise.} \end{cases}$
CC_h The closeness coefficient of supplier h
Z_{hj} Plant j is served by supplier h
P_j Maximum capacity of plant j
W_{hj} Penalty cost per piece for delivering products from supplier h to plant j

In the Eq. (2), it guarantees that quantities in each supplier h which sends to plant j are less than or equal to maximum capacity of plant j. Equation (3) shows that the quantities in each supplier h sending to plant j are greater than or equal to customer demand at i. Equation (4) indicates that plant can send products more than one customer. Equation (5) guarantees that customer can receive products one plant. For the Eq. (6), plant can receive products more than one supplier. In the Eqs. (7) and (9), Z_{hj} is a real number and less than or equal one.

For the case 2, the plants receive products from the passing suppliers but they can't serve all customers. So, plants have to receive the residual products from the passing suppliers in order to fulfill demand of the customers. Objective function and constrains are shown in below,

$$\text{Min} = \sum_{i=1}^{m}\sum_{j=1}^{n} A_i C_{ij} X_{ij} + \sum_{h=1}^{k}\sum_{j=1}^{n} U_h Y_h W_{hj} Z_{hj} + \sum_{j=1}^{n}\sum_{h=1}^{k} (1 - U_h) Y_h \left[W_{hj} + \lambda_{hj}\right] Z_{hj} - \sum_{j=1}^{n}\sum_{h=1}^{k} \frac{U_h}{(1 + U_h)} Y_h W_{hj} Z_{hj} \tag{11}$$

subject to

$$\sum_{h=1}^{k} U_h Y_h Z_{hj} + \sum_{h=1}^{k} (1 - U_h) Y_h Z_{hj} \le P_j, \forall j \tag{12}$$

$$\sum_{h=1}^{k} [U_h Y_h + (1 - U_h) Y_h] Z_{hj} \ge \sum_{i=1}^{m} A_i X_{ij}, \forall j \tag{13}$$

$$\sum_{i=1}^{m} X_{ij} \ge 1, \ \forall j \tag{14}$$

$$\sum_{j=1}^{n} X_{ij} = 1, \ \forall i \tag{15}$$

$$\sum_{h=1}^{k} Z_{hj} \geq 1,\ \forall j \tag{16}$$

$$\sum_{j=1}^{n} Z_{hj} \leq 1,\ \forall h \tag{17}$$

$$X_{ij} \in \{0, 1\} \tag{18}$$

$$Z_{hj} \in [0, 1] \tag{19}$$

$$U_h > 0 \tag{20}$$

where

λ_{hj} Penalty cost per piece that sends products form supplier h to plant j.

In the Eq. (12), it assures that products from supplier h are less than or equal to maximum capacity of plant j. Equation (13) shows that the products of supplier h are greater than or equal to customer demand at i.

In the case 3, the plants accept the products from the passing suppliers but are not enough to serve customers. Therefore, the plants must be received from the other suppliers. Objective function and constrains are shown in below,

$$\begin{aligned} \text{Min} = & \sum_{i=1}^{m}\sum_{j=1}^{n} A_i C_{ij} X_{ij} + \sum_{h=1}^{k}\sum_{j=1}^{n} U_h Y_h W_{hj} Z_{hj} + \sum_{j=1}^{n}\sum_{h=1}^{k} (1 - U_h) Y_h \left[W_{hj} + \lambda_{hj}\right] Z_{hj} \\ & + \sum_{j=1}^{n}\sum_{h=1}^{k} Y_{h|U_h=0} \left[W_{hj} + \lambda_{hj}\right] Z_{hj} - \sum_{j=1}^{n}\sum_{h=1}^{k} \frac{U_h}{(1 + U_h)} Y_h W_{hj} Z_{hj} \end{aligned} \tag{21}$$

subject to

$$\sum_{h=1}^{k} U_h Y_h Z_{hj} + \sum_{h=1}^{k} (1 - U_h) Y_h Z_{hj} + \sum Y_{h|U_h=0} Z_{hj} \leq P_j\ , \forall j \tag{22}$$

$$\sum_{h=1}^{k} [U_h Y_h + (1 - U_h) Y_h] Z_{hj} + \sum_{h=1}^{k} Y_{h|U_h=0} Z_{hj} \geq \sum_{i=1}^{m} A_i X_{ij}\ , \forall j \tag{23}$$

$$\sum_{i=1}^{m} X_{ij} \geq 1,\ \forall j \quad (24) \qquad / \qquad \sum_{j=1}^{n} X_{ij} = 1,\ \forall i \quad (25)$$

$$\sum_{h=1}^{k} Z_{hj} \geq 1,\ \forall j \quad (26) \qquad / \qquad \sum_{j=1}^{n} Z_{hj} \leq 1,\ \forall h \quad (27)$$

$$X_{ij} \in \{0, 1\} \quad (28) \qquad / \qquad Z_{hj} \in [0, 1] \quad (29)$$

$$U_h > 0 \quad (30)$$

In the Eq. (22), it guarantees that quantities include the other suppliers are less than or equal to maximum capacity of plant j. Equation (23) shows that the quantities in each supplier h sending to plant j are greater than or equal to customer demand at i.

3 Fuzzy Method

In this paper, we use 2 variables in term of linguistic variables. One is the importance weights of various criteria and the second is the ratings of qualitative criteria. All of them are considered as linguistic variables. We have 3 steps to proceeding in fuzzy methods. First step, we assign the linguistic variables to 7 criterions for assessments. The linguistic variables for importance weight are Very Low, Low, Medium Low, Medium, Medium High, High and Very High (Chen et al. 2006) and the importance weights in each criterion are represented as shown in Fig. 1.

For example, the linguistic variable “Medium High” can be represented as (0.5, 0.6, 0.7, 0.8) for the importance weight of each criterion. The second step, the linguistic variables for ratings of qualitative are as shown in Fig. 2.

In term of “Good” in ratings, the linguistic variables can be represented as (7, 8, 9) for the ratings of qualitative in each criterion. In this paper, there are 4 criterions including Supplier’s product quality, Supplier’s delivery/order fulfillment capability, Price/Cost reduction performance, and Supplier’s post-sales service (Wang 2010). The third step is reviewed from (Chen et al. 2006). In this

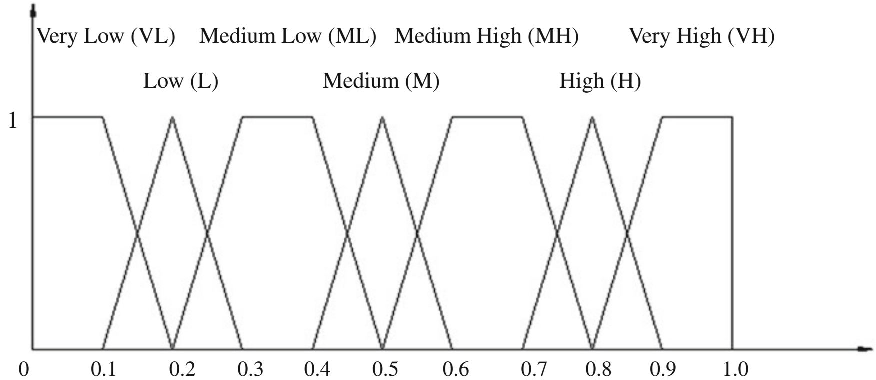


Fig. 1 Linguistic variable for importance weight of each criterion

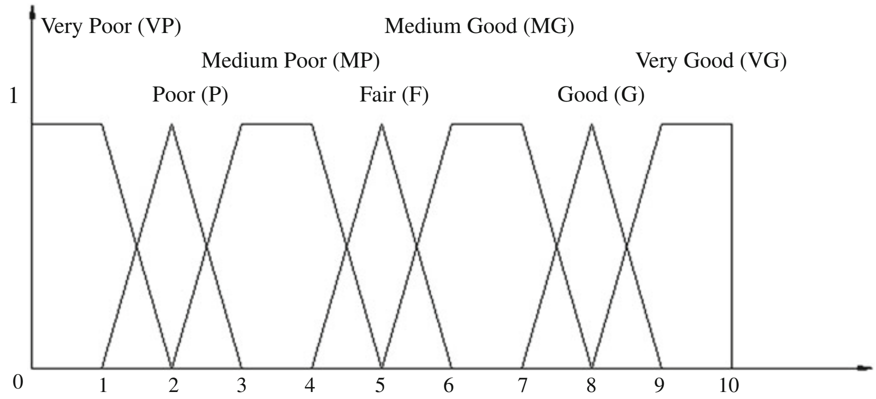


Fig. 2 Linguistic variable for ratings

research, we have 4 sets to group parameters for evaluating supplier. The sets describe as below

1. a set of K decision-makers called $E = \{D_1, D_2, \ldots D_k\}$
2. a set of m possible suppliers called $A = \{A_1, A_2, \ldots, A_m\}$
3. a set of n criteria, $C = \{C_1, C_2, \ldots, C_n\}$, with which supplier performances are measured
4. a set of performance ratings of Ai $(i = 1,2, \ldots, m)$ with respect to criteria C_j $(j = 1,2, \ldots, n)$, called $X = \{X_{ij}, i = 1,2, \ldots, m, j = 1,2, \ldots, n\}$.

The fuzzy ratings of each decision-maker D_k $(k = 1,2,\ldots,K)$ are represented as a positive trapezoidal fuzzy number $\widetilde{R}_k$ $(k = 1,2,\ldots,K)$ with membership function $\mu_{\widetilde{R}_k}(x)$ which translates the linguistic variable as below.

For example, the linguistic variable for importance weight in term of "Medium High (MH)" can be represented as (0.5, 0.6, 0.7, 0.8), the membership function of which is

$$\mu_{MediumHigh}(x) = \begin{cases} 0, & x < 0.5, \\ \frac{x-0.5}{0.6-0.5}, & 0.5 \le x < 0.6, \\ 1, & 0.6 \le x < 0.7, \\ \frac{x-0.8}{0.8-0.7}, & 0.7 \le x < 0.8, \\ 0 & x \ge 0.8. \end{cases} \tag{31}$$

And the linguistic variable for ratings in term of "Very Good (VG)" can be represented as (8, 9, 9, 10), the membership function of which is

$$\mu_{VeryGood}(x) = \begin{cases} 0, & x < 8, \\ \frac{x}{9-8} & 8 \le x < 9, \\ 1, & 9 \le x < 10, \end{cases} \tag{32}$$

The fuzzy ratings of all decision-makers is trapezoidal fuzzy numbers $\widetilde{R}_k = (a_k, b_k, c_k, d_k), \quad k = 1, 2, \ldots, K$. so, the aggregated fuzzy rating is defined as $\widetilde{R} = (a, b, c, d), \quad k = 1, 2, \ldots, K$
where

$$\left.\begin{array}{ll} a = \min_k\{a_k\} & b = \frac{1}{K}\sum_{k=1}^{K} b_k \\ c = \frac{1}{K}\sum_{k=1}^{K} c_k & d = \max_k\{d_k\} \end{array}\right\} \tag{33}$$

The fuzzy rating is $\widetilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk}, d_{ijk})$ and importance weights is $\widetilde{w}_{jk} = (w_{jk1}, w_{jk2}, w_{jk3}, w_{jk4})$where i =1,2,…,m; j = 1,2,…,n; k = the *k*th decision maker. The aggregated fuzzy ratings ($\widetilde{x}_{ij}$) with respect to each criterion can be calculated as $\widetilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$ where

$$\left.\begin{array}{ll} a_{ij} = \min_k\{a_{ijk}\} & b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ijk} \\ c_{ij} = \frac{1}{K}\sum_{k=1}^{K} c_{ijk} & d_{ij} = \max_k\{d_{ijk}\} \end{array}\right\} \tag{34}$$

The aggregate fuzzy weights ($\tilde{w}_j$) of each criterion can be calculated as $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4})$ where

$$\left.\begin{array}{ll} w_{j1} = \min_k\{w_{jk1}\} & w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2} \\ w_{j3} = \frac{1}{K}\sum_{k=1}^{K} w_{jk3} & w_{j4} = \max_k\{w_{jk4}\} \end{array}\right\} \tag{35}$$

A supplier-selection can be expressed in matrix format as below:

$$\left.\begin{array}{l} \widetilde{D} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \cdots & \widetilde{x}_{1n} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \cdots & \widetilde{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \widetilde{x}_{m1} & \widetilde{x}_{m2} & \cdots & \widetilde{x}_{mn} \end{bmatrix} \\ \widetilde{W} = [\widetilde{w}_1, \widetilde{w}_2, \ldots, \widetilde{w}_n] \end{array}\right\} \tag{36}$$

where

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij}) \text{ and } \tilde{w}_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4});$$

i =1,2,…,m, j = 1,2,…,n. can be approximated by positive trapezoidal fuzzy numbers. We use linear scale transformation to reduce mathematical operations in a decision process. The set of criteria can be divided into benefit criteria (using the larger the rating, the greater the preference: B) and cost criteria (using the smaller the rating, the greater the preference: C). The normalized fuzzy-decision matrix can be shown as

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \tag{37}$$

where B and C are the set of benefit criteria and cost criteria, respectively

$$\tilde{r}_{ij}=\left(\frac{a_{ij}}{d_j^*},\frac{b_{ij}}{d_j^*},\frac{c_{ij}}{d_j^*},\frac{d_{ij}}{d_j^*}\right), \quad j \in B \tag{38}$$

$$\tilde{r}_{ij} = \left(\frac{a_{\bar{j}}}{d_{ij}},\frac{a_{\bar{j}}}{c_{ij}},\frac{a_{\bar{j}}}{b_{ij}},\frac{a_{\bar{j}}}{a_{ij}}\right), \quad j \in C, \tag{39}$$

$$d_j^* = \max_i d_{ij}, \quad j \in B \tag{40}$$

$$a_{\bar{j}} = \min_i a_{ij}, \quad j \in C. \tag{41}$$

The weighted normalized fuzzy-decision matrix is arranged as

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times n}, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n \tag{42}$$

where

$$\tilde{v}_{ij} = \tilde{r}_{ij}(\circ)\tilde{w}_j \tag{43}$$

The fuzzy positive-ideal solution (FPIS, A*) and fuzzy negative-ideal solution (FNIS, A^-) can be described as

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*), \quad A- = (\tilde{v}_{\bar{1}}, \tilde{v}_{\bar{2}}, \ldots, \tilde{v}_{\bar{n}}), \tag{44}$$

where

$$\tilde{v}_j^* = \max_i [v_{ij4}] \text{ and } \tilde{v}_{\bar{j}} = \min_i [v_{ij1}] \tag{45}$$

The distance of each alternative A* and A^- is as below

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1, 2, \ldots, m. \tag{46}$$

$$d_{\bar{i}} = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_{\bar{j}}), \quad i = 1, 2, .., m. \tag{47}$$

Where d_v (•, •) is the distance measurement between two fuzzy numbers which are calculated by using the vertex method as Chen et al. (2006).

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{4}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + \cdots + (m_m - n_n)^2]} \tag{48}$$

Final step of fuzzy method, a closeness coefficient (CC_i) is described to calculate the ranking order of all suppliers. It has an equation as

Table 1 Percentage of U_h

Closeness coefficient $(CC_h)^*$	Assessment status**	U_h (%)
$CC_h \in [0,0.2)$	Do not recommend.	0
$CC_h \in [0.2,0.4)$	Recommend with high risk.	0
$CC_h \in [0.4,0.6)$	Recommend with low risk.	70
$CC_h \in [0.6,0.8)$	Approved.	85
$CC_h \in [0.8,1]$	Approved and preferred	100

*,** Chen-Tung Chen

$$CC_i = \frac{d_i^{--}}{d_i^* + d_i^{--}}, \quad i = 1, 2, \ldots, m. \tag{49}$$

The closeness coefficient is corresponded to Table 1.

4 Particle Swarm Optimization

The various steps involved in Particle Swarm Optimization Algorithm are as follows

step 1: The velocity and position of all particles are randomly set to within predefined ranges.

step 2: Velocity updating—At each iteration, the velocities of all particles are updated according to,

$$v_i^{t+1} = w_i v_i^t + c_1 R_1 (p_{i,best}^t - p_i^t) + c_2 R_2 (g_{i,best}^t - p_i^t). \tag{50}$$

step 3: Position updating—The positions of all particles are updated according to,

$$p_i^{t+1} = p_i^t + v_i^{t+1} \tag{51}$$

$$w_i = \frac{[(w_w - 0.4)(no.iter - iter_i)]}{(no.iter + 0.4)} \tag{52}$$

step 4: Memory updating—Update $p_{i,best}$ and $g_{i,best}$ when condition is met,

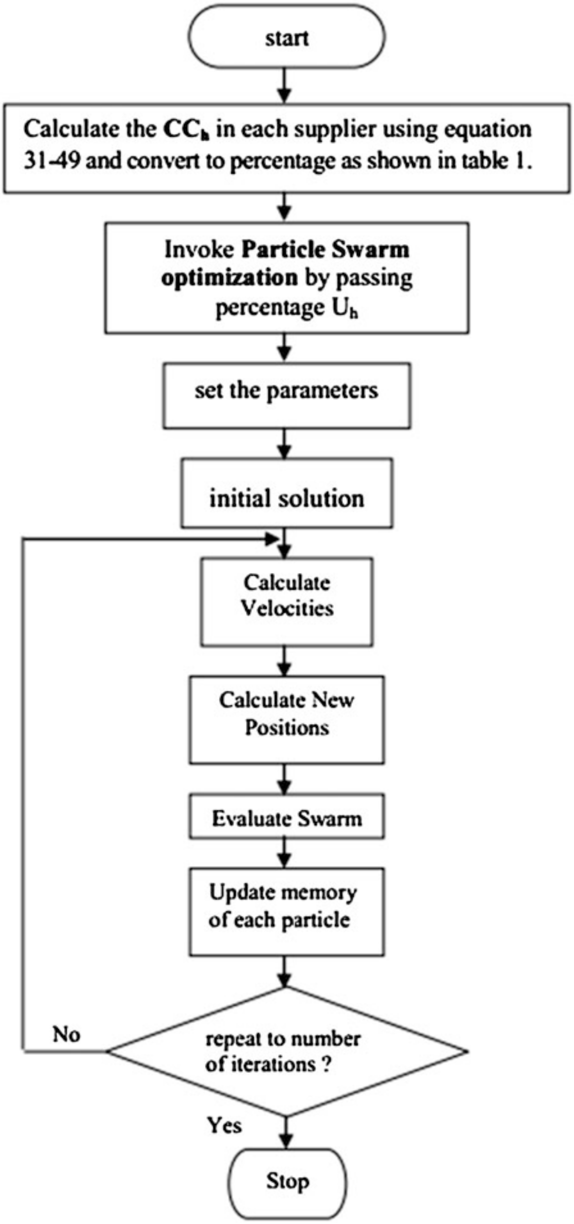


Fig. 3 Flowchart of process PSO

$$\begin{aligned} p_{i,best} &= p_i \text{ if } f(p_i) > f(p_{i,best}) \\ g_{i,best} &= g_i \text{if } f(g_i) > f(g_{i,best}) \end{aligned} \tag{53}$$

Table 2 Results of the experiments

Case	Optimum	Objective function of PSO	CPU time (min: sec: ms)		% Error
			Lingo	PSO	
1	3625090	3901156	01:28:00	00:04:22	7.62
1	3602470	4103373	01:28:00	00:04:20	13.90
1	3621240	3980837	01:28:00	00:04:18	9.93
1	3622100	3976914	01:28:00	00:04:20	9.80
1	3610880	4221071	01:28:00	00:04:20	16.90
2	10372902	11277106	>2 h	00:04:24	8.72
2	10560304	10412461	02:58:00	00:04:00	1.40
2	9983255	9339444	23:28:00	00:04:00	6.45
2	10043602	9445484	>2 h	00:04:06	5.96
2	11182905	9855059	>2 h	00:04:08	11.87
3	39872924	36894452	12:33:00	00:04:12	7.47
3	34572025	35201078	03:53:00	00:04:10	1.82
3	29506023	25449149	01:33:00	00:04:06	13.75
3	24641804	24421456	01:34:00	00:04:04	0.89
3	19433021	18476195	04:01:00	00:04:08	4.92
Average			1,197.33 s	4.12 s	8.09

where *f(x)* is the objective function to be optimized and w_i is the inertia of the velocity

5 Methodology

In this study, PSO is set by the parameters as $c_1 = 3$, $c_2 = 1.5$,$R_1 = 4$, $R_2 = 2$,$w_w = 1$ and number of particles = 10, iterations = 10. This problems set the number of supplier (h), plant (j) and customer (i) as 2,000, 50 and 4,000 consequently. The process of PSO is shown as flowchart in Fig. 3.

6 Experimental Results

In this study, we run on a notebook with the configuration of 2.10 GHz CPU and 4.0 GB memory. We solved problems and compared with optimal solution to test the performance of our algorithms. The %error are reported in column 10–11 and calculated as

$$\frac{f - f_{opt}}{f_{opt}} \times 100, \tag{54}$$

where f denotes the best solution found and f_{opt} is the optimal value in objective function.

The results of experiments are shown in Table 2. As the results, the maximum %error in PSO is 16.90 and 0.89 % for minimum %error, and average %error of PSO is 8.09 %. The average runtime of PSO is 4.12 s while average runtime for founding optimal solutions is 1,197.33 s. In no. 6, 9 and 10 of Table 2, they run more than 2 h to find a solution but PSO runs time about 4.13 s and have %error is 8.72, 5.96 and 11.87 respectively.

7 Conclusion

A new problem of location allocation problem has proposed in this study. It has considered between quantity and quality for finding the optimal solutions. We use fuzzy method in this problem for evaluating the quality.

A particle swarm optimization is proposed as an alternative for solving this problem and it is compared to optimal solutions solved by Lingo software. The results shown that a heuristics PSO can generate good solutions to location allocation problem.

As the results, PSO outperforms Lingo when the computational time is limited and the optimal solutions are nearly the best solutions. Moreover, this PSO can be easily implemented by location allocation problem under supplier evaluation. Based on our computational test, we believe that PSO have potential to be useful heuristic for this problem.

For the future work, this problem can be applied to the modified PSO in order to find the exactly optimal solutions and run on big scale.

References

Ahmadi S, Osman IH (2005) Greedy random adaptive memory programming search for the capacitated clustering problem. Eur J Oper Res 162(1):30–44

Chen CT, Lin CT, Huang SF (2006) A fuzzy approach for supplier evaluation and selection in supply chain management. Int J Prod Econ 102:289–301

Kuban Altinel I et al (2009) A location-allocation heuristic for the capacitated multi-facility Weber problem with probabilistic customer locations. Eur J Oper Res 198:790–799

Diaz JA, Fernandez E (2006) Hybrid scatter search and path relinking for the capacitated p-median problem. Eur J Oper Res 169:570–585

Fleszar K, Hindi KS (2008) An effective VNS for the capacitated p-median problem. Eur J Oper Res 191:612–622

Lorena LAN, Senne ELF (2003) Local search heuristics for capacitated p-median problems. Netw Spat Econ 3:407–419

Garey MR, Johnsoh DS (1979) Computers and intractability : a guide to the theory of NP-completeness. W.H. Freeman and Co, New York

Albareda-Sambola M, Fernandez E, Laporte G (2009) The capacity and distance constrained plant location problem. Comput Oper Res 36:597–611

Mulvey JM, Beck MP (1984) Solving capacitated clustering problems. Eur J Oper Res 18:339–348

Wang WP (2010) A fuzzy linguistic computing approach to supplier evaluation. Appl Math Model 34:3130–3141

Zhu Z, Chu F, Sun L (2010) The capacitated plant location problem with customers and supplier matching. Transp Res Part E 46:469–480

Evaluation Model for Residual Performance of Lithium-Ion Battery

Takuya Shimamoto, Ryuta Tanaka and Kenji Tanaka

Abstract This study suggested the evaluation model for Lithium-ion battery life. Considering the trend that eco-system has become serious concern against the global environment, Lithium-ion battery is most promising represented by Electric Vehicle. However, estimation method for residual battery performance has not been established. Therefore, asset value and payout period are forced to be unsure, namely, the spread of Lithium-ion battery has been prevented. This evaluation model developed in this study can calculate the residual battery performance by degradation rate database and assumed battery use pattern. The degradation rate database was established using charge–discharge test of Lithium-ion battery cell. By applying the database, the residual battery performance can be calculated under any battery use scenario. This model was validated by comparing the experimental data with the simulation result.

Keywords Lithium-ion battery · Life cycle simulation · Evaluation model

1 Introduction

Today, the necessity of large-scale storage battery is growing for following the electric power supply and demand that changes complicatedly. This trend is made from expanding the use of renewable energy, the challenges of power generation equipment stemmed from the Great East Japan Earthquake. Moreover, expanding the use of various electric vehicles (xEVs: Electric Vehicles/Plug-In Hybrid Electric Vehicles/Hybrid Electric Vehicles) aiming at Greenhouse Gas emission

T. Shimamoto (✉) · R. Tanaka · K. Tanaka
Department of Systems Innovation, School of Engineering, The University of Tokyo,
7-3-1 Hongo Bunkyo-ku, Tokyo 113-8656, Japan
e-mail: shimamoto@m.sys.t.u-tokyo.ac.jp

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_148,

reduction, and introducing smart grid are also increasing the importance of batteries.

Against this trend, Lithium-ion Battery (LiB) is most promising. LiB has a number of advantages compared with the conventional batteries, such as lead-acid storage battery and nickel-metal hydride battery. The points are high energy efficiency, charge and discharge energy density, and possibility of rapid charge and discharge. The market has so far been formed on small capacity articles such as a portable electric device or personal computer. Now, the research and development and use about the large capacity batteries are progressing rapidly adjusted to the above-mentioned purpose.

However, LiB has two major problems that the unit price and recycling cost per capacity are high, and degradation mechanisms are not fully understood (Vettera et al. 2005). These are factors inhibiting the spread of LiB.

With respect to these issues, on the user side of LiB, total life cost of LiB is tried to reduce through secondary use such as diversion xEVs use into stationary use. However, evaluation criteria for used LiB have not been established that is common to the various manufactures, storage capacity, and materials. In addition, usually, evaluation for the characterization of degradation of LiB is performed by the charge and discharge cycle test, the full charged preservation test, or the assumed pattern of LiB use.

This evaluation method is consistent for the purpose of the performance improvement, but it is not consistent for the purpose of the lifetime prediction for demand side expected complex usage patterns. Especially, the thing that a demand pattern becomes more complicated as storage batteries are introduced into community deeply, and the deviation with pre-supposed assessment conditions becomes large can be assumed easily. Moreover, preventive maintenance (PM) to prevent that the failure of battery triggered the hazard can be considered. From the above situations, there is an increasing necessity and importance of LiB evaluation method that can respond to all use patterns.

2 Existing Research

Abe et al. (2012) showed a method of separating LiB degradation into the "storage degradation" by the storage of LiB and the "charge–discharge degradation" by the charge and discharge cycles of LiB. Then, determined the approximate curve that represents each characteristic in order to estimate the degradation separately. Though this method can be set LiB operation freely, the use pattern across the State of Charge (SOC) range will be difficult to predict because the number of charge–discharge has been used in the degradation prediction formula.

Kaji (2012) build a degradation rate database by calculating the degradation rate based on the approximate curve through the initial state and the time of evaluation, however, it is difficult to predict in all conditions because it uses the number of charge–discharge as well. In addition, the effect of C-rate (=the amount of current/nominal full charge capacity) is not considered.

3 Aim and Approach

This study aimed the evaluation of LiB life with any use patterns. In order to achieve this purpose, the following approaches were taken.

- Define the battery performance.
- Establish the method to complement the experiment result in order to change the experiment result into database.
- Establish the method to estimate residual battery performance using database and assumed LiB use pattern.

Establishing the method to complement can reduce the number of required experiment. That means the time, money, and man-power required to the experiment can be saved. In addition, any use pattern of LiB will get to able to be dealt with.

It should be noted that the experiment was carried out by Japan Automobile Research Institute. It was storage test and charge–discharge cycle test for 18650-type LiB (2.4Ah, LCO-C).

4 Evaluation Method for Performance of LiB

4.1 Definition of Performance of LiB

In this study, the battery performance is defined from the user's point of view. We classified the battery performance into 2 factors: specific energy E (kWh/kg) and specific power P (kW/kg). As for EVs, each of the performance factors corresponds to the driving range and acceleration of the vehicle.

The equations of specific energy and specific power are shown as (1) and (2), where V represents the voltage, $V_{average}$ the average voltage during the discharge, Q the capacity, I the current, V_{OCV} the open circuit voltage, and R the internal resistance of the battery. As shown in the equations, the specific energy is a function of capacity (Q) and the specific power a function of internal resistance (R). Hence, the battery degradation can be attributed to the capacity fade and the increase in internal resistance. This indicates that it is sufficient to measure the capacity and internal resistance of the battery when evaluating the battery degradation.

$$E = \int P dt = \sum (V \cdot \Delta Q) = V_{average} \cdot Q. \quad (1)$$

$$P = I \cdot V = I \cdot (V_{OCV} - I \cdot R). \quad (2)$$

4.2 Method to Complement the Experimental Result and Develop the Degradation Rate Database

Complementing the experiment data is to deal with any use pattern of LiB. However, the method of interpolation has not been understood. This study established it by surveying the given graphs of the existing researches. This task was performed on 4 use-parameters (elapsed day, SOC, temperature, C-rate) that affect the degradation of battery. After determining each interpolation method, the experiment data was changed into database with that interpolation method. Figure 1 shows the procedure for establishing degradation rate database.

4.3 Method to Calculate the Residual Battery Performance

In this study, capacity degradation was supposed to have the additive property of the degradation due to storage ($\Delta Q_{storage}$) and the degradation due to current flows (ΔQ_{cycle}). As shown below, the total amount of degradation was calculated by

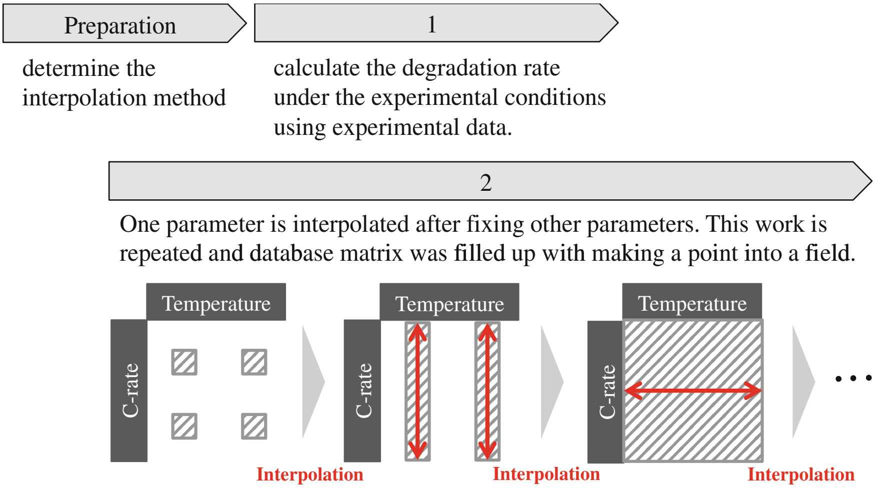


Fig. 1 Procedure for developing the degradation rate database

integrating degradation rate and stay time in each condition. In this calculation model, giving assumed LiB use pattern, the residual battery performance can be calculated using degradation rate database.

$$\Delta Q(time) = \Delta Q_{storage}(time) + \Delta Q_{cycle}(time). \quad (3)$$

$$\Delta Q_{storage}(time) = \int_0^{Day} \int_{SOC_L}^{SOC_H} \int_{T_L}^{T_H} \int \frac{dQ_{storage}(Day, SOC, T)}{dt} dt\, dT\, dSOC\, dDay. \quad (4)$$

$$\Delta Q_{cycle}(time) = \int_0^{Day} \int_{SOC_L}^{SOC_H} \int_{T_L}^{T_H} \int_0^{C} \int \frac{dQ_{cycle}(Day, SOC, T)}{dt} dt\, dC\, dT\, dSOC\, dDay. \quad (5)$$

5 Verification of Interpolation Method

5.1 Establishment of Interpolation Method

In this chapter, verification of interpolation method that was mentioned in Sect. 4.2 is performed. Among the 4 parameters, C-rate is described as a representative.

Figure 2 shows the digitizing data from the experimental results of 5 existing researches (Liu 2007; Gao et al. 2008; Passerini et al. 2000; Wu 2005; He et al. 2008). Through this figure, the dependence of capacity degradation upon C-rate could be seen. In this figure, capacity is seemed to degrade linearly with respect to C-rate.

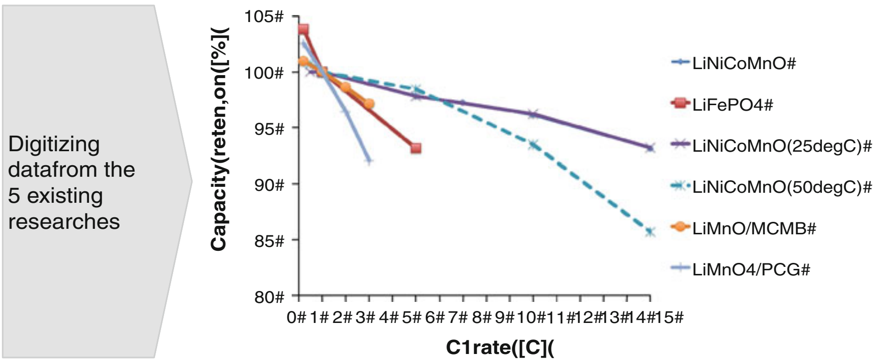


Fig. 2 Overall trend of capacity fade versus C-rate

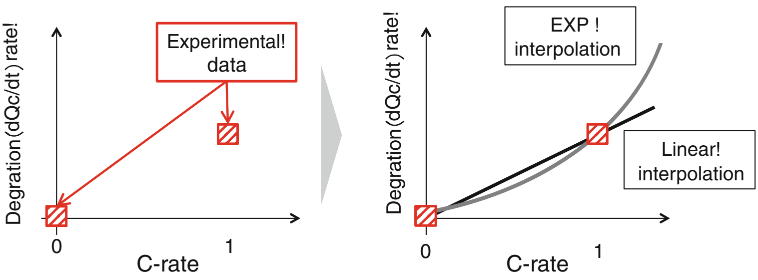


Fig. 3 Concept of C-rate interpolation

Through this survey, two interpolation methods that are the linear interpolation and the exponential interpolation were established as shown in Fig. 3. The exponential interpolation is for the possibility of accelerated degradation.

5.2 *Establishment of Degradation Rate Database*

These two interpolation methods were applied to the experimental result, then the degradation rate database was established as shown in Sect. 4.2. For other parameters (elapsed day, SOC, temperature), interpolation methods were fixed in order to verify the C-rate interpolation method. Each interpolation method was: elapsed day versus linear, SOC versus linear, temperature versus Arrhenius equation.

The experimental result that was changed into degradation rate database was performed by Japan Automobile Research Institute (JARI). This experiment was carried out for 18650-type LiB (2.4Ah, LCO-C). The test conditions were shown in Table 1.

5.3 *Verification of C-Rate Interpolation Method*

In order to verify the C-rate interpolation method, other experimental result that is shown in Table 2 was used. With the database based on Table 1 conditions and the use pattern based on Table 2 conditions, LiB degradation was calculated. The verification was performed by comparing the calculated result with the experimental result based on Table 2 conditions.

The outcomes are shown in Fig. 4. In this figure, plots mean the experimental result and lines mean the calculated result. In addition, the difference between the calculated result and the experimental result is shown in Table 3.

Table 1 Test conditions for database

Items	SOC	C-Rate	Temp
Charge discharge cycle	5–25 %	1C (CC)	25 °C
	25–45 %		50 °C
	45–65 %		
	65–85 %		
	0–100 %		
	0–100 %	1C	
Storage	100 % (4.2 V)	(CCCV)	
	90 % (4.1 V)		
	78 % (4.0 V)		

Table 2 Test conditions for verification

Items	SOC (%)	C-rate	Temp
Charge discharge cycle	0–100	0.3C (CC)	45 °C
	0–100	2C (CC)	

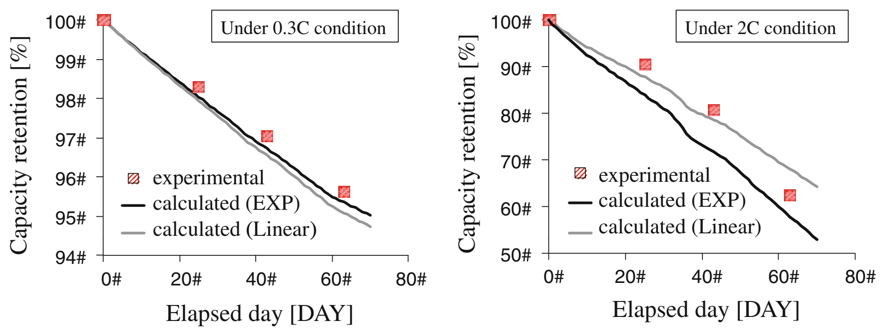


Fig. 4 Verification result under 0.3C/2C condition

Table 3 Differences between calculated result and experimental result

Elapsed day			0	25	43	63
0.3C	Difference (%)	EXP	0.0	−0.3	−0.3	−0.3
		Linear	0.0	−0.4	−0.5	−0.6
2C	Difference (%)	EXP	0.0	−7.4	−11.2	−7.3
		Linear	0.0	−3.2	−2.7	−9.0

Through these graphs and tables, linear interpolation was adopted as the C-rate interpolation method. The reason is that it could be estimated to within 0.5 % error at 0.3C condition.

In case of 2C condition, some care is needed. In Fig. 4, the right-most plot has fallen strongly. This is considered to be an exceptional degradation derived from very severe conditions of battery use. 2C condition means the battery usage

Table 4 High reproducible interpolation method

	Interpolation method
Elapsed day	Power
SOC	Exponential
Temperature	Arrhenius equation
C-rate	Linear

running out of full charge capacity in 30 min. Continuing this situation 24 h a day for 2 months brought about serious damage to the battery. Therefore, by regarding the rightmost plot as abnormal degradation and considering as non-existent, linear interpolation could be estimated the residual battery capacity with high accuracy.

From the above discussion, better interpolation method for C-rate is determined as linear one. Similar work was performed for other 3 parameters. Then it was found that the interpolation methods shown in Table 4 have high reproducibility for the experimental results.

6 Conclusion

The conclusion of this study is mentioned below.

- By converting the experimental data into degradation rate database, a system that can estimate the LiB residual performance under any operational patterns was developed.
- In order to build the degradation rate database, interpolation methods of experimental result was established.
- This approach can also be applied to the internal resistance estimation.

Acknowledgments This study was performed at Tanaka laboratory in the University of Tokyo. Grateful thanks for a lot of helpful supports of the all team members.

References

Abe M et al (2012) Lifetime prediction of lithium-ion batteries for high-reliability system. Hitachi Rev 94:334–337

Gao F et al (2008) Kinetic behavior of LiFePO4/C cathode material for lithium-ion batteries. Electrochim Acta 53:5071–5075

He Y-B et al (2008) Preparation and characterization of 18650 $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$/graphite high power batteries. J Power Sources 185:526–533

Kaji K (2012) Evaluation model for used lithium-ion battery life. Bachelor thesis, The University of Tokyo

Liu X (2007) A mixture of LiNi1/3Co1/3Mn1/3O2 and LiCoO2 as positive active material of LIB for power application. J Power Sources 174:1126–1130

Passerini S et al (2000) Lithium-ion batteries for hearing aid applications: I. Design and performance. J Power Sources 89:29–39

Vettera J et al (2005) Ageing mechanisms in lithium-ion batteries. J Power Sources 147:269–281

Wu H-C (2005) Study the fading mechanism of $LiMn_2O_4$ battery with spherical and flake type graphite as anode materials. J Power Sources 146:736–740

A Simulated Annealing Heuristic for the Green Vehicle Routing Problem

Moch Yasin and Vincent F. Yu

Abstract Nowadays, the encouragement of the use of green vehicle is greater than it previously has ever been. In the United States, transportation sector is responsible for 28 % of national greenhouse gas emissions in 2009. Therefore, there have been many studies devoted to the green supply chain management including the green vehicle routing problem (GVRP). GVRP plays a very important role in helping organizations with alternative fuel-powered vehicle fleets overcome obstacles resulted from limited vehicle driving range in conjunction with limited fuel infrastructure. The objective of GVRP is to minimize total distance traveled by the alternative fuel vehicle fleet. This study develops a mathematical model and a simulated annealing (SA) heuristic for the GVRP. Computational results indicate that the SA heuristic is capable of obtaining good GVRP solutions within a reasonable amount of time.

Keywords Alternative fuel vehicle · Green vehicle routing problem · Simulated annealing

1 Introduction

During recent years, many researchers have shown a high level of interest in developing green supply chain models. Incorporation of the ethical and environmental responsibilities into the core culture of today's business world is now

M. Yasin (✉) · V. F. Yu
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei 106, Taiwan, Republic of China
e-mail: yasin@saya.me

V. F. Yu
e-mail: vincent@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_149,

greater than it previously has ever been. With the high level of competition they are about to face, companies find promoting green supply chain very attractive. Escalating deterioration of the environment, e.g. diminishing raw material resources, overflowing waste sites and increasing levels of pollution are the main causes of the importance of Green Supply Chain Management (GSCM) implementation (Srivastave 2007).

Likewise, logistics reliance on transportation modes such as trucks and airplanes using fossil burning fuels and the subsequent emission of carbon dioxide (CO_2) can pollute the living environment such as air, water, and ground. In the European Union, transport is the largest consumer of oil products and second largest emitter of CO_2; within the sector, road transport dominates in both regards. To reduce oil dependency and to make transport more sustainable, the European Commission set out the target to replace 10 % of conventional transport fuels with renewable alternatives, such as biofuel, hydrogen, and green electricity, by the year 2020 (European Union 2009).

Raley's Supermarkets (Raley's), a large retail Grocery Company based in Northern California, decided to take participation on utilizing heavy-duty trucks powered by liquefied natural gas (LNG) in 1997. It was found that the LNG trucks emits lower levels of oxides of nitrogen and particulate matter than the diesel trucks. California, is willing (through the local air quality management district) to pay as much as $12,000 per ton of measurable NO_x reduction through the "Carl Moyer Program." Based on a 10-year life, this gives an annualized cost of $4,550 per year. Overall, the potential cost effectiveness would be $3,730/ton of NO_x. This cost effectiveness-compared to the $12,000 per ton of NO_x reduction that the state is willing to pay for a given project is extremely favorable for the Raley's project (Chandler et al. 2000).

Until recently, AFVs have not been sufficiently developed to appear competitive in the market. One of the most important reasons is the availability of the facilities or stations providing alternative fuel for the vehicles. Therefore, this research focuses on the Green Vehicle Routing Problem (G-VRP) which considers the need of utilizing alternative fuel vehicles in traditional Vehicle Routing Problem (VRP). The G-VRP aims at finding at most m tours which start and end at the depot. Each tour is serviced by a vehicle and required to visit a subset of vertices including Alternative Fuel Stations (AFSs) when needed. The goal is to minimize the total distance traveled by vehicles. A predetermined tour duration limit, T_{max}, specifies vehicle driving range that is constrained by fuel tank capacity and driver working hours. Without loss of generality, to reflect real-world service area designs, it is assumed that all customers can be visited directly by a vehicle with at most one visit to an AFS. This does not preclude the possibility of choosing a tour that serves multiple customers and contains more than one visit to an AFS.

Erdogan and Miller-Hooks (2012) proposed the G-VRP and implemented two construction heuristics, the Modified Clarke and Wright Savings and the Density-Based Clustering Algorithm with a customized improvement technique. This research proposes a Simulated Annealing (SA) algorithm for G-VRP. SA has some attractive advantages such as its ability to deal with highly nonlinear models, chaotic and noisy data and many constraints. In addition, SA is also empowered by the flexibility and ability to approach global optimality. SA does not rely on any restrictive properties of the model and this makes this method very versatile. Parameter settings significantly impact the computational results of SA. The coefficient used to control speed of the cooling schedule, Boltzmann constant used in the probability function to determine the acceptance of worse solution and the number of iterations the search proceeds at a particular temperatures are some of those. These parameters need to be adjusted and numerous trials are required to make sure that SA can provide good results (Lin et al. 2011).

2 Problem Statement

The G-VRP problem consists of a customer set, a depot and a set of alternative fuel stations (AFSs). It is assumed that the depot can also be used as refueling station, meaning that once the vehicle returns to the depot, the fuel tank will be filled to its maximum capacity. All refueling stations have unlimited capacities and will always be able to serve the vehicle until its tank reaches the full capacity. Once the truck visits an AFS, it is assumed that it is served until its maximum fuel capacity is reached. Each truck has the capacity of $Q = 50$ gallons and each truck has the fuel consumption rate of 0.2 gallons per mile or 5 miles per gallon fuel efficiency with the vehicle speed of 40 miles per hour. Visiting a customer node will cost a service time of 30 min and visiting an AFS node will cost a time of 15 min. The objective of the problem is to find at most m tours, one for each vehicle, which starts and ends at depot. The vehicles are required to visit all customer nodes and AFS, if necessary. The goal is to find the minimum total travel distance of vehicles. The travel distances are calculated by employing Haversine formula (radius of earth = 4,182.44949 miles). The problem needs to be solved without violating tour duration constraint. Vehicle driving range constraints depend on fuel tank capacity limitations. The AFSs can be visited more than once or not at all.

3 Mathematical Formulation

The notations and mathematical formulation for G-VRP are adopted from Erdogan and Miller-Hooks (2012).

Notations

- I_0 Set of customer nodes (I) and depot (v_0), $I_0 = \{v_0\} \cup I$
- F_0 Set of AFS nodes (F) and depot, $F_0 = \{v_0\} \cup F$
- p_i Service time at node i (If $i \in I$ then p_i is the service time at the customer node, if $i \in F$ then p_i is the refueling time at the AFS node, which is assumed to be constant.)

r Vehicle fuel consumption rate (gallons per mile)
Q Vehicle fuel tank capacity
x_{ij} Binary variables equal to 1 if a vehicle travels from node i to j and 0 otherwise
y_j Fuel level variable specifying the remaining tank fuel level upon arrival at node j. It is reset to Q at each refueling station node i and the depot
τ_j Time variable specifying the time of arrival of a vehicle at node j, initialized to zero upon departure from the depot.

Mathematical Formulation

$$\min \sum_{i,j \in V', i \neq j} d_{ij} x_{ij} \tag{1}$$

$$\sum_{j \in V', j \neq i} x_{ij} = 1, \quad \forall i \in I \tag{2}$$

$$\sum_{j \in V', j \neq i} x_{ij} \leq 1, \quad \forall i \in F_0 \tag{3}$$

$$\sum_{j \in V', j \neq i} x_{ij} - \sum_{j \in V', j \neq i} x_{ij} = 0, \quad \forall j \in V' \tag{4}$$

$$\sum_{j \in V' \setminus \{0\}} x_{0j} \leq m \tag{5}$$

$$\sum_{j \in V' \setminus \{0\}} x_{j0} \leq m \tag{6}$$

$$\tau_j \geq \tau_i + (\tau_{ij} - p_j) x_{ij} - T_{\max}(1 - x_{ij}), \quad i \in V', \forall j \in V' \setminus \{0\} \text{ and } i \neq j \tag{7}$$

$$0 \leq \tau_0 \leq T_{\max} \tag{8}$$

$$\tau_{0j} \leq \tau_j \leq T_{\max} - \left(t_{j0} + p_j\right), \quad \forall j \in V' \setminus \{0\} \tag{9}$$

$$y_j \leq y_i - r d_{ij} x_{ij} + Q\left(1 - x_{ij}\right), \quad \forall j \in I \text{ and } i \in V', i \neq j \tag{10}$$

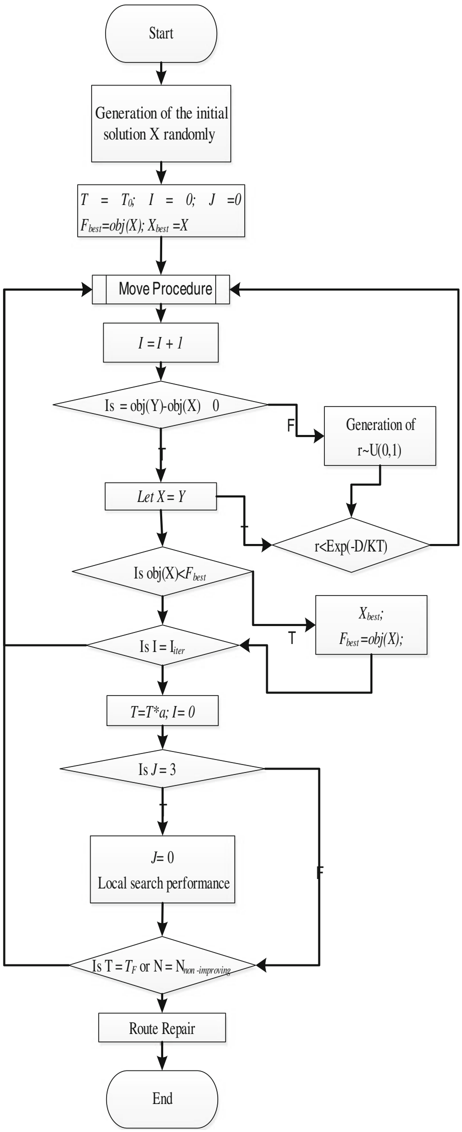
$$y_j = Q, \quad \forall j \in F_0 \tag{11}$$

$$y_j \geq \min\left\{ r d_{j0}, r\left(d_{jl} + d_{l0}\right)\right\}, \quad \forall j \in I, \forall l \in F' \tag{12}$$

$$x_{i,j} \in \{0, 1\}, \quad \forall i, j \tag{13}$$

The objective (1) is to find the minimum total distance traveled by the AFV fleet in a day. Constraint (2) ensures that each customer node has only one successor. The successor can be a customer, AFS or depot. Constraint (3) ensures that each AFS node can only have at most one successor because it is not required to visit all AFSs. Constraint (4) is flow conservation constraint that requires the equality between the number of arrivals and the number of departures at each node. Constraint (5) limits the number of vehicle to be routed out of depot. The vehicles to be routed must not be more than available ones, which is denoted as m. Constraint (6) ensures that at most m vehicles return to the depot in a day. A copy of the depot is created in order to differentiate departure and arrival times at the depot. This will be important in tracking the time at each node and preventing

Fig. 1 Flowchart of the SA heuristic



sub-tours. The time of arrival at each node by each vehicle is tracked through constraint (7). Constraint (8) ensures that the vehicle will arrive and depart at depot without violating T_{max} constraint. Constraint (9) requires all vehicles to complete the service before T_{max} and no vehicles are allowed to perform service after T_{max}. Constraints (7), (8) and (9) ensure all vehicles to return at depot no later than T_{max}. Constraint (10) tracks a vehicle's fuel level based on node sequence and type. If

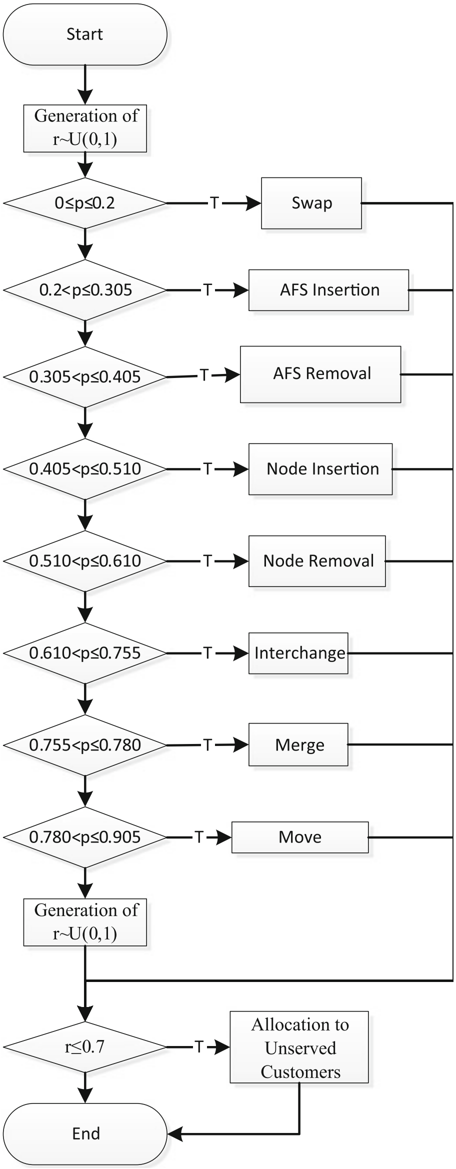


Fig. 2 Flowchart of move procedure

node j is visited right after vertex i ($x_{ij} = 1$) and vertex i is a customer node, the first term in constraint (10) reduces the fuel level upon arrival at node j based on the distance traveled from vertex i and the vehicle's fuel consumption rate. Time and fuel level tracking constraints, constraint (7) and (10), respectively, serve to eliminate the possibility of sub-tour formation. Constraint (11) reset the amount of fuel to the tank full capacity. This happens once the refueling is done at the AFS. Constraint (12) ensures that the fuel remaining on the vehicle will be enough for the vehicle to perform a route returning to the depot. Constraint (13) is about binary integrality.

4 Simulated Annealing Algorithm

The proposed SA algorithm begins by setting current temperature T to be T_o (3,500,000,000) and randomly generating an initial solution X. The current best solution X_{best} and the best objective function value obtained so far, denoted by F_{best}, are set to be X and $obj(X)$, respectively.

For each iteration, a new solution Y is generated from the neighborhood of the current solution X, $N(X)$, and its objective value is evaluated. Let $\Delta = obj(Y) - obj(X)$. If Δ is less than or equal to zero (Y is better than X), X is replaced with Y. Otherwise, the probability of replacing X with Y is $\exp(\Delta/KT)$. X_{best} and F_{best} record the current best solution and the best objective function value obtained so far, as the algorithm progresses. The current temperature T is decreased after I_{iter} (80) iterations after the previous temperature decrease, according to the formula $T = \alpha T$, where $\alpha = 0.99$. After every three temperature reductions, a local search procedure that sequentially performs swap, AFS insertion, AFS removal, Node insertion, Node removal, exchange, merge and move is conducted.

The algorithm is terminated when the current temperature T is lower than T_F (5) or the current best solution X_{best} has not improved for $N_{non\text{-}improving}$ (3,000) consecutive temperature decreases. Following the termination of SA procedure, the (near) optimal routing plan can be derived from X_{best}. Figures 1 and 2 illustrate the proposed SA heuristic the Move Procedure, respectively.

5 Computational Results

The proposed simulated annealing has proven to be very effective. From Tables 1 and 2, it can be seen that simulated annealing algorithm outperforms CPLEX on 8 out of 10 problems. The percentage improvement ranges from −6 to −15 %. Further, the proposed algorithm shows even higher improvement over MCWS and DBCA algorithms.

Table 1 Comparison between computational results of the proposed simulated annealing heuristic and CPLEX

Sample	CPLEX	MCWS	DBCA	Simulated annealing			
	Exact solution (miles)	Lower bound	Lower bound	Number of tours	Customer served	Total cost	Difference (%)
20c3sU1	1,797.51	1,818.35	1,797.51	6	20	1,269.34	−29
20c3sU2	1,574.82	1,614.15	1,613.53	7	20	1,427.14	−9
20c3sU3	1,765.9	1,969.64	1,964.57	6	20	1,361.38	−23
20c3sU4	1,482	1,508.41	1,487.15	8	20	1,635.21	10
20c3sU5	1,689.35	1,752.73	1,752.73	7	20	1,594.69	−6
20c3sU6	1,643.05	1,668.16	1,668.16	4	20	1,128.94	−31
20c3sU7	1,715.13	1,730.45	1,730.45	7	20	1,591.3	−7
20c3sU8	1,709.43	1,718.67	1,718.67	6	20	1,450.17	−15
20c3sU9	1,708.84	1,714.43	1,714.43	7	20	1,526.35	−11
20c3sU10	1,261.15	1,309.52	1,309.52	6	20	1,528.66	21
						Average	−10

Table 2 Comparison between computational results of the proposed simulated annealing heuristic and CPLEX

Sample	CPLEX	MCWS	DBCA	Simulated annealing			
	Exact solution (miles)	Lower bound	Lower bound	Number of tours	Customer served	Total cost	Difference (%)
S1_2i6 s	1,578.15	1,614.15	1,614.15	7	20	1,447.05	−8
S1_4i6 s	1,438.89	1,561.3	1,541.46	8	20	1,635.21	14
S1_6i6 s	1,571.28	1,616.2	1,616.2	6	20	1,365.18	−13
S1_8i6 s	1,692.34	1,902.51	1,882.54	6	20	1,423.66	−16
S1_10i6 s	1,253.32	1,309.52	1,309.52	7	20	1,611.76	29
S2_2i6 s	1,645.8	1,645.8	1,645.8	5	20	1,036	−37
S2_4i6 s	1,505.06	1,505.06	1,505.06	6	20	1,087.89	−28
S2_6i6 s	2,842.08	3,115.1	3,115.1	7	20	1,527.62	−46
S2_8i6 s	2,549.98	2,722.55	2,722.55	6	20	1,423.66	−44
S2_10i6 s	1,606.65	1,995.62	1,995.62	6	20	1,594.81	−1
						Average	−15

6 Conclusions

This research proposes a simulated annealing heuristic for G-VRP. Computational results indicated that the proposed SA outperforms two existing algorithms. This research can be extended by incorporating hybrid vehicles in the model. In addition, consideration of fuel prices variation, heterogeneous fleets, driving range variation and different sources of fuel will bring the model closer to reality.

References

Chandler K, Norton P, Clark N (2000) Raley's LNG truck fleet: final results. LNG Truck Utilization Report

Erdogan S, Miller-Hooks E (2012) A green vehicle routing problem. Transp Res Part E 48:100–114

European Union (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Amendment, Strasbourg

Lin SW, Yu VF, Lu CC (2011) A simulated annealing heuristic for the truck and trailer routing problem with time windows. Expert Syst Appl 38:15244–15252

Srivastave SK (2007) Green supply-chain management: a state-of-the-art literature review. Int J Manage Rev, pp 53–80

Designing an Urban Sustainable Water Supply System Using System Dynamics

S. Zhao, J. Liu and X. Liu

Abstract This paper addresses the issue on designing an effective sustainable water supply system both in quantity and quality side, which is considered as a prerequisite for a sustainable development strategy. In order to achieve a sustainable water supply system, System Dynamics, which is an effective system analysis and development tool, is employed in modeling and simulating the system. The study presents a decision platform, where a quantified expected resilience model is built to measure water supply satisfaction rate, and to meet the requirements of sustainability indicators firstly. After determining the sustainability requirements, namely customer requirements, water supply system is constructed using system dynamics approach, through which the threats of the system such as demand boosting, pipeline aging, and other events that cause supply disruptions are illustrated subsequently. Further, prevention strategies will be taken into account to achieve the resilience ratio in the water system. Finally, a case study of water system in Shanghai is demonstrated to show the effectiveness of the proposed method.

Keywords Water supply · Sustainability · Resilience · System dynamics

S. Zhao (✉) · X. Liu
Department of Industry Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Min-Hang District, Shanghai 200240, People's Republic of China
e-mail: Sixiang.zhao@hotmail.com

X. Liu
e-mail: X_liu@sjtu.edu.cn

J. Liu
Sino-US Global Logistic Institute, Shanghai Jiao Tong University, 1954 Huashan Road, Xu-hui District, Shanghai 200030, People's Republic of China
e-mail: Liujian007@sjtu.edu.cn

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_150,

1 Introduction

Bulging population and rapid urbanization cause higher pressure on urban water supply system by deteriorating water quality and increasing water demand. As water is one of the most critical resources for human being, a sustainable urban water supply system (SUWSS) is needed to meet this challenge. Sustainable development is seen as an unending process—defined by an approach to creating change through continuous learning and adaptation (Mog 2004). The core indicators to measure the sustainability of water system can be concluded as water demand satisfaction rate and quality satisfaction rate (UN 2007; GCIF 2007). Thus, the ultimate goal of a sustainable urban water system is to meet the objective satisfaction rate of qualify water continuously. To achieve this goal, resilience in water system is the leading character (Milman and Short 2008). This paper defines resilience of SUWSS as joint ability of absorption and recovery to resist and recover from any disturbance, and ability of adaption to enhance the absorption and recovery capacity by self-adjustment (Walker et al. 2004; Bruneau et al. 2003; Ouyang et al. 2012).

Researches about sustainable water resource focus on assessment or indicators of sustainable water system (Lundin and Morrison 2002; Hedelin 2007; Milman and Short 2008), sustainability in Singapore water system (Xi and Kim 2013), sustainability in Yellow River (Xu et al. 2002). Few studies present a quantitative and resilient model in realizing a continuously satisfied demand, both long-term and short-term, in urban water system. To fill in this gap, this study combines resilience thinking and systematical thinking in realizing SUWSS. In this paper, we formulate a SUWSS model using system dynamics, which is an effective modeling and simulation tool. Then the case study of water system in Shanghai is presented, and several policy suggestions are given to achieve SUWSS.

2 Model

As mentioned earilier, the main indicators to achieve SUWSS is the continuity of both water quality and quantity satisfaction rate. These critical indicators are incorporated with other elements from both water quality/quantity demand side and water supply side in SD modeling. Combining resilience thinking, a casual loop digram (CLD) capturing the key elements of SUWSS is built as Fig. 1. Signs B represents negative feedback loop that means balance and equilibrium. Quality satisfaction rate and demand satisfaction rate, which are the most important aspects of SUWSS in the CLD, are quantified by Eqs. (1) and (2)

$$\text{Demand Satisfaction Rate} = \frac{\text{Water Supply}}{\text{Water Expected Demand}} \tag{1}$$

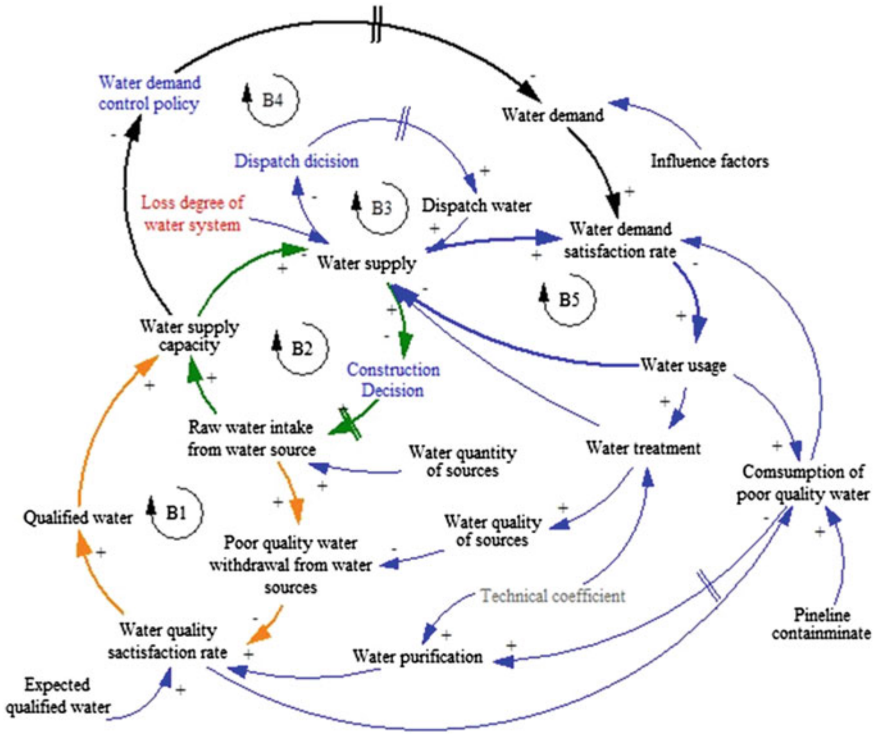


Fig. 1 Casual loop of the resilient SUWS

$$\text{Quality Satisfaction Rate} = \frac{\sum W_i \cdot Q_i}{\sum W_i} \tag{2}$$

where W_i is the total water withdrawn from water resource i and Q_i is the quality satisfaction rate in resource i. Incorporating the indicators of sustainability in urban water system, resilience is water satisfaction rate in this study. A metric of resilience is given as follows:

$$R = E\left[\frac{\int_0^T F(t)dt}{\int_0^T Tar(t)dt}\right] = \left[\frac{\int_0^T Tar(t)dt - \sum_{n=1}^{N(T)} AL_n(t_n)}{\int_0^T Tar(t)dt}\right] \tag{3}$$

where *F(t)* represents the utility function of the system at a given time *t*; *T* is the time interval; *Tar(t)* the target performance curve; $AL_n(t_n)$ is the area between the real performance curve and the target. In reality, loss of resilience can be caused by any disturbance of supply, such as demand boosting, pipeline aging etc. Therefore, for assurance of stable water supply and then to meet the target satisfaction rate, supply capacity redundancy and appropriate level of water reservoir are needed (B5). Besides, dispatching decision will be capable to recover the satisfaction rate when water emergency happens (B3). Meanwhile, construction decision will take effect to increase water supply when incapability is about to occur (B2). In addition, on the demand side, an infinite increasing demand can be control by demand-control policy to realize the continuity (B4). On the demand side, a balance loop is added to describe switching from poor quality resource to high quality will enhance quality satisfaction rate (B1).

3 Case Study

3.1 Model Development

Located at the estuary of the Yangtze River, Shanghai, with the population of 23.0 million, has been one of the largest city in Asia. The highly increasing urbanization rate and the poor water quality put great pressure on achieving SUWSS in Shanghai from both supply and quality side. Based on the CLD in Fig. 1, stock-flow diagram of water supply system in Shanghai is developed as Fig. 2. For the purpose of practicality and simplicity, some elements that exceed our research scope are omited. Most of the input data are obtained from the Shanghai Statistics Bureau and Shanghai Water Authority (Shanghai Statistics Bureau 2002–2012; Shanghai Water Authority 2006–2010). Several assumptions have been made because of the limitation of available data. The first assumption is that the water quality of resources remains unchanged during the simulation horizen. The second assumption is that the maximum of total supply capacity is limited by the design withdrawal capacity of water reservoir, and there will be no new reservoir constructed during the simulation horizon.

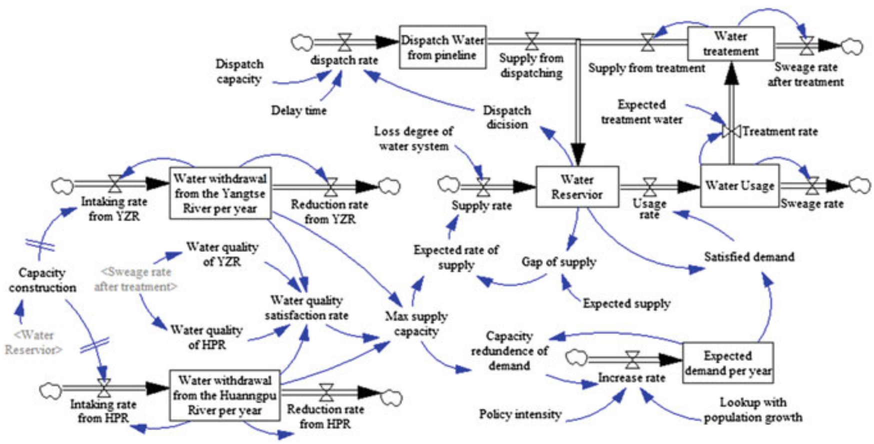


Fig. 2 Stock-flow diagram for Shanghai SUWS

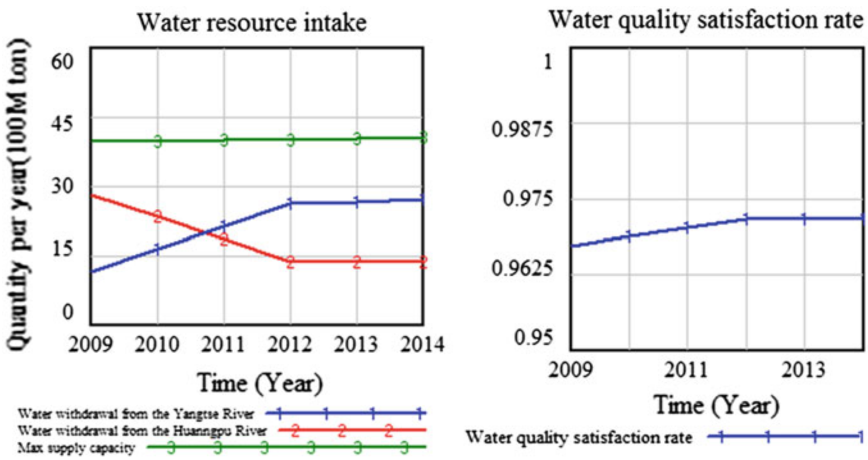


Fig. 3 Simulation results under switching resources policy

Yangtze river and Huangpu river are the two major water resources for Shanghai. In 2010, the total raw water withdrawal proportion from Yangtze and Huangpu river is 70 % and 30 % respectively. As the quality of Huangpu river is poor, the government raised the withdrawal proportion from Yangtze river to 60 % by 2012 through the construction of Qing Cao Sha reservoir. A simulation is run on the water quality satisfaction rate to illustrate this improvement after water resources switching (Fig. 3). Note that the satisfaction rate here is measured by water quality after purification. Though the improvement is slight, it shows a great releasing of purification pressure from poor quality water.

As the prediction of water demand, which consists of industrial, agricultural and residential demand, is a complicated mechanism, we perform a roughly prediction in total water consumption via second exponential smoothing method. Figure 4 illustrates the simulation results under a specific exploitation rate of existing capacity of water reservoir, which is derived by linear regression from the historical data. In 2033, the water supply capacity reaches its maximum without construction of new reservoirs, while the demand is still climbing. After 2045, the water demand will exceed the supply capacity, and 4 years later, water will be inadequate since the water of reservoir runs out. In our time horizon, the satisfaction rate, which is 97.55 %, can be easily calculated by Eq. 3. Obviously, the satisfaction rate will decrease as the time horizon expands.

3.2 Results and Discussions

Demand control policies are needed to limit the infinite increasing water demand to achieve SUWSS. Besides, to ensure stable water supply, capacity redundancy of 10 to 15 % is necessary as consensus of capacity redundancy in water supply

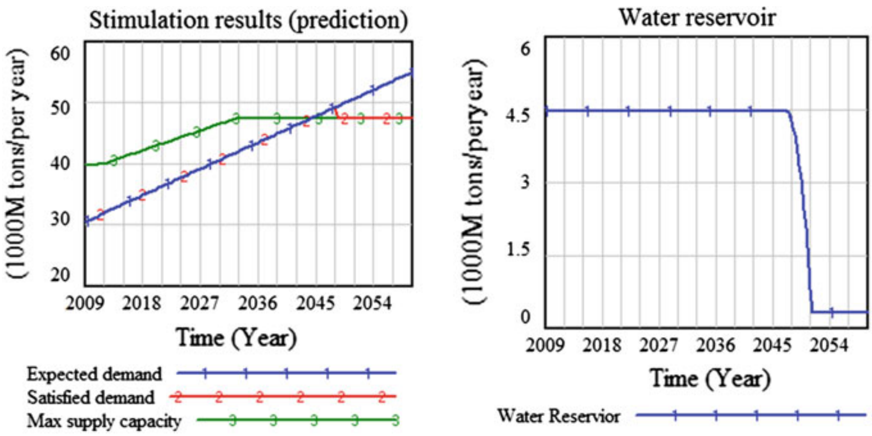


Fig. 4 Simulation results

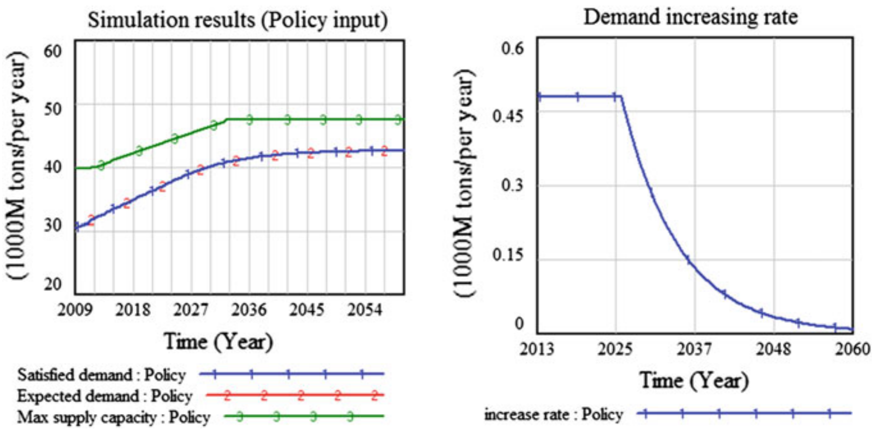


Fig. 5 Simulation results under policy control

industries. With an 11.3 % annually decline in water increasing rate, expected demand converge after demand control policy taking effect in 2026 (Fig. 5). The decline rate is determined by the policy intensity, and a high intensity policy will lead to a sharply decline in the increasing rate. A combination of certain policies such as stepped-pricing, control of immigration and industrial water saving polices will take effect in declining the demand increasing rate.

Simulation result under fluctuation is also presented by Fig. 6. If the expected demand soars by 20 % in a specific year every decade, water supply is also adequate under the coaction of both capacity redundancy and reservoir redundancy.

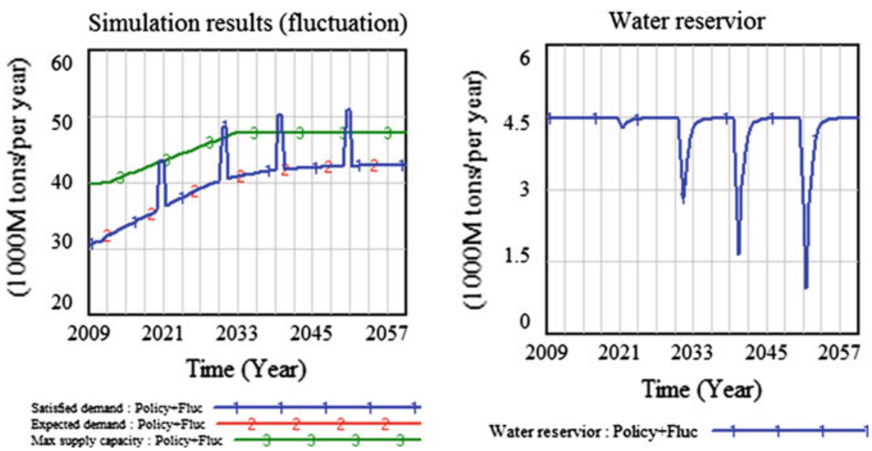


Fig. 6 Simulation results under demand fluctuation

Hereinbefore, we set a strict unchanged water quality assumption because of limitation of input data. However, poor water treatment of upriver plants will contaminate downriver water resource. Thus the treatment rate of sewage water of upriver plants must be improved to prevent the water resource from contamination.

4 Conclusions

This research has demonstrated how to achieve a sustainable urban water supply system with combination of systematical thinking and resilience thinking. A system dynamics framework was built and a quantified expected resilience model was proposed to measure the water satisfaction rate. In this framework, sustainable requirements are met by achieving continuously satisfied sustainability indicators. At the end of the article, the result of the simulation in Shanghai SUWSS suggested that the increasing rate of water demand should be controlled by certain policies. Meanwhile, a 10 % capacity redundancy was proved to be capable to withstand the disturbance of soaring demand.

However, this study is not without limitations. One is that the prediction of water demand by second exponential smoothing method is lack of precision. Another one is that this research doesn't present specific policies strategies to each water demand component. These limitations provide guidance to our further research.

Acknowledgments This research is partly supported by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) and the NSFC (91024013, 91024131).

References

Bruneau M, Chang SE, Eguchi RT et al (2003) A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra 19(4):733–752

Global city indicators facility (2007) List of GCIF indicators. http://www.cityindicators.org/ProjectDeliverables.aspx. Accessed 12 Apr 2013

Hedelin B (2007) Criteria for the assessment of sustainable water management. Environ Manage 39:151–163

Lundin M, Morrison GM (2002) A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems. Urban Water 4:145–152

Milman A, Short A (2008) Incorporating resilience into sustainability indicators: an example for the urban water sector. Global Environ Change 18:758–767

Mog JM (2004) Struggling with sustainability: a comparative framework for evaluating sustainable development programs. World Dev 32:2139–2160

Ouyang M, Dueñas-Osorio L, Min X (2012) A three-stage resilience analysis framework for urban infrastructure systems. Struct Saf 36–37:23–31

Shanghai Statistics Bureau (2002–2012) The year book, online edition. Available: http://www.stats-sh.gov.cn/data/release.xhtml. Accessed 28 Apr 2013

Shanghai Water Authority (2006–2010) Water resources bulletin. Available: http://222.66.79.122/BMXX/default.htm?GroupName=%CB%AE%D7%CA%D4%B4%B9%AB%B1%A8. Accessed 28 Apr 2013

United Nations (2007) Indicators of sustainable development: guidelines and methodologies. http://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=107&menu=35. Accessed 12 Apr 2013

Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social–ecological systems. Ecol Soc 9(2):5

Xi X, Kim LP (2013) Using system dynamics for sustainable water resources management in Singapore. Paper presented at the conference on systems engineering research (CSER'13), Georgia Institute of Technology, Atlanta, GA, March 19–22, 2013

Xu ZX, Takeuchi K, Ishidaira H, Zhang XW (2002) Sustainability analysis for yellow river water resources using the system dynamics approach. Water Resour Manage 16:239–261

An Evaluation of LED Ceiling Lighting Design with Bi-CCT Layouts

Chinmei Chou, Jui-Feng Lin, Tsu-Yu Chen, Li-Chen Chen and YaHui Chiang

Abstract Light-emitting diodes (LEDs) became an important home-lighting device. Due to the property of high efficiency LED lighting sources, thus we expected to apply high efficiency LED lighting to improve or enhance our lighting environment. The purpose of this study is to design LED ceiling lightings layout based on evaluating human's physiological responses and subjective feelings, where the experiments were conducted in the office-like laboratory. We had four experimental combinations included two Correlated Color Temperature (CCT) and two different types of lighting sources (lower Blue-value and high-efficiency). Two different types of lighting sources, one was that the lower Blue-value lighting sources was equipped at the center of the device, the other was that high-efficiency equipped around the lower Blue-value lighting source. Six participants were recruited in this study to perform sheet, laptop-typing, and tablet-searching tasks under the four experimental combinations. In addition to working performance measures, heart rate, Galvanic Skin Response (GSR), eyes blink duration, blink time, and critical fusion frequency (CFF) values were measured as well. The results showed that CCT 4,000 K-high efficiency lightings design would affect human's physiological alert and stress. Thus we suggested the CCT 4,000 K-high efficiency participants had lower Tablet-searching error rate higher physiological alert and less eye fatigue.

Keywords LED · Correlated color temperature · Physiological responses · Ceiling lighting design

---

C. Chou (✉) · J.-F. Lin · T.-Y. Chen · L.-C. Chen
Department of Industrial Engineering and Management, Yuan Ze University, 135 Yuan-Tung Road, Chung-Li 32002 Taiwan, People's Republic of China
e-mail: kinmei@saturn.yzu.edu.tw

Y. Chiang
Industrial Technology Research Institute, 195, Sec. 4, Chung Hsing Road, Chutung, Hsinchu 31040 Taiwan, People's Republic of China

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_151,

1 Introduction

The increase of green consciousness and energy saving. Light-emitting diode (LEDs) has become an important home-lighting device in the home or office lighting environment. Many research mentioned that the LED Correlated Color Temperature (CCT) would influence human's physiological responses. (Manav 2007) Investigated that CCT 4,000 Kwas preferred to CCT 2,700 K for impressions of 'comfort and spaciousness'. Navvab (2002) mentioned that between CCT 3,500 and 7,000 K, the higher CCT caused the higher reading corrective rate by participants. Thus we set two CCT 4,000 k and 6,500 K as our lighting CCT parameters. In this study we also discussed the difference of Blue-value in our lighting sources. Blue-value was a quantitative value, which concerns the ratio of the blue-ray in the visible lighting spectrum, and this value could be evaluated by the degree of human's blue light hazard. (Viola AU et al. 2008) mentioned that fitting blue-ray could increase human's working performance, higher blue value might increase the risk of blue hazard, which would affect human's health. To reduce the Blue Hazard we used low Blue-value lighting sources as our lighting element, however the low Blue-value lighting sources would consume more electricity. To solve this situation we design the high-efficiency lighting source that is expected to make a balance between decreasing the Blue hazard and saving more energy. The aim of this study was to design LED ceiling lightings layout base on evaluating human's physiological responses and subjective feelings where conducted in the office-like laboratory.

2 Methods

2.1 Experimental Setup and Equipment

This study was conducted in an office-like experimental room furnished with an office table, and interchangeable LED lighting devices. To measure physiological responses of the participants and eye movement, the equipment used in this study included Bluetooth wireless biofeedback system (NeXus-10), Eye Tracker (View Point Eye Tracker®), Flicker fusion apparatus (FLICKER), laptop and tablet. While conducting the experiment, the desktop illumination was set at 500 lx, room temperature was controlled in 25 °C, and the relative humidity was controlled at 50 % RH.

2.2 Participants

Six male participants, aged from 20 to 24 (mean age 21.33), were recruited in this study. All of them were familiar with basic computer and tablet usage (e.g., Windows office word processing tasks, and tablet article explore). All participants had normal or corrected-to-normal vision.

2.3 Parameters Design

In our study used two difference lighting sources and two CCT for our ceiling lighting parameter design. We set Lower Blue value and High-Efficiency lighting as our lighting sources and the CCT of lighting sources, which we set to 4,000 and 6,500 K. We designed four ceiling LED lighting devices which equipped lighting sources were mentioned above.

We divided the devices into two types first type of design were basic ceiling lighting design (as shown in Fig. 1a, b. They were all equipped the Lower Blue Value lighting source. Second types designed were equipped lower Blue-value and high-efficiency lighting sources (as shown in Fig. 1c, d. Which equipped the Lower Blue Value lighting source in the part of central and the higher-efficiency lighting sources was equipped around central which in the device.

These two kinds of lighting sources set CCT in 4,000 and 6,500 K which equipped in different types of lighting design as shown in Fig. 1.

2.4 Experimental Variables

The independent variable discussed in this study were the four ceiling lighting design included two different CCT which were 4,000 and 6,500 K, and two different type lighting sources. The dependent variables were four office-like task performance, objective physiological responses, and subjective questionnaire.

Task performance were measured the completion and error rates by evaluated participants' task performance. Physiological responses were measured as Heart Rate (HR), Galvanic Skin Response (GSR), eye Blink Duration (BD), Blink Time (BT) and Critical Fusion Frequency (CFF) values which could represent our emotion regulation and eye fatigue under the four LED lighting ceiling design.

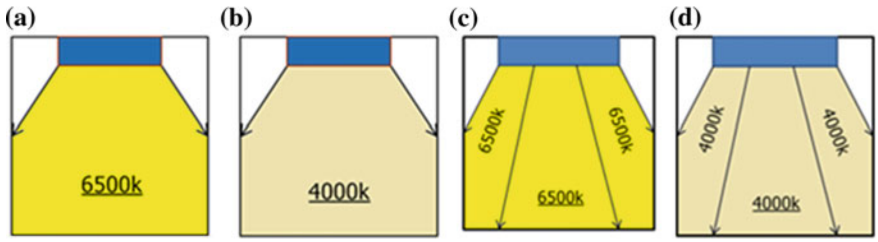


Fig. 1 Experimental ceiling lighting design

Table 1 Overview the Karolinska sleepiness scale (KSS)

Value	English rating
1	Extremely alert
2	Very alert
3	Alert
4	Rather alert
5	Neither alert nor sleepy
6	Some sign of sleepiness
7	Sleepy, no effort to stay awake
8	Sleepy, some effort to stay awake
9	Very sleepy, great effort to keep awake, fighting

The subjective questionnaires were measured as Karolinska Sleepiness Scale (KSS) as shown in Table 1. Linhart and Scartezzini (2011) KSS is a subjective rating scale which to state their actual alertness level on a 9-stage scale between "extremely alert" (1) to "very sleepy, great effort to keep awake, fighting sleep" (9).

2.5 Experimental Protocol

There were four tasks that were conducted in this study to simulate the office work. The first task was Psychomotor Vigilance Task, which executed at start and end of this protocol. It took five minutes for measuring average reaction time. The task was a laptop task. Participants had to enter the corresponded alphabet button on laptop keyboard to eliminate the alphabet, which was showed up on the laptop monitor. Each alphabet is shown randomly and only one alphabet is shown on the monitor during the task. Second task was Landolt Ring counting which was sheet task, took 50 min for measured the Completion and Error Rates as participants working performance. In this Task participants were gave A4 sheets randomly filled with four different directions of Landolt rings. Each sheet had 240 Landolt rings which diameter was 9 mm and gap width was 0.5 mm. Participants counted the number of Landolt rings for each gap direction of rings. Third Task was Three-digit Addition Laptop Typing Task, which took 50 min for measuring the Completion and Error Rates as participants working performance. Participants had to use laptop to calculate Three-digit Addition questions, the Three-digit Addition question of this task would randomly showed up the Three-digit numbers on laptop monitor. Fourth Task was Listening and Wrong Identify Tablet Searching Task, which took 50 min for measuring the Error Rates as participants' working performance. In this study participants had to listen the speech and identify the difference words between the speech and article. All of these tasks order were fixed. Between each Task participants have ten minutes to rest and write the Karolinska Sleepiness Scale which evaluated participants' subjective sleep feeling, and alertness. Critical Fusion Frequency values which measured at the beginning and end of this protocol.

2.6 Statistic

Analysis of variance general linear model and post-analysis Tukey comparisons were applied for analysis all physiological responses and the Karolinska Sleepiness. Critical Fusion Frequency values were applied Paired student T test for analysis.

3 Results

3.1 Task Performance

The results showed that the Tablet-Searching Task under the four lighting parameters did have significance effect on task performance. As shown in Fig. 2 we found the mean error rate which under the CCT 4,000 and 4,000 K-high efficiency. The mean error rates and standard deviation were 0.23 ± 0.07 and 0.22 ± 0.07 which had significance lower than the CCT 6,500 and 6,500 K-high efficiency lighting design.

3.2 Physiological Responses

Physiological responses including HR, GSR, BD, BT, and CFF value. The detail of significance effect under the four lighting parameters will be below. As shown in Fig. 3 shown participants' average HR was measured as the highest and the lowest (75.89 ± 8.65 Beats/min and 68.80 ± 5.37 Beats/min) when the HR at the set of CCT 6,500 K high-efficiency and CCT 4,000 K-high efficiency. As shown in

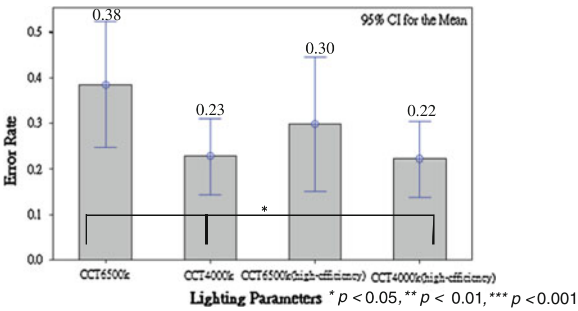


Fig. 2 The effect of lighting parameters on tablet-searching task performance

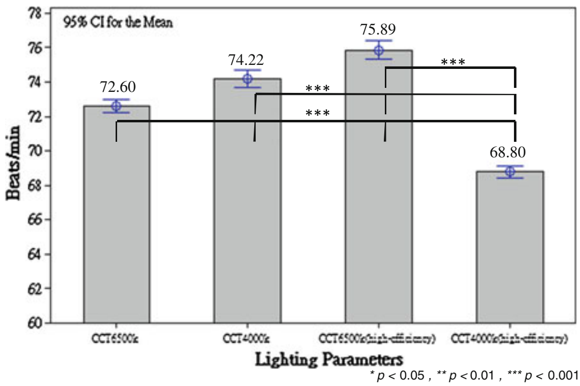


Fig. 3 The effect of lighting parameters on heart rate

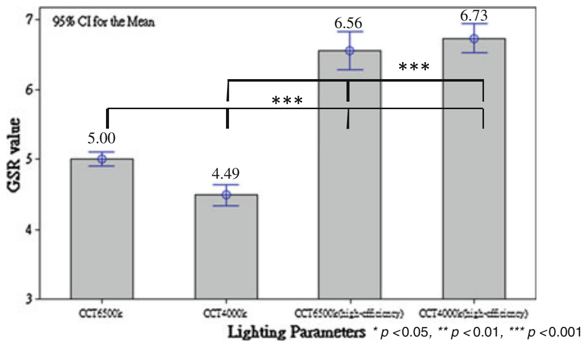


Fig. 4 The effect of lighting parameters on GSR

Fig. 4 shown participants' average GSR value was measured as the highest (6.56 ± 4.20 and 6.73 ± 3.15) when the Lighting Parameter was designed at the set of CCT 6,500 K high-efficiency and CCT 4,000 K high-efficiency. Figure 5 had shown under the high-efficiency lighting design included CCT 6,500 and 4,000 K the average Blink Duration was 12.42 ± 8.46 counts and 15.23 ± 11.14 counts. Participants had lower Blink Duration than original lighting design. Figure 6 had shown under the CCT 4,000 K-high efficiency, participants had lowest Blink Time was measured as 36.68 ± 1.93 ms.

3.3 Subjective Questionnaire

The Subjective Questionnaire of this study was Karolinska Sleepiness Scale (KSS), which measured about eyes fatigue. In Fig. 7 we found under the CCT 6,500 K high-efficiency would make participants had more awake than CCT 4,000 K high-efficiency on the Landolt Ring counting task performance in the result of KSS.

Fig. 5 The effect of lighting parameters on blink duration

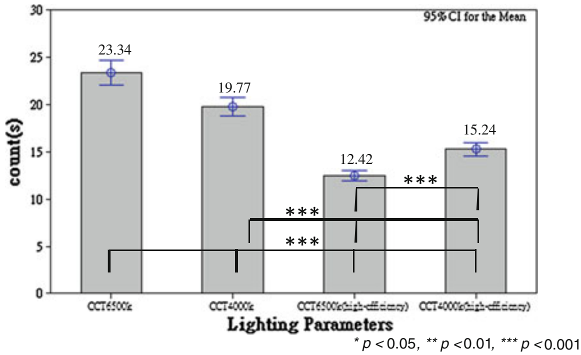


Fig. 6 The effect of lighting parameters on blink time

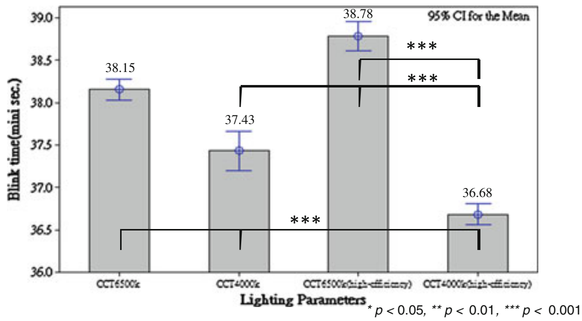
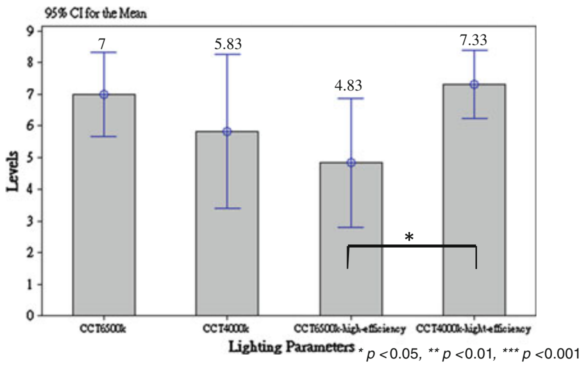


Fig. 7 The effect of lighting parameters on karolinska sleepiness



4 Discussion

In this study different Ceiling Lighting Design had significant affected on human's Tablet task performance, objective physiological responses and subjective Karolinska Sleepiness Scale (KSS). The reason which caused the significance might be due to the different CCT or the different Blue-Value lighting sources, these lightings would affect participants' emotion, however many research indicated different lighting conditions would affect human's psychological perception. According to (Riva et al. 2003), some specific physiological responses such as heart rate and GSR value while increasing the alert and exciting the heart and the conductivity of GSR would change, thus this research is focused in the heart rate and GSR value to represent human's psychological stress and awakens. In eye measurement (Schleicher et al. 2008) mentioned that Blink Duration and Blink Time could be a indicator to eye fatigue. Although in this study we had significance effect on our physiological responses, however in these results of our eye measurement we just only explained these results had a trend to become fatigue. We didn't have specific evidence to identify the eye fatigue.

5 Conclusion

In this study the effect of different LED ceiling lighting design on four types of office-like tasks Psychomotor Vigilance Task, Landolt Ring counting Sheet Writing Task, Three-digit Addition Laptop Typing Task, Listening and Wrong Identify Tablet Searching Task. Our results showed that participants working under our lighting parameters in CCT 4,000 K (included original and high-efficiency design) could lower their Tablet-Searching error rate. In physiological responses CCT 4,000 K high-efficiency would make participants feel comfort due to its lower stress (HR) and eye fatigue (Blink Time), however in the high-efficiency lighting design(included CCT 4,000 and 6,500 K) participants would feel alert and comfort due to the higher GSR value and less Blink Duration.

Acknowledgments This work is partially supported by Taiwan Industrial Technology Research Institute (ITRI).We would like to acknowledge the grant support from the Taiwan Industrial Technology Research Institute (ITRI).

References

Manav B (2007) An experimental study on the appraisal of the visual environment at offices in relation to colour temperature and illuminance. Building and Environment. doi:http://dx.doi.org/10.1016/j.buildenv.2005.10.022

Navvab M (2002) Visual acuity depends on the color temperature of the surround lighting. Illum Eng Soc 31:70–84

Viola AU JL, Schlangen LJM, Dijk D-J (2008) Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health 34(34):297–306

Linhart F, Scartezzini J-L (2011) Evening office lighting e visual comfort vs. energy efficiency vs. performance? Build Environ 46:981–989

Riva G, Davide F, IJsselsteijn W (2003) 7 Measuring presence: subjective, behavioral and physiological methods. being there: concepts, effects and measurement of user presence in synthetic environments, pp 110–118

Schleicher R, Galley N, Briest S, Galley L (2008) Blinks and saccades as indicators of fatigue in sleepiness warnings: looking tired? Ergonomics. doi:10.1080/00140130701817062

Postponement Strategies in a Supply Chain Under the MTO Production Environment

Hsin Rau and Ching-Kuo Liu

Abstract Postponement strategies that decrease the impact of uncertainty of demand and improve customization have implemented for a long time in the supply chain. Postponement is to start to perform some operations until the customized order is received, and it does not go by forecast like the traditional approach. In modeling postponement, most researchers focus on manufacturing postponement and they do not consider production environment. This study considers the production environment of make to order to develop a supply chain network and to study the optimal combination of postponement operations in the supply chain, such as manufacturing, packaging, and logistics. We take notebook computer as an example to show the optimal combination of postponement strategies when the minimum total cost is reached. We believe that the results of this study would provide suggestions to managers for their supply chain operational decisions.

Keywords Supply chain · Make to order · Postponement

1 Introduction

The concept of postponement was introduced in the literature by Alderson (1950), but it only attracted more researches in recent years (Yang et al. 2004; Yang and Yang 2010). The concept of postponement is to redesign the product and process and delay the difference of product to the upmost, it doesn't complete the final operation until getting customer order, and it's a way for customization and could decrease many uncertain factor and operational risk (Lee and Billington 1994).

H. Rau (✉) · C.-K. Liu
Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chungli 320, Taiwan, Republic of China
e-mail: hsinrau@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_152,

Lee et al. (1993) considered that the location of customization could affect the level of inventory and service, and the design of product and process also affects the operational process, for example, some products are suitable to be produced by the mother factory, some are by distributor, and the others are by final customer. The postponement of customization could improve the flexibility of demand and the inventory cost; on the other hand, the speed of delivery and the service level are likely to be decreased.

The classification of postponement strategies have been proposed by many scholars with different concepts. Zinn and Bowersox (1998) considered postponement is to delay the customer order de-coupling point to the downstream of the supply chain. They classified five postponement strategies: labeling, packaging, assembly, manufacturing and time. Cooper (1993) developed four postponed strategies, bundled manufacturing, deferred assembly, deferred packaging, and unicentric manufacturing if the specification of product and characteristic of the peripheral product had the same community of market. Bowersox and Closs (1996) mentioned time, space and form postponement strategies according to the concept of delaying the operational time, space and design of product. Pagh and Cooper (1998) integrated postponement and speculation (P/S) of manufacturing and logistics postponement into four general supply P/S strategies called P/S Matrix, included full speculation, manufacturing postponement, logistics postponement and full postponement strategy. Van Hoek (2001) proposed four postponement strategies with respect to the viewpoint of time and space by performing postponement, namely, time postponement, bundled manufacturing, deferred assembly and deferred packaging. Yang and Burns (2003) proposed six postponements, namely, design, purchasing, manufacturing, assembly, packaging/labeling, logistics and discussed with a continuum of customization and standardization, where includes make to forecast, shipment to order, packaging/labeling to order, final manufacturing/assembly to order, make to order, buy to order, and engineering to order. Yang et al. (2004) studied the role of postponement in the management of uncertainty; and the postponement includes product development, purchasing, production, logistics postponements. From the above literature review we could know that the classification of postponement may not be all the same, but their concept is very close. This study will use three kinds of postponements: manufacturing postponement, packaging postponement and logistics postponement to study the best postponement strategies for notebook computer in the supply chain under the make to order (MTO) production environment.

With respect to the mathematical model regarding postponement, Lee et al. (1993) considered the community of component with the expected benefits and product life cycle. They computed the difference of cost for performing postponement and considered the transshipment at a fixed service level. Lee and Tang (1997) developed a cost model for a multi-stage system of inventory and discussed the cost difference resulted from product difference. Ernst and Kamrad (2000) discussed modularization in product design and logistics postponement in light of processes of manufacturing, assembly, and packaging and developed four structures: rigid, modularized, postponed and flexible. They developed a total cost model for them and compared their cost. Rau and Liu (2006) developed a network of postponement for notebook computer industry and used a mathematical model to discuss the optimal combination of postponement with the minimum cost. From the above observation, we find that no research has developed a mathematical model to obtain the optimal postponement strategies under the production environment such as MTO.

The above literature review gives a motivation to this paper. This study considers the production environment of MTO (make to order) to develop a supply chain network and to study the optimal combination of postponement operations in the supply chain, such as manufacturing, packaging, and logistics. We take notebook computer as an example to show the optimal postponement strategies when the minimum total cost is reached.

2 Modeling the Optimal Combination of Postponement Strategies

2.1 Development of the Postponed Network of Supply Chain

This section focuses on developing the postponed operations in the supply chain. In modeling postponement, most researches pay more attentions on the description of theory and the discussion of benefits of performing postponement. Fewer researches discussed the implementation of postponement in the supply chain and most only focus the manufacturing postponement. This research extends the postponement to the whole supply chain and discusses the implementation of various postponements in the supply chain.

In order to describe our supply chain environment, we have the following assumptions:

- The finished product is composed of standard, crucial, differential components; semi-finished product 1 is composed of standard components; semi-finished product 2 is composed of standard and crucial components, which means it consists of semi-finished product 1 from product the component structure.
- The standard semi-finished product is made by the assembly of components after we purchase its components, and it is not from the purchase directly.
- Assume the product could perform any types of postponements and their combination.

Partners in our system have supplier, assembler, distributor, retailer and customer to form the supply chain network as shown in Fig. 1. This study would discuss manufacturing, packaging and logistics postponements and use notebook computer as an example.

Three postponements used in this study are described as follows:

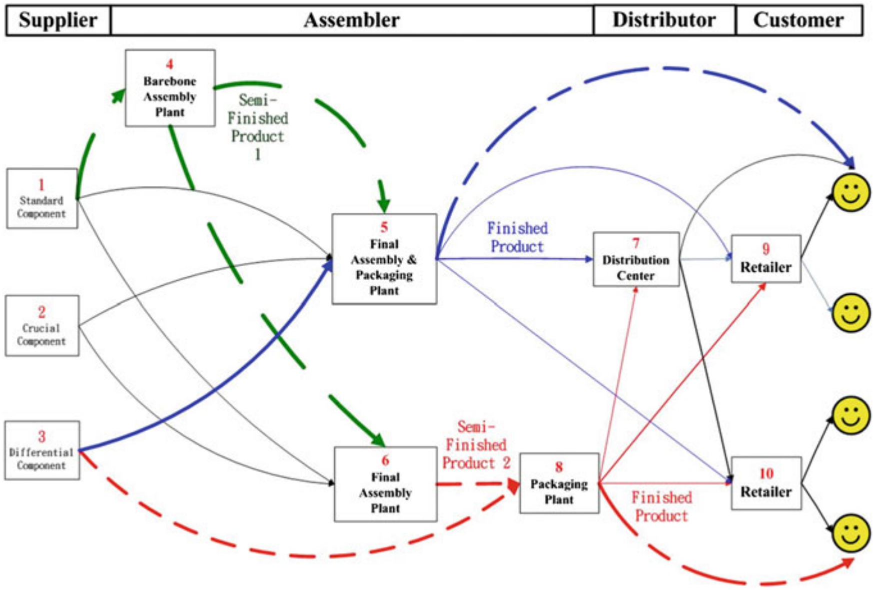


Fig. 1 Supply chain network

- Manufacturing postponement—this happens when standard components (1) are sent to a barebone assembly plant (4) to become semi-finished products 1, which are called as barebones in the notebook computer industry. These barebones can be postponed to become semi-finished products 2 according to the request from demand. If standard components (1) and crucial components (2) are assembled at a final assembly and packaging plant (5) or at a final assembly plant (6) to become semi-finished products 2, then we do not have manufacturing postponement.
- Packaging postponement—this happens when semi-finished products 2 stay at a final assembly plant (6) and not going to a packaging plant (8) right away to become finished products. If differential components (3) such as power supply, manual, etc. are sent to a final assembly and packaging plant (5) for becoming finished products, then there is no packaging postponement.
- Logistics postponement—this study defines logistics postponement as replacing de-centralized inventory with centralized inventory by direct distribution to final customer without passing the distribution center and retailer after the finished products have been completed. This happens when the finished products completed at a final assembly and packaging plant (5) or a packaging plant (8) in Fig. 1, they are delivered to a final customer directly without through a distribution center (7) and/or retailer (9 or 10). On the other hand, if the finished products are delivered through a distribution center and/or retailer, then there is no logistics postponement.

The MTO production environment for the notebook computer can be set by the decoupling point (DP) (Yang and Burns 2003) for the above three postponements as shown in Fig. 2.

2.2 Model Development

Due to space limitation, this paper only discusses the concept of mathematical model development and the mathematical model itself will be neglected. The goal of mathematical model in this study is to search the optimal combination of postponed strategies at the minimum cost and satisfying customer's lead time. The cost includes the purchasing cost, processing cost (including manufacturing, assembly, and packaging cost), inventory cost, transportation cost, penalty cost, over-production cost, and shortage cost. The penalty cost is for products not delivering at the lead time that a customer requests. In the consideration of time, it includes the processing time and transportation time.

3 Example Illustration

One of major Taiwan notebook computer OEM company is chosen. For its American market, the barebones are made in China, and then they are sent to the final assembly plant and final assembly and packaging plant in Houston of

Fig. 2 The framework of postponement in MTO production environment

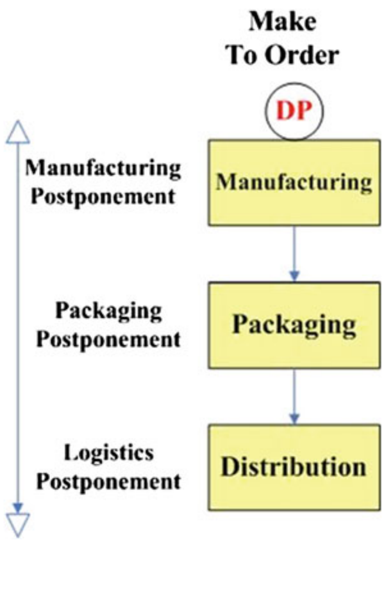


Table 1 Component classification

	Standard	Crucial	Differential
Components	Case	TFT-LCD	Keyboard
	Battery	CPU	Package and others
	Motherboard	DRAM	
	CD-ROM	HD	

Table 2 Sales data is used is from 2003 to 2006 (1000 units)

	2003	2004	2005	2006
Q1	360.44	401.80	545.6	915.02
Q2	337.74	430.49	697.66	
Q3	401.10	527.64	882.46	
Q4	489.98	599.98	1,010.06	
	Mean		Standard deviation	
	584.62		216.20	
	The rate of market in the American about 17.6 %			

Table 3 The optimal combination of postponed strategies

Postponement			Total cost (M US$)
Manufacturing	Packaging	Logistics	
0	0	1	8,528
0	0	2	9,460
0	0	3	10,515
0	1	1	8,708
0	1	2	9,696
0	1	3	10,755
1	0	1	6,735
1	0	2	**6,649**
1	0	3	7,704
1	1	1	6,916
1	1	2	6,886
1	1	3	7,944

American. Distribution center and packaging plant are located in the main market of American in order to process the delivery and postponed packaging.

The finished product is composed of standard, crucial, differential components; and the components used in this study are shown in Table 1. Sales data is used is from 2003 to 2006 as shown in Table 1. The software of Mathematica is used to solve the optimal combination of postponement strategies with the objective of minimum cost in the MTO production environment with consideration of operational lead time. The result of total cost for the optimal combination of postponed strategies is shown in Table 3, where 0 and 1 denote without and with postponement respectively for either manufacturing or packaging postponement. In logistics, 1 denotes with postponement (direct ship); 2 and 3 denote without postponement, and 2 is for two stage shipment and 3 is for three stage shipment (Table 2).

Table 3 shows that for all the manufacturing postponement cases are better than all the non-manufacturing postponement ones. This is because in the MTO environment, the lead time is very short, so we have to make barebones first that can reduce the lead time, increase the subsequent assembly efficiency to satisfy customer's service level. The optimal solution occurs at the situation with manufacturing postponement, without packaging postponement, and without logistics postponement; but with two stage shipment. This outcome balances between inventory cost and transportation cost. The result obtained here matches the real practice.

4 Conclusions

Postponement strategies can help reduce the effect of uncertainty of demand and improve customization in the supply chain operations. In modeling postponement, most researchers before focused on manufacturing postponement and they did not consider production environment. This study used notebook computer as an example to propose a supply chain model to study the optimal combination of postponement strategies including manufacturing, packaging, and logistics postponements for the MTO production environment using the concept of decoupling point.

The example chosen is one of major Taiwan notebook computer OEM company with its barebones manufacturing site in China and the final assembly plant and final assembly and packaging plant in Houston of American. Distribution center and packaging plant are located in the main market of American. The optimal solution occurs at the situation with manufacturing postponement, without packaging postponement, and without logistics postponement; but with two stage shipment. The result obtained in this study matches the real practice and give more insights.

Due to the space limitation, the mathematical modeling is not shown and various factors such as package size, inventory cost, and lead times are also not shown to explore the effects on postponement strategies selection.

Besides the MTO production environment, there are several other production environments such as packaging/labeling to order, final manufacturing/assembly to order, buy to order, and engineering to order to be able to study in the future.

Acknowledgments Although we only present a partial work in this paper due to space limitation, the full work is supported in part by National Science Council of Republic of China under the grants NSC 93-2213-E-033-042 and NSC 101-2221-E-033-037-MY3, and College of Electrical Engineering and Computer Science of Chung Yuan Christian University under the grants CYCU-EECS-10001.

References

Alderson W (1950) Marketing efficiency and the principle of postponement. Cost Profit Outlook 3:1–3

Bowersox DJ, Closs DJ (1996) Logistical management: the integrated supply chain process. McGraw-Hill, New York

Cooper JC (1993) Logistics strategies for global businesses. Int J Phys Distrib Logis Manag 23:12–23

Ernst R, Kamrad B (2000) Evaluation of supply chain structures through modularization and postponement. Eur J Oper Res 124:495–510

Lee HL, Billington C (1994) Designing products and processes for postponement. In: Dasu S, Eastman C (eds) Manage Des: Eng Manage Perspect. Kluwer Academic, Norwell, pp 105–122

Lee HL, Billington C, Carter B (1993) Hewlett-Packard gains control of inventory and service through design for localization. Interfaces 23:1–11

Lee HL, Tang SC (1997) Modelling the costs and benefits of delayed product differentiation. Manage Sci 43:40–53

Pagh JD, Cooper MC (1998) Supply chain postponement and speculation strategies: how to choose the right strategy. J Bus Logist 19:13–33

Rau H, Liu C-T (2006) The optimal conbination of postponement operations in a supply chain. J Chin Inst Ind Eng 23:253–261

Van Hoek RI (2001) The rediscovery of postponement a literature review and directions for research. J Oper Manage 19:161–184

Yang B, Burn N (2003) Implications of postponement for the supply chain. Int J Prod Res 41:2075–2090

Yang B, Burn N, Backhouse CJ (2004) Management of uncertainty through postponement. Int J Prod Res 42:1049–1064

Yang B, Yang Y (2010) Postponement in supply chain risk management: a complexity perspective. Int J Prod Res 48:1901–1912

Zinn W, Bowersox DJ (1998) Planning physical distribution with the principle of postponement. J Bus Logis 9:117–136

Consumer Value Assessment with Consideration of Environmental Impact

Hsin Rau, Sing-Ni Siang and Yi-Tse Fang

Abstract In response to climate change, environmental issues, such as greenhouse gas emissions and carbon footprint, become important. Products are required to take into account of life-cycle thinking in their product design phase. In the past, enterprises only pursued the quality improvement and technology development of green products, but they ignored the value of consumers in those eco-design products. This ignorance results in weak competition; however, it gives the motivation of this study. This study is based on the concept of eco-efficiency to develop a consumer value assessment model with consideration of environmental impact. Several different types of laptop computers are used as examples to illustrate the application of our assessment model. This model simultaneously considers the value of functional performance, the total cost of ownership, and the environmental impact for the product. The environmental impact includes the assessment of energy consumption, pollution and non-recyclability. We believe that our proposed model can be served as a guidance of product improvement or innovation for the designer, and a reference of purchasing products for consumers.

Keywords Consumer value · Environmental impact · Eco-design

1 Introduction

In recent decades, governments have legislated and formulated policies regarding to environmental issues in response to energy shortages, greenhouse gas emissions, climate change, and other serious environmental problems. As the environmental

H. Rau (✉) · S.-N. Siang · Y.-T. Fang
Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chungli 320, Taiwan, Republic of China
e-mail: hsinrau@cycu.edu.tw

S.-N. Siang
e-mail: g9602408@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_153,

impact of a product is determined at the product development stage, the designers are supposed to have the responsibility for the sustainable product development through the Eco-design concept.

Eco-design, known as Design for Environment (DfE), can be referred to as green design focusing on the integration of environmental considerations and business oriented goal in product development. It attempts to include environmental variables at the same level of importance of functionality, costs, ergonomics, and efficiency (Platcheck et al. 2008). It incorporates the principles of the productive closed-loop supply chain, starting from the raw material selection, the production, the use, and the end-of-life of industrial products. The application of eco-design techniques have been done on various areas such as mini-compressor, mouse, and automotive electronics (Platcheck et al. 2008; Herrmann et al. 2005; Borchardt et al. 2009). Here, indicators such as factor X and eco-efficiency are needed as design criteria by product developers, as decision criteria by companies and as purchasing criteria by consumers.

Eco-efficiency analysis has been applied for several studies in different areas such as agricultural, furniture production, industrial system, paper mills, iron rod industry, and power plants (Reith and Guidry 2003; Michelsen et al. 2006; Zhang et al. 2008; Hua et al. 2007; Kharel and Charmondusit 2008; Korhonen and Luptacik 2004).

Based on a comprehensive literature review above, we found that most of the relevant literature concentrated on the implementation of eco-design. As we know, to date there are no reports discussing the value of consumer under environmental impact based on the concept of eco-design. Therefore, this study will take this advantage to introduce a new, simple, and practical methodology to both producers and consumers as a consideration in the decision making of producing or purchasing green products. Several different types of laptop computers were used as examples to illustrate the application of our proposed methodology.

2 Methodology

2.1 Model Development

This study develops a framework as a basis to calculate the value of consumer under environmental impact. The proposed method consists of two main steps, quantifying value of consumer and quantifying environmental impact. To quantify value of consumer, three steps are applied: quantifying value of product, determining lifespan of product, and quantifying total cost of ownership. We will discuss them as follows.

Zeithaml (1988) defines value of consumer (V_C) as consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given, as shown in Eq. (1). Receipts (R_C) cover quality, functionality, personal value, and positive feelings while contributions (C_C) cover money, time or effort, and negative feelings.

$$V_C = \frac{R_C}{C_C} \tag{1}$$

This study defines the receipts of customer as a multiplication of the product value (V_p) and the lifespan (L_p) of a product obtained by consumer, as shown Eq. (2).

$$R_c = V_p \times L_p \tag{2}$$

1. To obtain the value of product (V_p), the calculation steps are the following:
2. Determine a reference product (R) and other products to compare or evaluate based on the reference product.
3. Identify key components of the product ($m = 1, 2, \ldots M$).
4. Choose the most significant attributes or functions for each key component, then find their performance ($Y_{m,n}$, $m = 1, 2, \ldots M$, $n = 1, 2, \ldots N(m)$, where $Y_{m,n}$ is the performance of attribute n of key component m of the evaluated product.
5. As the contribution for each component and attribute is different, then we can apply the weighting factor to express their importance.
6. Using factor X to find each attribute performance after factor X as shown in Eq. (3), where $R_{m,n}$ is the performance of attribute n of key component m of the reference product.
7. Use root mean square to obtain the mean performance of component m, as shown in Eq. (4).
8. Calculate the value of product V_p, as shown in Eq. (5).

$$X_{m,n} = \frac{Y_{m,n}}{R_{m,n}} \tag{3}$$

$$U_m = \sqrt{\frac{1}{N(m)} \sum_{n=1}^{N(m)} X_{m,n}^2} \tag{4}$$

$$V_p = \sqrt{\frac{1}{M} \sum_{m=1}^{M} Q_m^2} \tag{5}$$

where $Q_m = U_m \times W_m$, W_m is the weighting factor of component m.

We use the term TCO (Total Cost of Ownership) (Kirwin 1987) to represent C_c in Eq. (1). TCO includes total cost of acquisition and operating cost. The cost of product to the consumer includes purchasing cost, any costs related to use of the product and any costs that arise when the product is disposed (Bengtsson 2004). In this study, total cost of ownership is modelled as the sum of purchasing cost (C_P), use cost (C_{Use}), repair cost (C_R), and other cost (C_O), as shown in Eq. (6).

$$TCO = C_P + C_{Use} + C_R + C_O \tag{6}$$

Life Cycle Assessment (LCA) is a powerful tool that identifies and evaluates the life cycle impact that the product has on the environment. Eco-design products should be more energy-efficient, less polluting, and efficiently recycled than other products. Thus, indicators including energy consumption (E_c), pollution (P), and recyclability ($\boldsymbol{N_r}$) are used to measure the environmental impact of a product over its life cycle (E_{lc}) as defined by Eq. (7).

$$E_{lc} = E_c + P + N_r \tag{7}$$

In this study, we collect their value from a questionnaire.

We can define the value of consumer under environmental impact based on the concept of eco-design as Eq. (8).

$$V_{CE} = \frac{V_C}{E_{lc}} \tag{8}$$

The value of consumer (V_C) can be described as the ratio of the value of product (V_p) during the lifespan (L_p) to Total Cost of Ownership (TCO). Substituting Eqs. (1), (2) and (6), then we can obtain the value of consumer under environmental impact as

$$V_{CE} = \frac{V_p \times L_P}{TCO \times E_{lc}} \tag{9}$$

From WBCSD (2000), eco-efficiency can be defined as the ratio of product value to environment impact, also following the above definitions, then we can define eco-efficiency as a multiplication of the product value (V_p) and the lifespan (L_p) of a product to its whole environmental impact (E_{lc}) based on Life Cycle Assessment (LCA), as shown in Eq. (10).

$$Eco - efficiency = \frac{V_p \times L_p}{E_{lc}} \tag{10}$$

Then the value of consumer under environmental impact based on the concept of eco-design can be defined as the ratio of eco-efficiency to TCO (customer contribution during life span).

$$V_{CE} = \frac{V_p \times L_P}{TCO \times E_{lc}} = \frac{Eco - efficiency}{TCO} \tag{11}$$

This study will use Eq. (11) to evaluate consumer value that involves product eco-efficiency and consumer contribution. However, the eco-efficiency considers product value under the environmental impact during the life cycle of the product;

therefore, the consumer value proposed here can be served as not only a purchasing reference for consumers but also a reference of product design improvement or innovation for producers with consideration of environment impact.

3 Example Illustration

3.1 Calculation of Product Value

In this section, we evaluated the applicability of our proposed methodology using laptop computers as examples. With regard to product type, there are three types of laptop computers are considered in this study as evaluated products. Each type has two computers and there are six computers (A to F) in total, as shown in Table 1. In order to compare with those six evaluated products, we determine a reference product as shown in Table 2 that is chosen as a reference product because its sales volume is number one among all types of laptop computer at that moment. Table 3 presents the value of product for each of the evaluated product. It is well known that the higher the functionality performance value, the greater the preference value of a product. Thus, it is not surprising that product F (notebook computer) and product B (CULV) got the higher score. Negative scores of product D and product C mean that the functional performance of those products (netbook computers) cannot compete with the reference product, where $V_P' = V_P/(V_P)_R$.

3.2 Calculation of Total Cost of Ownership

In order to quantify the total cost of ownership, purchasing cost, use cost, repair cost, and other cost should be defined first. In this study we used selling price as purchasing cost, electricity cost as use cost. The most important factors of electricity cost are energy consumption and lifespan of laptop computers. According to EuP Lot 3 (EuP 2005), different operational mode (off, sleep, and active mode) will lead to different total energy consumption. The percentage for each mode is off (49 %), sleep (37 %), and active (14 %). Lifespan is set 43800 h. Repair cost constant (F) = 85 USD.

3.3 Calculation of Value of Consumer

After calculating value of products and total cost of ownership, then we can find the value of consumer based on Eq. (1). Product D is in the first rank, and its

Table 1 Attributes of evaluated products

Type	A	B	C	D	E	F
	Consumer ultra-low voltage (CULV)		Netbook		Notebook	
CPU	Intel Core 2 Duo Clock Speed(1.3 GHz) L2 Cache(3 MB) Number of Cores(2) Bus Speed (800 MHz)	Intel Core 2 Duo Clock Speed(1.4 GHz) L2 Cache(3 MB) Number of Cores(2) Bus Speed (1066 MHz)	Intel Atom N270 Clock Speed(1.6 GHz) L2 Cache(1 MB) Number of Cores{1) Bus Speed (133 MHz)	Celeron M Clock Speed(1.7 GHz) L2 Cache(1 MB) Number of Cores(l) Bus Speed (133 MHz)	Intel Core i5 540 M Clock Speed(2.1 GHz) L2 Cache(2 MB) Number of Cores(2) Bus Speed (800 MHz)	Core 2 Duo T4500 Clock Speed(2.5 GHz) L2 Cache(3 MB) Number of Cores(2) Bus Speed (1066 MHz)
Memory	DDR2, 800 MHz, Max 4 GB	DDR3, 1,066 MHz, Max 4 GB	DDR2, 667 MHz, Max 1 GB	DDR2, MHZ, Max 1GB	DDR3, 1,066 MHz, Max 8 GB	DDR2, 800 MHz, Max 8 GB
Display	12.1″ LED Backlight (1366 × 768)	15.6″ LED Backlight (1366 x 768)	8.9′ (1024 × 600)	10′ (1024 × 600)	14′ LED Backlight (1366 × 768)	15″ LED Backlight (1366* 769)
Storage	320 GB, 5,400 rpm	500 GB, 5,400 rpm	12 GB, 4,800 rpm	80 GB, 4,800 rpm	640 GB, 5,400 rpm	320 GB, 5,401 rpm
Dimensions	296 x 210 x 25.1 mm	386 × 259 × 26.4 mm	225 × 175 × 39 mm	226 × 191 × 38 mm	349 × 238 × 36.5 mm	345 × 249 × 35.5 mm
Weight	1.5 kg	2.4 kg	1.1 kg	1,45 kg	2.2 kg	2.36 kg
Price (USD)	1,063	1,197	666	600	1,230	797

Table 2 Attributes of reference product

Reference product	
CPU	Intel Pentium T4500
Memory	DDR3 1,066 MHz 2 GB
Display	14″(1,366 × 768)
Hard disk	500 GB 5,400 rpm
Dimensions	239 × 342 × 38.6 mm (W × D × H)
Weight	2.36 kg

Table 3 Functional performance value

Reference product $(V_p)_R$	Type	Product value (V_p)	Improvement rate $(V_p{}')$	Rank
0.352	A	0.396	1.13	3
	B	0.405	1.15	2
	C	0.323	0.92	6
	D	0.347	0.99	5
	E	0.364	1.03	4
	F	0.418	1.19	1

product value is not the highest, but it has the lowest TCO. This phenomenon can explain why netbook computer was so popular a couple of years ago.

Figure 1 shows a comparison with the reference product in terms of product value and TCO, where $TCO' = TCO/TCO_R$. The value located in the second quadrant is the best and that has better performance for both $V_p{}'$and TCO'. However, none of the six laptop computers has this situation. Products D and C have better values in TCO' and others have better values in $V_p{}'$ Combining with these two factors, product D has the highest value in consumer value, followed by products F, C, A, C, and E.

3.4 *Calculation of Value of Consumer under Environmental Impact*

In this step, we quantify the environmental impact of those evaluated products based on LCA and use energy consumption, pollution, and recyclability as the indicators. We conducted a questionnaire to the computer company which owns

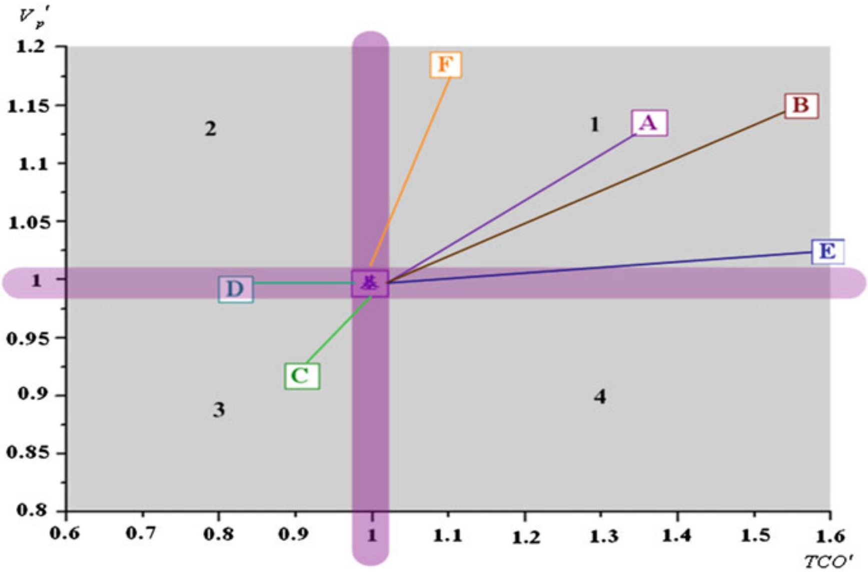


Fig. 1 Value of consumer

Table 4 Value of consumer under environmental impact

Type		Consumer value (V_C')	Environmental impact (E_{lc}')	V_{CE}'	Rank
CULV	A	0.81	1	0.81	4
	B	0.73	1	0.73	5
Netbook	C	1.00	1.01	0.98	3
	D	1.19	1.01	1.17	1
Notebook	E	0.64	1	0.64	6
	F	1.09	1	1.09	2

the six evaluated computer. The 58 questions are clustered into LCA processes: raw material extraction, production, transportation, use, and end-of-life aspects. Table 4 presents the environmental impact and the value of consumer under environmental impact of each evaluated products. From this indicator, product D is the most worthy product, followed by products F, C, A, B, and E. The rank order follows the order of consumer value, and this is due to there are no significant differences of environmental impacts among evaluated products.

When consumers demand for attributes such as compact, lightweight, easy to carry, and low price, netbook computer is the most recommended. Compared to product C, product D is better in the value of product and total cost of ownership. In the case of CULV, product A is better than product B. Product A has a lower value in product value than product B, but it has a lower value in total cost of ownership. As for notebook computer, product F is much better than product E as its value of product is much higher than product E and its total cost of ownership is also lower than product E.

4 Conclusions

The purpose of this study was to develop an assessment model that simultaneously considered the value of product based on functional performances, the total cost of ownership paid by consumer during life cycle, and the environmental impact complied by products. Six laptop computers ranging from CULV super light and thin, netbook, to main stream laptop computers were used to illustrate the applicability of our proposed assessment model. From this illustration, we can determine which laptop computer can be recommended to purchase for consumers in terms of not only functional performance and/or the total cost of ownership paid by consumer during life cycle, but also the environmental impact. At the same time, this model can be served as a reference of product design improvement or innovation for producers with consideration of environment impact. For the future study, we would suggest to extend our model to consider more data and develop software to make this assessment model in line with actual application.

Acknowledgments This work is supported in part by National Science Council of Republic of China under the grants NSC 98-2221-E-033-031-MY3 and 101-2221-E-033-037-MY3, and College of Electrical Engineering and Computer Science of Chung Yuan Christian University under the grants CYCU-EECS-10001.

References

Bengtsson S (2004) The BASF eco-efficiency analysis method: applied on environmental impact data from an LCA study of two colorants. Akzo Nobel Surface Chemistry. http://www.dantes.info/Publications/Publication-doc/. Accessed 1 May 2012

Borchardt M, Poltosi LAC, Sellitto MA, Pereira GM (2009) Adopting ecodesign practices: case study of a midsized automotive supplier. Environ Qual Manage 19:7–22

EuP (2005) Lot 3 personal computers (desktops and laptops) and computer monitors final report (Task 1-8). European Commission DG TREN http://extra.ivf.se/ecocomputer/downloads/Eup%20Lot%203%20Final%20Report%20070913%20published.pdf. Accessed 1 May 2012

Herrmann C, Stachura M, Yim HJ (2005) Methodic eco-design considering consumer needs and requirements: case study with computer mouse. In: Paper presented at the forth international symposium on environmental conscious design and inverse manufacturing. Tokyo, 12–14 Dec 2005

Hua ZS, Bian YW, Liang L (2007) Eco-efficiency analysis of paper mills along the Huai River: an extended DEA approach. Int J Manage Sci 35:578–587

Kharel GP, Charmondusit K (2008) Eco-efficiency evaluation of iron rod industry. J Cleaner Prod 16:1379–1387

Kirwin B (1987) End-user computing: measuring and managing change. Gartner Group Strategic Analysis Report, Stamford CN, USA
Korhonen P, Luptacik M (2004) Eco-efficiency analysis of power plants: an extension of data envelopment analysis. Eur J Oper Res 154:437–446
Michelsen O, Fet AM, Dahlsrud A (2006) Eco-efficiency in extended supply chains: a case study of furniture production. J Environ Manage 79:290–297
Platcheck ER, Schaeffer L, Kindlein W, Candido LHA (2008) EcoDesign: case of a mini compressor re-design. J Cleaner Prod 16:1526–1535
Reith CC, Guidry MJ (2003) Eco-efficiency analysis of an agricultural research. J Environ Manage 68:219–329
WBSCD (2000) Eco-efficiency: creating more value with less impact, World Business Council for Sustainable Development. ISBN 2-94-024017-5
Zeithaml VA (1988) Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. J Mark 52:2–22
Zhang B, Bi J, Fan ZY, Yuan ZW, Ge JJ (2008) Eco-efficiency analysis of industrial system in China: a data envelopment analysis approach. Ecol Econ 68:216–306

A Study of Bi-Criteria Flexible Flow Lines Scheduling Problems with Queue Time Constraints

Chun-Lung Chen

Abstract This paper considers the scheduling problems in a flexible flow line (FFL) with queue time constraints. The objective of the scheduling problems is to minimize the primary criterion which is exceeding queue time constraint times and the secondary criterion which is makespan. The problem considered in the paper is a NP-hard in a strong sense. It requires much computation time to find the optimal solution; therefore, heuristics are an acceptable practice for finding good solutions. In this paper, a meta-heuristic is proposed to solve the candidate problems. In order to evaluate the performance of the proposed heuristics, a conventional tabu search algorithm is examined for comparison purposes. The results show the proposed meta-heuristic performs effective.

Keywords Flexible flow line · Queue time constraints · Bi-criteria · Dispatching rule · Meta-heuristic

1 Introduction

This research is aimed at developing heuristic algorithms to solve bi-criteria of flexible flow lines scheduling problems with queue time constraints. The objective of the scheduling problems is to minimize the primary criterion which is exceeding queue time constraint times and the secondary criterion which is makespan. The flexible flow lines scheduling problems are perceived as NP-Hard problems, therefore we intend to develop heuristic methods to solve the problems in this study. Heuristics are developed for the primary criterion which is exceeding queue time constraint times and the secondary criterion which is makespan.

C.-L. Chen (✉)
Department of Accounting Information, Takming University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: charleschen@takming.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_154,

Flexible flow line (FFL) problems are also known as flexible flow shop (FFS), hybrid flow shop (HFS), or flow shop with multiple processors (FSMP) problems. A typical flexible flow line production system could be defined in this way: There are N number of jobs to pass through J number of stages, and every stage may contain one or more than one machine, and the waiting area between stages is assumed to be infinite, in other words, there is no job jammed in the waiting area. All jobs have the same routing over the stages of the shop and the flow of jobs through the shop moves in one direction from the first stage to the last.

It is common to control queue time in the production process in the making of many products. For example, queue time control is carried out in the assembly process of LCD (Cell), between wet etch and furnace in the fabrication of wafer in semiconductor industry, and in the procedure of wafer bumping in IC packaging industry. The queue-time constraint is defined as the time elapsed between two processes (Scholl and Domaschke 2000; Ono et al. 2006). In order to avoid quality defects due to long queue time in the production line, therefore these factories set up a maximum queue time between production processes so that no part needs to be reworked or discarded due to exceeding the queue time limit that causes production capacity reduction and economic loss (Su 2003).

Since queue time constraint phenomenon usually exists in FFL, they can be classified as flexible flow line with queue time constraint problems. There are some studies to FFL with no-wait or limited waiting time constraint. Wang et al. (2005) presents a heuristic algorithm to solve a two-stage flexible flowshop scheduling problem with no waiting time between two sequential operations of a job and no idle time between two consecutive processed jobs on machines of the second stage. Some studies relax the no-wait constraint that job must be processed continuously without waiting time between consecutive stages. Su (2003) presented a heuristic algorithm and a mixed integer program to solve a hybrid two-stage flowshop with limited waiting constraints. Chen and Yang (2006) proposed eight mixed binary integer programming models for the open-shop, job-shop, flow-shop, and permutation flow-shop scheduling problems with limited waiting time. The above two studies are to minimize makespan. Gicque et al. (2012) proposed a discrete time exact solution approach for a complex hybrid flow-shop scheduling problem with limited-wait constraints and considered the objective of minimizing the total weighted tardiness.

The mentioned above studies considered the jobs must be processed within every given queue time between each consecutive stages in the whole system. However, there are many situations usually occur in wafer fabrication and wafer bumping procedures, the mentioned above studies do not consider. For example, queue time constraints may be a time window set between two specified stages to prevent quality defects and the specified stages may not be consecutive. Figure 1 illustrates the physical relationship for queue time constraint between two specified stages. As shown in Fig. 1, there is a queue time among stage k to stage $k + b$, and the queue time is represented by $QT_{k,k+b}$, and among stage k to stage $k + b$ there is zero to b-1 stages. For convenience, the queue time constraint between two specified stages can be regarded as a queue time constraint block

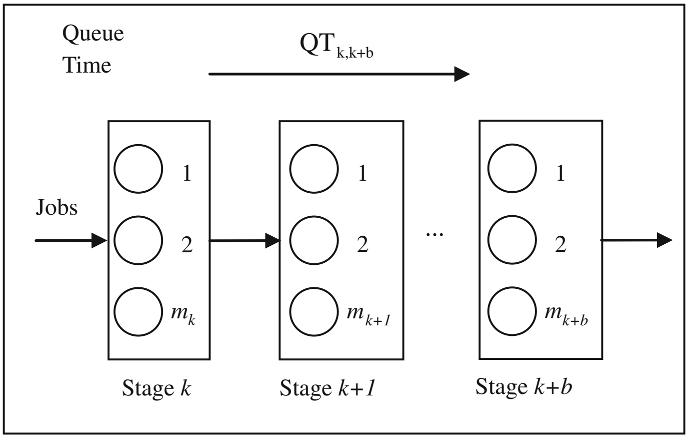


Fig. 1 Queue time constraint among stages

(QTCB). In addition, the QTCB may not include all stages in the whole FFL system. This means that there are many QTCBs in the FFL system controlled by several given queue times. For convenience, in this paper we named stage k as "the upstream specified process stage", and stage $k + 1$ as "the downstream specified process stage". In addition, we name the stages in FFL except for stages k and $k + 1$ as "general stage".

To the best of our knowledge, there are no studies that consider the bi-criteria of FFL scheduling problems with multiple QTCBs. The objective of the problem is to minimize the primary criterion which is exceeding queue time constraint times and the secondary criterion which is makespan. Hoogeveen et al. (1996) proved that minimizing makespan for two-stage FFL problems with stage 1 having one machine and stage 2 having two machines or with stage 1 having two machines and stage 2 having one machine is NP-hard. Therefore, the candidate FFL problem considered is at least NP-hard. Since it requires much computation time to find the optimal solution, heuristics are proposed to solve the candidate problems. A lot of test problems will be used to evaluate the performance of the proposed heuristics.

2 Description of the Considered Problem

The FFL with queue time constraints problems considered in this paper assumes that there are J stages and include at least a QTCB. We introduce the following characters which are considered in this paper.

There are m_j identical parallel machines in stage j and the number m_j may vary from stage to stage. Each stage has at least one machine, and at least one stage must have more than one machine. There are n jobs to be processed and each job has the same routing and must visit all the stages consecutively. Each job i has a positive processing time p_{ij}. A machine can process only one job at a time, and jobs cannot be preempted. There are unlimited buffers between stages. There are at least one QTCB existing in the system. There is no machine breakdown and all information is known in advance. If a job exceeds the queue time constraints, automatically return to the upstream specified process stage waiting re-work, and without taking into consideration the rejection. Bi-criteria are considered in the research, exceeding queue time constraint times and makespan. The objective is to find a schedule that optimize the primary criterion (exceeding queue time constraint times) followed by the optimization of the secondary criterion (makespan) subject to the primary objective value.

3 Proposed Heuristics

Due to the effect of queue time constraints, when a job is selected, it is important to pay attention to the queue time constraints lest the job to be reworked or discarded. Therefore, one needs to make several decisions and carry them out in the stage, and the first decision is whether to release a job from the waiting area to a upstream specified process stage, and secondly, to carry out the dispatching decision made under the queue time constraints at the downstream specified process stages.

The decision of upstream specified process stage is to determine whether the release of the job will collide with the queue time constraints. If it will, then the release of the job is not allowed. Due to the fact that once a job is selected at an upstream specified process stage, we have to make sure that the job won't collide with the queue time constraints at the downstream specified process stages. We develop a trial simulation method (TSM) that selects a job by the machine from the upstream specified process stage buffer, and computes the job whether it passes the queue-time constraint block.

In the downstream specified process stage, if a job stays in the waiting area for too long and exceeds the queue time limit, then it requires rework; therefore, we see the queue time limit as the most important decision criterion. In order to determine if the job exceeds the queue time limit of the various stages in the queue time area, the maximum queue time should be first established. The RQT rule is used to determine the job with the minimum remaining queue-time. The RQT can be expressed as (MQT_{ik}), where MQT_{ik} is the maximum queue time of job i could stay in the queue at stage k.

An extended iterated local search algorithm (EILS) is developed to solve the candidate problems. The workflow of the proposed EILS algorithm is shown as Fig. 2. The figure shows that an approach can be applied to generate a feasible initial solution, and a greedy local search is applied to improve the initial solution obtained. In addition, a shaking operator, Shake(), is constructed to perturb the incumbent solution and to increase diversification of the search in EILS. In this paper, the destruct-construct method (Ruiz and Stützle 2007) is applied to generate a set of input candidate solutions which are different from the incumbent solution. Then, a minimal solution from the input candidate solutions is selected to be the input solution in the next iteration.

4 Computational Experiments and Analysis of Results

In this paper, we developed a deterministic scheduling model to verify the performance of the proposed methods and the assumptions of the model are:

(1) There are 6 stages. The routing information and the related queue time information are shown in Table 1.
(2) The number of machines at each stage is generated from the uniform distribution U(1, 5).
(3) The number of jobs is 30 and 50.

```
Procedure EILS
Generate an initial solution S_0.
Set S_b = S_0. // S_b = the incumbent best solution
Set the value of exceeding queue time constraint times: V_qb = f(S_0)
Set the value of makespan: V_mb = f(S_0)
Repeat
  //apply a greedy local search and initial solution S_0 to obtain an improved solution S_k
  S_k = LS(S_0)
   Set V_qk = the value of exceeding queue time constraint times obtained by LS(S_0)
  Set V_mk = the value of makespan by LS(S_0)
  If V_qk < V_qb Then
        V_qb = V_qk
        S_b = S_k
  ELSE IF V_qk = V_qb Then
        If V_mk < V_mb Then
                V_mb = V_mk
                S_b = S_k
        End If
  End If
    Apply Shake() function to generate a set of input candidate solutions which is dif-
        ferent from the best solution
    S_0 = Select a minimal solution from the generated input candidate solutions
Until termination condition met
End
```

Fig. 2 The procedure of the proposed EILS algorithm

Table 1 Relevant data for job in multiple queue time constraints section

Routing number	Stage	Beginning stage with queue time constraints	Final stage with queue time constraints
N	Stage k		
N + 1	Stage $k + 1$	Stage $k + 1$	Stage $k + 3$
N + 2	Stage $k + 2$		
N + 3	Stage $k + 3$	Stage $k + 3$	Stage $k + 4$
N + 4	Stage $k + 4$		
N + 5	Stage $k + 5$		

(4) It is assumed that the processing time is generated from the uniform distribution U(10, 100) * M_j,where M_j means the number of machines at stage j.
(5) The queue time limit is generated from 100 (maximum processing time) * *q_len* * 5 (loose) and 100 * *q_len* * 4 (tight). *q_len* is the number of the downstream specified process stages within a QTBC.
(6) If a job exceeds the queue time constraints, automatically return to the upstream specified process stage waiting re-work, and without taking into consideration the rejection.

To verify the performance of the algorithms developed in this paper, we conducted computational experiments comparing the results between conventional tabu search and the proposed heuristics. The first-come first-served (FCFS) rule is used in the general and upstream specified process stages. RANDOM rule is applied to generate the input sequence of jobs. Six trials are conducted. In verifying the performance of the proposed methods, we considered the following performance measures: number of exceeding queue time constraint times, average makespan, relative deviation index (RDI), and number of best solutions (NBS). RDI is defined as:

$$RDI = \begin{cases} \frac{S_a - S_b}{S_w - S_b} & \text{if } (S_w - S_b) \neq 0, \\ 0 & \text{otherwise.} \end{cases}$$

S_a is the solution value obtained by method a, and S_b and S_w are, respectively, the best and worst values among the solutions obtained by the methods included in the comparison.

The results are presented in Table 2. In Table 2, we found that the proposed EILS with shaking 20 candidate solutions performs better than other algorithms. Furthermore, if the queue time limit is tight, the average of the RDI produced by EILS with shaking 20 candidate solutions will be 0; and the RDI of EILS with shaking one candidate solution will be 0.0776. This means that EILS with more candidate solutions performs better than EILS with one candidate solution. The proposed EILS with shaking 20 candidate solutions should be considered as the best choice for the candidate problem.

Table 2 Results for the computational experiments

Queuetime	Algorithms	Number of exceeding queue time constraint times	Average makespan	RDI	NBS
Loose	RANDOM	0	4,157	1.0000	0
	Tabu search	0	3,525	0.2528	0
	EILS with shaking one candidate solution	0	3,370	0.0363	3
	EILS with shaking 20 candidate solutions	0	3,346	0.0052	9
Tight	RANDOM	0	4,903	1.0000	0
	Tabu search	0	4,062	0.2388	0
	EILS with shaking one candidate solution	0	3,893	0.0776	0
	EILS with shaking 20 candidate solutions	0	3,810	0.0000	12

5 Conclusions

In this paper we propose a metaheuristic to solve the scheduling problems in a FFL with queue-time constraints. The objective of the scheduling problems is to minimize the primary criterion which is exceeding queue time constraint times and the secondary criterion which is makespan. To evaluate the performance of the proposed heuristic, we designed a lot of test scenarios to simulate practical shop-floor problems. For these candidate problems, we conducted computational experiments to compare the performance of the proposed heuristic. The proposed EILS with shaking 20 candidate solutions performs better than other algorithms. Our future research will consider other system characteristics, which are not included in this paper, such as machine availability and machine eligibility. Furthermore, the idea which generates a set of shaking candidate solutions by destruct-construct method can also be applied to solve other scheduling problems in the following studies.

Acknowledgments This paper was supported in part by the National Science Council, Taiwan, ROC, under the contract NSC 101-2221-E-147 -001.

References

Chen JS, Yang JS (2006) Model formulations for the machine scheduling problem with limited waiting time constraints. J Info Optim Sci 27(1):225–240

Gicquel C, Hege L, Minoux M, Canneyt W (2012) A discrete time exact solution approach for a complex hybrid flow-shop scheduling problem with limited-wait constraints. Comput Oper Res 39:629–636

Hoogeveen JA, Lenstra JK, Veltman B (1996) Preemption scheduling in a two-stage multiprocessor flowshop is NP hard. Eur J Oper Res 89:172–175
Ono A, Kitamura S, Mori K (2006) Risk based capacity planning method for semiconductor fab with queue time constraints. In: Paper presented at the 2006 IEEE international symposium on semiconductor manufacturing
Ruiz R, Stützle T (2007) A simple and effective iterated greedy algorithm for the permutation flowshop scheduling problem. Eur J Oper Res 177(3):2033–2049
Scholl W, Domaschke J (2000) Implementation of modeling and simulation in semiconductor wafer fabrication with time constraints between wet etch and furnace operation. IEEE Trans Semicond Manuf 13(3):273–277
Su LH (2003) A hybrid two-stage flowshop with limited waiting time constraints. Comput Ind Eng 44:409–424
Wang ZB, Xing WX, Bai FS (2005) No-wait flexible flowshop scheduling with no-idle machines. Oper Res Lett 33:609–614

Modeling the Dual-Domain Performance of a Large Infrastructure Project: The Case of Desalination

Vivek Sakhrani, Adnan AlSaati and Olivier de Weck

Abstract The performance of a large infrastructure project depends on not only technical design choices, but also contractual and other economic arrangements. These choices and arrangements interact in the context of uncertainty to result in the project's realized performance. Large infrastructure projects such as desalination plants are thus multi-dimensional design problems in which the dimensions can be broadly categorized into either the technical or institutional domains, creating the need for "dual-domain design". This paper describes the concept of dual-domain design for infrastructure in the context of desalination projects in the Kingdom of Saudi Arabia. It demonstrates the results of an analytical model that relates design choices along some technical and institutional design dimensions to plant economic performance. The analysis shows that plant design can be optimized subject to an uncertainty profile of water demand, and is sensitive to technology type, output capacity and potentially to price/contractual terms embedded in the delivery mode. The lens of dual-domain design thus provides a richer understanding of the relationship between project design and potential performance. Next steps can include multi-attribute assessments of performance (energy, environmental impact, etc.) as well as a greater variation in contractual forms in the institutional domain of design.

V. Sakhrani (✉)
Engineering Systems Division, Massachusetts Institute of Technology, 77 Massachusetts Avenue E40-252, Cambridge, MA 02139, USA
e-mail: sakhrani@mit.edu

A. AlSaati
KACST-MIT Center for Complex Engineering Systems, King Abdulaziz City for Science and Technology, P.O. Box 6086, Riyadh 11442, Kingdom of Saudi Arabia
e-mail: a.alsaati@cces-kacst-mit.org

O. de Weck
Aeronautics and Astronautics and Engineering Systems, Massachusetts Institute of Technology, 77 Massachusetts Avenue E40-261D/33-410, Cambridge, MA 02139, USA
e-mail: deweck@mit.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_155,

Keywords Design · Uncertainty · Projects · Infrastructure · Desalination · Management

1 Introduction

This paper describes the concept of "dual-domain design" for infrastructure (Lessard et al. 2013) and links it to project performance. The performance of a large infrastructure project depends on not only technical design choices, but also contractual and other economic arrangements (Miller and Lessard 2001; Esty 2004; Merrow 2011; Lessard and Miller 2013), which interact in the context of uncertainty to result in the project's realized performance (de Weck et al. 2004; de Neufville and Scholtes 2011). Large infrastructure projects such as desalination plants are thus multi-dimensional dual-domain design problems. Considerations such as technology choice (reverse osmosis, multi-stage flash), output capacity, and load factor in the technical domain may interact with water tariff, delivery contract structure, or availability requirements in the institutional domain (Korn et al. 1999; Wolfs et al. 2002; Voutchkov 2012).

The paper first develops the notion of dual-domain design space, using desalination as a case example and data for the Kingdom of Saudi Arabia (Sect. 2), and then demonstrates how choices along those design dimensions affect performance under water demand uncertainty (Sect. 3). The paper concludes that project managers or sponsors can get a richer understanding of potential project performance through the lens of dual-domain design (Sect. 4).

2 Dual-Domain Attributes of Desalination in Saudi Arabia

To gain an understanding of desalination plant design choices and how they may affect plant performance, projects in the Kingdom of Saudi Arabia were analyzed for differences along design attributes or dimensions. The data source is Global Water Intelligence's (2013) IDA Plant Inventory online data repository. The database contains approximately 2,500 desalination projects in KSA. The final analysis retains about 1,400 plants that were commissioned in or after 1990, after accounting for plant closures, build cancellations, and unknown operating status.

The main independent variables affecting plant design is water demand from different end uses and the desired water quality for those uses. The main design dimensions are plant size or output capacity, desalination technology, and delivery mode. Choices along the design dimensions interact with the independent variables to result in performance, a multi-attribute dependent variable. While the database does not reflect either the aggregate demand (independent variable) or realized plant performance (dependent variable), the dual-domain design space can still be identified based on the plant design choices.

2.1 Technical Design

Plant capacity in KSA varies significantly with technology type, and to some extent, also with primary use for water. Figure 1 shows a comparison of plant capacities (using a log scale for ease of comparison) across main technology categories, and also by primary use within each technology category. The main technology categories are Multi-effect Distillation (MED), Multi-Stage Flash (MSF), Reverse Osmosis (RO), and Other (to denote experimental or less common technologies such as Electro Dialysis). Primary use is classified into Drinking (total dissolved solids, tds of 10– < 1,000 ppm), Industrial (tds < 10 ppm) and Other (which includes agriculture, tds > 1,000 ppm, and military/defense applications). MSF plants supplying drinking water are the largest in the Kingdom with a median plant size of around 13 log cubic meters/day (ln cu.m./d). Reverse Osmosis plants (RO) tend to be much smaller—around 6 ln cu.m./d—with a similar distribution of plant capacities across the drinking, industrial and other categories. MSF plants are commonly large capacity plants and more conducive to meeting drinking water and other mid-to-low water quality needs, whereas RO plants may be more versatile in meeting different types of end use, because of flexibility in sizing, water quality and modularity (Voutchkov 2012).

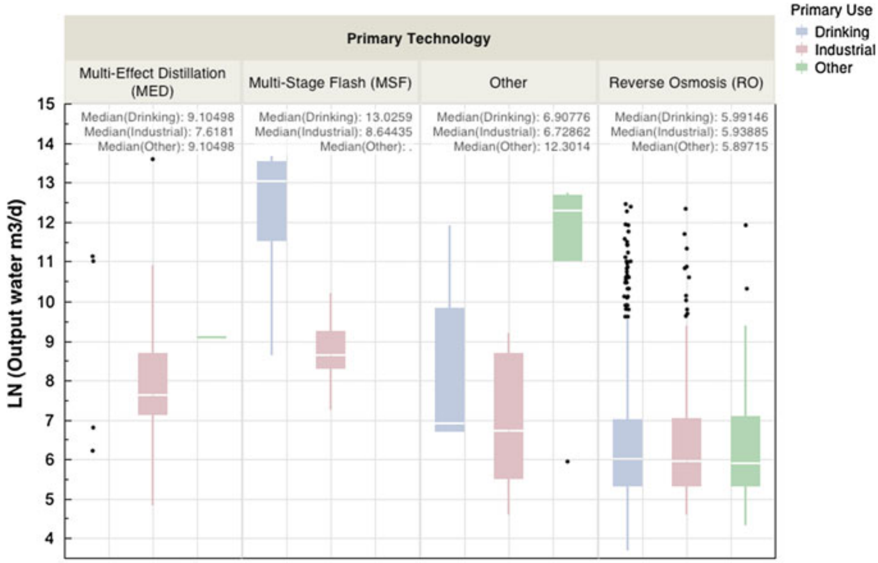


Fig. 1 Desalination plant capacity (log scale) in KSA by primary technology and use

2.2 Institutional Design

There are many 'delivery modes'—institutional-organizational approaches to delivering large projects such as desalination plants (Hallmans et al. 1999; Grimsey and Lewis 2007). The modes can be broadly classified into Asset Procurement (or Engineering-Procurement-Construction), Independent Water Producers (IWPs), or Service Provision (a hybrid category of water delivery contracts).

Plant capacity in KSA varies by delivery mode, and also by primary use. Figure 2 shows a comparison of plant capacities (using a log scale for ease of comparison) across delivery modes, and also by primary use within delivery mode. Plant capacities are much larger on average for Independent/Private plants. This arrangement is better suited to dedicated operations of industrial facilities, where a facility such as a refinery may contract with an Independent Water Producer. Service provision arrangements for drinking water also tend to make use of large plants, in comparison with the asset procurement (EPC) mode. These observations reflect potential economies of scale when water is delivered under independent or contractual arrangements (Hart 1996; Joskow 1988). While many technologies have been deployed under the EPC mode, large IWP plants have used the MED technology, whereas smaller service provision plants have used primarily RO technologies for supplying drinking water (Fig. 2).

The analysis in this section shows that there are many combinations of plant output capacity, technology types, and delivery modes for meeting different water end use needs. The next section describes an uncertainty-based analysis for how

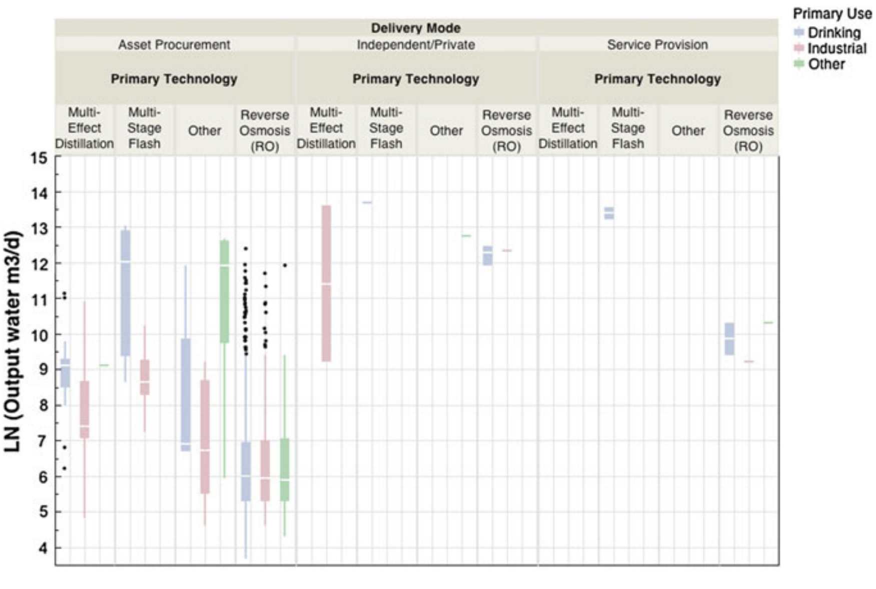


Fig. 2 Desalination plant capacity (log scale) in KSA by delivery mode, technology and use

project architects can evaluate project performance given different design choices in the fact of uncertain and volatile water demand.

3 Modeling Performance

Desalination project performance is evaluated using a stochastic simulation model in which uncertain water demand is the main independent variable, and Net Present Value is the main performance or dependent outcome variable. The analysis in this paper is limited to these variables, but other independent and dependent variables can easily be added.

3.1 Simulating Uncertain Water Demand

The Monte Carlo simulation generates 1,000 possible water demand scenarios, with a demand growth rate (drift) of 2 % per year and variability in growth rate (volatility) of 5 % per year, using Eq. (1) for water demand so that

$$D(t_i) = D(t_0) * e^{R(t_0,t_i)} \tag{1}$$

$$\text{where } R(t_0, t_n) = \sum_i R(t_i), \tag{2}$$

$$\text{and } R(t_i) = m + v * \tilde{\varepsilon}, \quad \text{where} \tag{3}$$

$R(t)$ Is the instantaneous return in demand or growth rate per time period (%/year);
m Is the drift, or expected growth rate per time period (%/year);
v Is the volatility, or standard deviation of growth rate per time period (%/year);
ε Is a standard normal random variable, $\sim$ N(0,1);
D(t) Is the instantaneous water demand (million cu. m., MCM/year).

3.2 Simulating Plant Build and Operations

The design space for the desalination plant consists of technology type, output capacity and delivery mode.

Table 1 lists the possible values for the design vector and other key assumptions for the model. The design vector [Reverse Osmosis, 50 MCM/year, Asset Procurement/Fixed Tariff] fully specifies a plant design. The model iteratively tests 1,089 such plant designs.

3.3 Assessing Plant Performance

The main performance variable of is the Net Present Value (*NPV*) of plant cash flows. *NPV* is a useful indicator because it gives a much better idea of plant project value than capital build cost by including operating expenses, and adjusting for the time value of money by explicitly considering the timing of cash flows. The standard *NPV* formulation in Eq. (4) is

$$NPV = \frac{1}{N}\sum_{i}^{n}\frac{CF_t}{(1+r)^t} \tag{4}$$

$$\text{where } CF_t = B_t - (op_t + I_t) \text{ and} \tag{5}$$

NPV	Is the Net Present Value (USD millions);
CF_t	Is the cash flow in a given year (USD millions);
r	Is the discount rate (%/year);
n	Is the plant life, or horizon of the study (years)
B_t	Is the revenue in that year (USD millions);
op_t	Is the plant operating expense in that year;
I_t	Is the capital investment in that year;
N	Is the number of water demand scenarios.

The model first calculates the present value of cash flows for any plant design for each of the $N = 1{,}000$ water demand scenarios, then calculates *NPV* as the expected present value, and iterates over the 1089 possible designs. The discount rate for the analysis in this paper is 7.5 %/year. This approach gives both a

Table 1 Design vector choices and key assumptions

	Multi-stage flash (MSF)	Multi-effect distillation (MED)	Reverse osmosis (RO)
Capital cost ($/cu.m./day)	1,750	1,275	1,200
Operating cost ($/cu.m.)	0.45	0.50	0.55
Electricity consumption (kWh/cu.m.)	–	1.25	4.2
Plant capacity range (MCM/year)	1.5–50		
Delivery mode	Asset procurement/fixed tariff		
Water tariff ($/cu.m)	1		

probability distribution of present values for the plant and a single *NPV* number that is easier to compare across designs.

3.4 Model Results

Plant capacity for each technology type can be selected to maximize *NPV*, in effect truncating the downside (low or negative *NPV* scenarios) from the plant's distribution of value. Figure 3 (left) shows the plant's expected project value as a function of capacity for each technology type. The delivery mode is held constant as 'Asset Procurement/Fixed Tariff'. NPV first increases as the plant is able to meet an increasing share of demand with increased capacity, but then decreases as capacity is underutilized for large plant capacities. Subject to the assumptions, each technology peaks in roughly the same region (~29 MCM/year); however one technology may dominate the others in the "sub-optimal" capacity regions. Figure 3 (right) shows how selecting the optimal capacity (~29 MCM/year, thick lines) minimizes the chance of negative plant value, whereas oversizing (for ex, 45 MCM/year, faint lines) leaves 25–45 % chance across technology types that the plant value is negative.

Similar analyses can be conducted for the other delivery modes (not shown here), demonstrating that not only plant value (*NPV*), but also shares of the value accruing to the water customer (typically public sector) and plant owner or operator (typically private) are sensitive to the contract structure in place under different delivery modes (see Sakhrani and AlMisnad 2013).

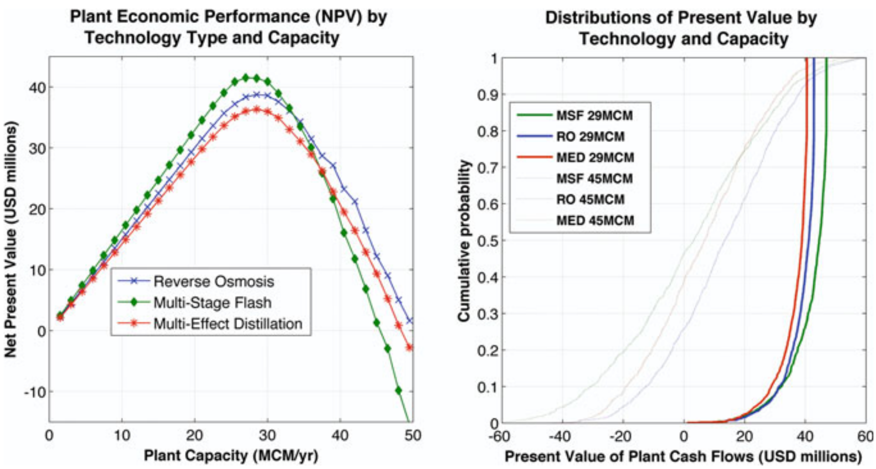


Fig. 3 Plant economic performance (net present value—USD millions), *left*, and distribution of present value (USD millions), *right*, by technology type and plant capacity (MCM)

4 Conclusions

This paper has described the concept of dual-domain design for infrastructure in the context of desalination projects in the Kingdom of Saudi Arabia. It has also demonstrated the results of an analytical model that relates design choices along some technical and institutional design dimensions to plant economic performance. The analysis shows that plant design can be optimized subject to an uncertainty profile of water demand, and is sensitive to technology type, output capacity and potentially to price/contractual terms embedded in the delivery mode. The lens of dual-domain design thus provides a richer understanding of the relationship between project design and potential performance. Next steps can include multi-attribute assessments of performance (energy, environmental impact, etc.) as well as a greater variation in contractual forms in the institutional domain of design.

Acknowledgments The authors are grateful for support from the Center for Complex Engineering Systems at KACST and MIT, and from the Sustainable Infrastructure Planning Systems project.

References

de Neufville R, Scholtes S (2011) Flexibility in engineering design. MIT Press, Cambridge
de Weck O, de Neufville R, Chaize M (2004) Staged deployment of communications satellite constellations in low earth orbit. J Aero Comp Info and Comm 1(3):119–136
Esty B (2004) Why study large projects? An introduction to research on project finance. Eur Fin Management 10(2):213–224
Global Water Intelligence (2013) IDA plant inventory. http://www.DesalData.com. Accessed 16 May 2013
Grimsey D, Lewis M (2007) Public private partnerships: the worldwide revolution in infrastructure provision and project finance. Edward Elgar, Cheltenham
Hallmans B, Stenberg C (1999) Introduction to BOOT. Desalination 123(2):109–114
Hart O (1996) Firms, contracts, and financial structure. Clarendon, Oxford
Joskow P (1988) Asset specificity and the structure of vertical relationships: empirical evidence. J Law Econ Org 4(1):95
Korn A, Bisanz M, Ludwig H (1999) Privatization of dual-purpose seawater desalination and power plants—structures, procedures and prospects for the future. Desalination 125(1):209–212
Lessard D, Miller R (2013) The shaping of large engineering projects. In: Priemus H (ed) International handbook on mega projects. Edward Elgar, Cheltenham (Forthcoming)
Lessard D, Sakhrani V, Miller R (2013) House of project complexity: understanding complexity in large infrastructure projects. In: Paper to be presented at the engineering project organizations conference, Winter Park, CO, USA, 9–11 July 2013
Merrow E (2011) Industrial megaprojects: concepts, strategies, and practices for success. Wiley, Hoboken
Miller R, Lessard D (2001) The strategic management of large engineering projects: shaping institutions, risks, and governance. MIT Press, Cambridge

Sakhrani V, AlMisnad A (2013) Evaluating contractual implications in the dual-domain design of a large infrastructure project. In: Paper submitted to the complex systems design and management conference, Paris, France, 4–6 December 2013

Voutchkov N (2012) Desalination engineering: planning and design. McGraw-Hill Professional, New York

Wolfs M, Woodroffe S (2002) Structuring and financing international BOO/BOT desalination projects. Desalination 142(2):101–106

Flexibility in Natural Resource Recovery Systems: A Practical Approach to the "Tragedy of the Commons"

S. B. von Helfenstein

Abstract "As overuse of resources reduces carrying capacity, ruin is inevitable" (Hardin 1998). In his controversial paper of 1968, Garrett Hardin introduced the concept of the *tragedy of the commons* in which the freedom of individuals to maximize their personal utility of common resources/goods (water, air, land, and so forth) leads to the destruction of those resources. While this problem is initially one of economic, socio-political, and ecological systems, in the end, it also an engineering problem since many current and future solutions depend on engineering systems design and implementation. Focusing on a single area of concern—construction and demolition (C&D) waste—I examine current U.S. practices in waste management and resource recovery. I then present a case study demonstrating the real-world use of flexibility in C&D natural resource recovery systems and explore its practical implications for a proposed paradigm shift that could resolve this one aspect of the *tragedy of the commons*.

Keywords Flexibility · Natural resource recovery systems · Construction and demolition waste

1 Introduction

The December 1968 issue of *Science* published a controversial paper by Garrett Hardin titled "The Tragedy of the Commons." Although the author was addressing the problem of human over-population, the phrase he coined, *the tragedy of the commons*, has since been used to describe a dilemma in which the

S. B. von Helfenstein (✉)
Value Analytics and Design, One Broadway—14th Floor, Cambridge, MA 02142, USA
e-mail: svonhelf@valueanalyticsanddesign.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_156,

freedom of individuals to maximize their personal utility of common resources/goods (water, air, land, and so forth) leads to the destruction of those resources.

The locus of the *tragedy of the commons* initially resides in economic, socio-political, and ecological systems. But, in the end, it is also an engineering systems problem since many current and future solutions depend on engineering systems design and implementation. The *tragedy* takes its most poignant forms in the large-scale use/abuse of natural resource inputs and the overwhelming accumulation of waste outputs accompanying mass urbanization. Thus, it also becomes a critical consideration for new city design.

This paper is dedicated to the conceptual exploration of a single area of concern—construction and demolition (C&D) waste. It examines current waste management practice and proposes the use of flexibility to turn ineffective waste management systems into effective systems for resource recovery. A real-world case study is presented that demonstrates the attractiveness of flexibility in C&D resource recovery systems and the potential it offers to resolve this one major aspect of the *tragedy of the commons*.

2 Nature and Magnitude of the Challenge

As with other resource waste and recovery problems, the nature and magnitude of C&D waste involves both the use of non-renewable resource inputs and the generation of waste material outputs for which there is no current or future use. Consider rock aggregates as an example: "Aggregates play a major role in the construction industry as they are the major component of roadways, bridges, airport runways, concrete buildings, drainage systems, and many other constructed facilities. Because aggregates are the major component of much of the nation's infrastructure, their use is engineered to provide the necessary performance in place. For instance, concrete is approximately 75 % aggregate…

"In the past, when concrete structures reached the end of their service life or needed to be repaired or replaced, the resulting materials were considered waste and were disposed of in embankments and landfills. The costs of transporting these materials to waste areas were considered a necessary part of the replacement work. Likewise, the costs associated with the mining of new aggregates, the production of the replacement concrete, and the transportation and placement at the project were also considered a necessary part of the work" (CMRA 2012).

This is the description of an engineering, ecological, and economic input–output problem on a very large scale.

2.1 Urbanization as a Driver of C&D Waste

It is fair to say that the majority of C&D inputs and waste outputs are directly or indirectly generated to support urban growth and development.

While the definition of an *urban area* differs from country to country, the blistering pace of urbanization over the last 60 years and the expected pace of continued urbanization in the future is uncontested. Most sources state that over half of the world's population (e.g. 3 billion) now lives in cities, with at least 500 cities with populations of over 1 million. The forecast for 1015 is 50 megacities, 23 of which will boast a population over 10 million. CEIC Data Company Ltd, the U.N. Population Division, and *The Economist* forecast that by 2025, urbanization will be approximately 90 % in Western Europe, the U.S., and Brazil, 60 % in China, 50 % in Southeast Asia, and 38 % in India.

By way of contrast, in 1950, less than 30 % of the world's population lived in cities. Two hundred years ago, Peking was the only city with a population as large as 1 million.

Demographic shifts of the scale suggested above affect not only established cities. They also affect the surrounding suburbs/exurbs, rural areas, and the design of new cities in significant ways and for all related systems. Current economic, socio-political, ecological, and engineering systems are incapable of addressing such resource challenges. Instead urban systems around the globe are in gridlock.

2.2 Size of C&D Resource Use and Waste Streams

Further understanding of the magnitude of C&D resource use and waste streams generated by urbanized societies can be gained from the following—quite dated—U.S. statistics. It is notable that there appear to be no current updates indicating improvement in the status of these issues.

Landfill: In 1999, Staten Island, New York, contained what was the world's largest landfill. It received 26 million pounds of commercial and residential waste per day. In 1999, it contained 2.9 billion cubic feet (100 million tons) of trash. This was only 0.018 % of all the waste generated in the U.S. on a daily basis. Total annual waste in the U.S., excluding wastewater, exceeded 50 trillion pounds per year. Wastewater added another 200 trillion pounds. Less than 2 % of the total waste stream was being recycled (Hawken et al. 1999).

Construction and demolition waste: In the U.S., 40 % of all material flows were construction materials. 15–40 % of U.S. landfill space is taken by waste from these flows (Hawken et al. 1999). In 2006, un-recycled construction and demolition (C&D) waste in the U.S. was estimated at 325 million tons per year (Bouley 2006).

Roads: The U.S. has 3.9 million miles of public roads and an unknown number of miles of private roads. "The pervasiveness of roads and their cumulative effect on the environment are now of increasing concern…" (Deen 2003).

3 Current U.S. Waste Management and Resource Recovery Systems

3.1 Waste Management

Waste management is performed throughout the U.S. on organic and inorganic waste streams from municipalities, industry, healthcare, agriculture, and other sources. Current waste management systems are massive in scale, long-lived, capital intensive, and costly to run and replace. They are also centralized, stand-alone and single purpose, and toxic (even with best environmental efforts). With a far-reaching footprint, they are over-burdened with current use but lacking in scalability, and tightly bound to layers of conflicting public policy and funding—making them unresponsive to both planned change and unforeseen events. With regards to C&D waste, standard practice is to incinerate or landfill it all.

These are highly inflexible systems and they create further inflexibility in the economic, socio-political, and ecological systems that support them. Their entire function contributes to the *tragedy of the commons* because: (1) they utilize large amounts of common resources to operate; (2) they are themselves considered common goods by the populations they serve, and are not stewarded carefully; and (3) they produce further waste streams that are disposed of in the commons.

3.2 Resource Recovery

In the U.S., resource recovery is still a relatively narrowly-applied approach to waste management. Wikipedia defines *resource recovery* as "the selective extraction of disposed materials for a specific next use, such as recycling, composting or energy generation. The aim of resource recovery is to extract the maximum practical benefits from products, delay the consumption of virgin natural resources, and to generate the minimum amount of waste."

Further, "Resource recovery is the practice of reclaiming materials that were previously thought of as unusable. It is not managing waste, which is the standard for most garbage companies. Traditional waste companies collect and move wasted materials to large-scale, single-use sites such as landfills or incinerators. Unlike the management of waste, resource recovery recognizes that there is still value in those materials. The intention of resource recovery is always to make the best and highest use of all materials, and landfill only those materials for which there is no current use" (http://recology.com/).

At this time, most of the efforts of resource recovery practitioners are focused in a few areas: recycling of residential waste, wastewater treatment, and one or two others. Resource recovery systems are fragmented, heavily dependent on ever-changing, multi-level government regulation and funding, and conducted in industry/waste stream silos, much like their traditional waste management system peers. Unfortunately, they provide only a temporary relief for the *tragedy of the commons*, since their outputs end up back in traditional waste management systems, generally in less recoverable condition than they were the first time around.

3.3 State of the System

Environmental protection and sustainability have been a major topic of public discourse in the U.S. since the 1960s. The effects of waste streams on urban areas, rural land, flora and fauna, and humans are well and publicly documented. Decades of environmentalists have protested and proposed solutions. The four *eco-efficient* strategies—*reduce, reuse, recycle, and regulate* (McDonough and Braungart 2002)—have become mantras for green initiatives. Many eco-efficient solutions have been applied by government, commerce, and academia, codified in thousands of regulations, and become common practice.

"**But ultimately a regulation is a signal of design failure.** In fact, it is what we call a *license to harm*: a permit issued by a government to an industry so that it may dispense sickness, destruction, and death at an "acceptable" rate… [G]ood design can require no regulation at all…." (McDonough and Braungart 2002).

This paper proposes a paradigm shift involving system reconfiguration that will correct current design failure through incorporating flexibility.

4 Flexibility in Natural Resource Recovery Systems

To gain an appreciation of the nature of the paradigm shift represented by C&D Natural Resource Recovery Systems (NRRS), we must first define flexibility and develop a general description of a proposed flexible NRRS. The taxonomy used for system description is suggested by (Baldwin et al. 2011). This conceptual framework is then applied to a real-world C&D NRRS, built and operating in Maine, United States.

4.1 Flexibility

Flexibility is a term that describes a system's capacity for dealing dynamically with uncertainty. Flexible system design builds components into the system that provide for system change capacity, should it be desirable in the future. Not everything that might be needed is built into the system from the outset.

"The right kind of flexibility in design gives… three kinds of advantages. It can: (1) greatly increase the expected value of the project or products; (2) enable the system manager to control the risks, reducing downside exposure while increasing upside opportunities, thus making it possible for developers to shape the risk profile. This not only gives them greater confidence in the investment but may also reduce their risk premium and further increase value; and (3) often significantly reduce first costs of a project—a counterintuitive result due to the fact that the flexibility to expand means that many capital costs can easily be deferred until prospective needs can be confirmed" (de Neufville and Scholtes 2011).

4.2 General Description of the Proposed Flexible NRRS

In direct contrast to the rigid, massive, costly waste management system configurations currently in use, the proposed flexible NRRS is:

Local, exhibiting an intimate city-rural linkage: The proposed NRRS may be a city-based system. But, it receives from and contributes to its rural context rather than viewing that context as a dumping ground for its own waste. As a local system, it responds to local needs, "fits into the character of the land and its topography, soils, climate" and utilizes "locally available materials, regional construction techniques,… labor-saving functionality, and minimal cost to build, operate, and maintain" (Thorbeck 2012).

Small scale, decentralized, modular, and scalable: Unlike traditional systems, the proposed NRRS is built on a smaller scale and can be modular. It is a decentralized system, allowing it to be flexible and scalable—even mobile—to meet local needs and growth. Its scale and decentralization also allow it to change and innovate at a low cost, or to shut down at modest cost without leaving behind massive system remains.

Adaptive, amenable to innovation: Adaptive behavior is "the ability to alter one's own functions or goals… to adjust to environmental changes without significant changes to the system configuration" (Baldwin et al. 2011). The proposed NRRS's flexibility allows it to adjust and adapt to change with far less stress and disturbance to its context than its current peers. As the environment or technologies change, the system configuration can continue to absorb and incorporate change gracefully.

Small footprint: Since system inputs are large in scale, the proposed NRRS manages its technological and ecological footprint with care, reducing it wherever and however possible.

Closed loop-circular flow "waste is food" philosophy: "Our move toward sustainable cities will require an important shift in thinking of cities not as linear resource-extracting machines but as complex metabolic systems with flows and cycles, where, ideally, the things that have been traditionally viewed as negative outputs (e.g., solid waste, wastewater) are re-envisioned as productive inputs to satisfy other urban needs, including food, energy, and clean water" (Beatley 2011).

Simple, reasonably priced and cost-effective: Driven by private industry cost-benefit concerns, proposed NRRS components are as simple, accessible, and cost-effective as possible. Where components are initially more complex and costly, their flexible uses create operating efficiencies and short payback periods.

Self-organizing: Organizational development and management theory, the theory of free market systems, and many other disciplines attest to the success of self-organization in bringing about system creation, growth and change. Rather than being tightly overseen by government, the proposed NRRS is designed to be self-organized and self-regulated.

4.3 Case Example: CPRC Group, Scarborough, Maine

CPRC Group (Commercial Paving and Recycling http://www.cpcrs.com/) was founded in 1945 as a traditional asphalt paving company. In 1990, its original owner discovered that his cold-mix equipment, used to make asphalt, could turn contaminated soil into fully usable construction fill. Further experimentation led to uses of the same machinery for other C&D waste remanufacturing. Since 2004, current owners, John Adelman and Jim Hiltner, have turned CPRC into a leader in *conversion technology* and a classic example of flexibility in engineering design.

The company focuses on *making the turn*—i.e., taking in C&D (and other) waste materials and converting them into useful, saleable construction, landscaping, and agricultural product. One of its four divisions operates and manages the City of Portland's Riverside Recycling Facility. The others receive and convert: asphalt pavement, concrete, bricks, rock, ledge, and miscellaneous aggregate-based material; residential asphalt shingles of any size, shape, and color; asbestos-tested commercial asphalt roofing material; catch basin and sand-blast grit; stumps, branches, wooden pallets, demo woods, clean wood, leaves, brush, grass clippings; gypsum board that is free of paint, wallpaper, and contamination by wood, cans, paper or other debris; glass and porcelain materials (except containers that once held hazardous products, automotive headlights, and residential incandescent light bulbs); uncontaminated inert materials such as unscreened loam; soil containing heating oil, motor oil, and waste oil; and institutional food waste.

Once waste materials are sorted, CPRC remanufactures reusable components into an array of conversion products, such as: C&R gravel that is crushed, screened and blended from pavement, concrete, and rock materials, asphalt shingles, glass, and inert materials in various proportions, and then used to build roads, parking lots, bridge approach ramps, embankments, shoulders, construction project sites, and other heavy infrastructure projects; erosion control materials made from converted green waste; licensed inert fill dirt (made from converted petroleum-containing soil) that is highly compatible and uniform and is both structurally and environmentally sound; screened loam made from converted non-contaminated soils; biomass fuel made from demolition wood and clean wood; bark mulch for landscaping purposes; organic compost for agricultural uses.

Operations are designed to be highly flexible. Land, buildings, and technologies are multi-use. Employees are trained and incentivized to implement lean manufacturing methods. Customers are given valuable options that make using CPRC desirable. For instance, waste inputs can be transported to CPRC facilities by the customer, picked up by CPRC, or converted on-site by CPRC's mobile equipment. Remanufactured waste outputs can be picked up at CPRC facilities or delivered to the customer. In addition, outputs can be custom mixed, based on customer specifications.

CPRC is an excellent illustration of the proposed flexible NRRS system structure. Based in a rural suburb of Portland, Maine, it is local, but exhibits an intimate city-rural linkage through its use, conservation, and improvement of both urban and rural land and resources. Because CPRC is small scale, decentralized, modular, and scalable, it is also far more adaptive and amenable to innovation than larger traditional waste management systems.

While C&D remanufacturing facilities involve sizeable land allotments and large-scale technologies, CPRC manages its technological and ecological footprint with care. The company owns its land and intend to keep it pristine for a range of future uses. And, company inputs and outputs form a closed-loop circular flow in which waste inputs become "food," i.e. productive outputs to satisfy other needs.

Is the CPRC system simple, reasonably priced and cost-effective? It is, for the customer. In addition, although C&D conversion technologies are becoming increasingly sophisticated and costly, CPRC's use of these technologies demonstrates that older, simpler machinery can be re-engineered and used successfully where necessary. Even if new technologies must be purchased, they are long-lived, mobile, and can be redeployed for multiple uses with a minimum of retrofitting. This makes ongoing operations cost effective and efficient.

As for the attribute of self-organization, while all environmental activities in the U.S. are tightly enforced by regulation, CPRC and the industry of which it is a part exhibit a high degree of self-organization within the proscribed limits. Both industry and other literatures suggest that the complexity and arbitrariness of the regulatory environment and its slowness in accepting C&D conversion products currently present a hindrance to further beneficial contributions by this industry. But, hopes are high for a regulatory paradigm shift to match and support other system shifts.

5 System Valuation

Genichi Taguchi insisted that manufacturing waste created a significant cost to society. The same could be said about natural resource use/abuse and the *tragedy of the commons*. Thus, the economic, socio-political, ecological and engineering problems discussed in this paper are also problems of value. How do we value the commons? How do we value the systems that might contribute to its recovery and restoration?

Although the scope of this paper does not allow for a discussion of such valuation issues, valuation "plays an important role in any engineering field, primarily as an aid in making design decisions" (Kangas 2004). Therefore, we mention two areas in which progress has been made: (1) Ecological economics, a discipline that seeks "to reinvent economics with connections to ecology" (Kangas 2004); and (2) the work of de Neufville and Scholtes (2011) that suggests a portfolio of screening and valuation techniques allowing engineering systems designers to directly address uncertainty and flexibility.

There is more work to be done but these steps offer a way forward.

6 Extended Applications of Flexible C&D NRRS

While there are any number of potential applications of flexible C&D NRRS, two offer immediately appealing value propositions: landscape architecture/ecological engineering; and new city design and construction.

Landscape architecture and ecological engineering both concern themselves with natural resource use and restoration as well as innovation in urban fabric, infrastructure, and material technologies. The small-sample literature search performed for this paper indicates that there is little to no current use of remanufactured C&D waste in landscape architecture or ecological engineering projects. Yet, C&D conversion products seem like ideal candidates for such projects.

New city design and construction might also benefit from the use of C&D conversion products. Imagine bringing conversion equipment on site and using both the C&D waste from site preparation and the C&D waste generated during ongoing new construction to build out the baseline infrastructure of the city—a city that builds itself with greatly reduced utilization of virgin materials.

7 Conclusions

The conclusions to be drawn seem simple. In a world in which financial resources are becoming increasingly limited but natural resource use/abuse and waste increasingly prevalent and threatening, we can continue to design and build huge, costly, inflexible systems that exacerbate the very problems they purport to address and then impose these systems on stakeholders by regulatory diktat and tax schemes. Or, we can begin to explore and adopt flexible, smaller-scale, affordable systems that transform problems into benefits and self-organize through ingenious local capabilities and initiatives. If we choose the latter, we can look to C&D conversion technologies and the flexible NRRS they embody to show us a practical approach to reversing the *tragedy of the commons.*

References

Baldwin WC, Felder WN, Sauser BJ (2011) Taxonomy of increasingly complex systems. Int J Ind Sys Eng 9(3):298–316
Beatley T (2011) Biophilic cities: integrating nature into urban design and planning. Island Press, Washington
Bouley J (2006) Tearing up the road. Mainebiz 12(9)
Construction Materials Recycling Association (2012) Recycled concrete aggregate. White paper
de Neufville R, Scholtes S (2011) Flexibility in engineering design. The MIT Press, Cambridge
Deen TB (ed) (2003) Road Ecology: Science and Solutions. Island Press, Washington
Hardin G (1998) Extensions of the tragedy of the commons. Science 280(5364):682
Hawken P, Lovins A, Lovins LH (1999) Natural capitalism. Little, Brown and Company, New York
Kangas PC (2004) Ecological engineering: principles and practice. CRC Press LLC, London
McDonough W, Braungart M (2002) Cradle to Cradle. North Point Press, a division of Farrar, Strauss, and Giroux, New York
Thorbeck D (2012) Rural design: a new discipline. Routledge, New York

The Workload Assessment and Learning Effective Associated with Truck Driving Training Courses

Yuh-Chuan Shih, I-Sheng Sun and Chia-Fen Chi

Abstract Present study examined the workload and applied the theory of learning curve to evaluate the learning effective for training of driving courses. The trainees' workloads were assessed by the NASA-TLX twice, one on the 10th and the other on the last (28th) practice. Forty healthy male solders with an average age 23.2 years participated in this study, and a HINO 10.5T trunk was used for training in a standard training field. Five driving tasks evaluated were "going up and down a hill (up/down hill)", "three-point turn on a narrow road (3-point turn)", "moving forward and backward on an S curve (S-curve)", "reversing the car into a garage (reversing-into-garage)", and "parallel parking". For learning cures, the values of among 40 participants were averaged within each practice for each task, and the overall Wright's learning curves model for each driving task was fitted. Results showed all R^2s were significantly high with a range of 0.88–0.97. This implied that these learning curves of trunk driving tasks were able to be fitted by power function very well. Specifically, the learning rate was 0.9162 for up/down hill, 0.8912 for 3-point turn, 0.8802 for parallel parking, 0.8736 for reversing-into-garage, and 0.8698 for S-curve. For workload, the results indicated that the second measure (on 28th practice) was lower than the first measure (on 10th practice) for all evaluated tasks. This implied that practice was also able to reduce the overall workloads. Additionally for the task effect, S-curve task had the highest workload, 3-point-turn task had the lightest workload, and the rest three were not significantly different from each other. After practices, there were more

Y.-C. Shih (✉)
Department of Logistics Management, National Defense University, Taipei, Taiwan
e-mail: river.amy@msa.hinet.net

I.-S. Sun · C.-F. Chi
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: s510678@yahoo.com.tw

C.-F. Chi
e-mail: chris@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_157,

reduction in workload for the tasks of S-curve, reversing-into-garage, and parallel parking.

Keywords Driving training · Learning curves · Workload · Trunk

1 Introduction

Trunks are one of the important and effective transporting tools for logistics. Anyone who wants to be a qualified trunk driver in Taiwan should first possess the license of small passenger vehicle for at least six months and, second, pass both written and driving tests in an examining agency. These requirements are the same for the military, in which solders possessing the license of small passenger vehicle were recruited and practiced in a training center for a period of 4 weeks. In these 4 weeks, they should accept an intensive training and have a formal driving examination on the last day. Five difficult and important driving tasks from the driving tests were evaluated, namely up/down hill, reversing into garage, parallel parking, 3-point turn, and moving forward and backward on a S-curve.

For decades the learning curves have been a valuable measurement tools to predict and monitor the performance of individuals, a group of individuals, and organization. They were widely applied in various sectors, such as manufacturing, healthcare, education, construction, and so on.

The most popular of all available models is one proposed by Wright in 1936. It is a power function of the number of practice, as shown in Eq. (1). Its popularity is attributed to its simple mathematics and to its ability to fit a wide range of data fairly well.

$$T_n = T_1 n^b \tag{1}$$

Where T_n is the time for the nth practice, and T_1 is the theoretical time to finish the first practice. n is the number of practice and b is the learning constant between 0 and -1. In addition, $\varphi = 2^b$ is called the learning rate between 0.5 and 1, and the smaller the learning rate, faster the learning.

Learning can be classified into two parts, cognitive learning and motor learning. The learning rate for purely cognitive learning task has been shown to be around 0.7, and around 0.9 for purely motor learning (Dar-el et al. 1995). Noticeably, most tasks usually involve both cognitive and motor learning. Konz and Johnson (2000) indicated that the learning rate was 0.74 for the machining and fitting of small castings, 0.83 for the assembly of a radio tube, and 0.89 for operating the punch press. Reid and Mirka (2007) used the learning curve to evaluate a patient lift-assist device and revealed that the learning rate was 0.83.

As to the applications of learning curves on driving simulator, authors concerned how to designed a practice scenario for adaptation for pedals (Sahami et al. 2009) and steering (Sahami and Sayed, 2010). Both revealed that a power function was suitable to model the adaptation for drivers to learn from the simulation system. Recently, Sahami and Sayed (2013) demonstrated that in driving simulator the adaptation time and leaning rate between male and female was not significantly different. More importantly, adaptation to a driving simulator was task-independent.

Driving training is, of course, to improve the driving skills for the novice drivers, even past studies used the learning curves to assess the adaptation time while a driving simulator was used, but in real driving tasks the information about the application the learning curves on the trainees during training is still deficient. This knowledge is helpful to how to allocation the training resources; for example, how many hours are needed for different training tasks.

2 Methods

2.1 Participants

Forty healthy male solders with an average age 23.2 years (s.d. = 3.4, range: 19–35 years.) participated in this study. All had valid license driving license of light vehicle for an average 30.5 months (s.d. = 23.7, range: 6–96 months).

2.2 Trunk and Driving Tasks

The trunk used for training was a HINO 10.5T trunk (KUOZUI MOTORS, LTD.), which was shown in Fig. 1 and its length, width, height, and wheelbase was 822.5, 217.5, 247.5, and 482 cm, respectively. Five driving tasks evaluated were "going up and down a hill" (denoted by up/down hill), "three-point turn on a narrow road" (denoted by 3-point-turn task), "moving forward and backward on an S curve" (denoted by S-curve task), "reversing the car into a garage" (denoted by reversing-into-garage task), and "parallel parking" (denoted by parallel-parking task). They are illustrated in Fig. 2 and all driving tasks were conducted in a standard training field.

2.3 Experimental Procedures and Data Acquisition

The training period was four weeks. During the first week the trainers instructed the basic knowledge about the trunk, and all trainees were allowed to familiarize with all training procedures and environment. The rest three weeks were for

Fig. 1 The HINO 10.5T trunk used in this study

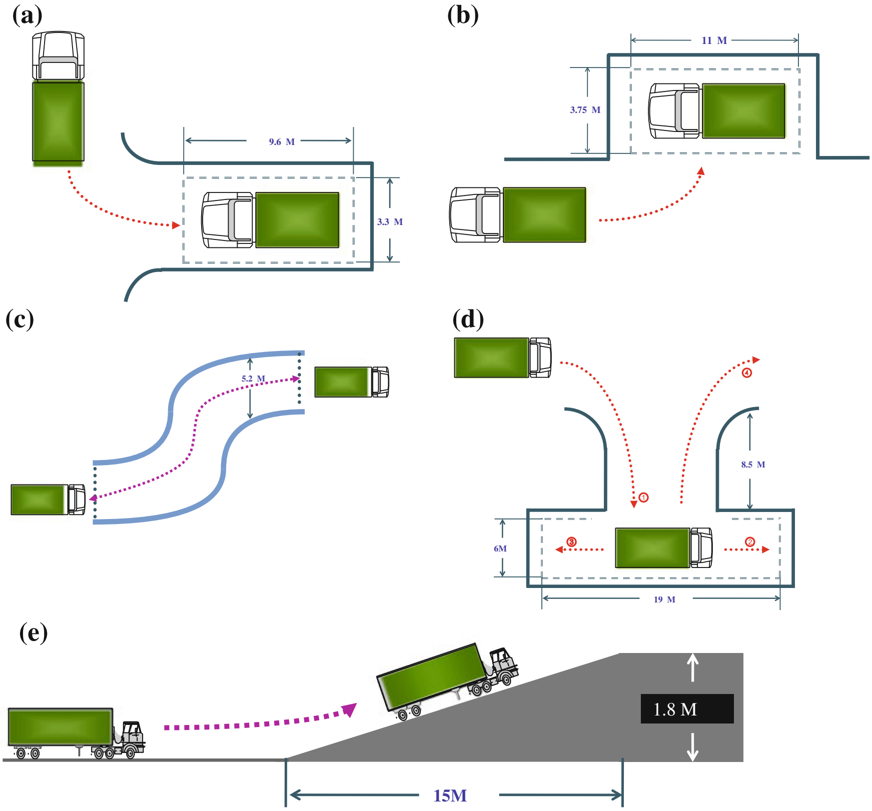


Fig. 2 The graphical illustration for five driving tasks. **a** Reversing-into garage. **b** Parallel parking. **c** S-curve. **d** 3-point turn **e** up/down hill

practice, five days per week, and the last day of the fourth week was for license examination. Each day participant had two times to practice, namely morning (09–12 o'clock) and afternoon (14–17 o'clock). Therefore, there were a total of 28 times for trainees to practice.

The allocation of driving field is a cycle with tasks in sequence of parallel parking, S-curve, 3-point turn, and reversing-into-garage. For each practice trainees should randomly start from one of these four tasks, and then completed them following the sequence. On the other hand, the site of up/down hill was located in the other side of training field, so it was the last to conduct for every practice. The finishing time associated with each practice was recoded. In addition, the NASA-TXL was used to assess the workload at the 10th practice (on the end of the second week) and 28th practice (the last one).

2.4 Experimental Design and Data Analysis

For the performance of practice, namely the time needed to complete each driving task, the effect of number of practice was examined. Additionally, the learning curve of each participant associated with each driving task was fitted according to the Wright's model, then the theoretical time to complete the first practice (T_1) and learning rate (ϕ) of each participant was adopted for ANOVA with the factor of driving tasks. For NASA-TLX, a factorial design was employed with two factors of driving task and stage (10th or 28th practice). In the all ANOVA models, the highest interaction order with participant was served as the error term to precisely test the influence of all main effect. The software Statistica 8.0 was used for data analysis, and a post hoc Newman-Keuls test was used to test paired differences for significant main effects and interactions. The level of significance (α) was set at 0.05.

3 Results

The ANOVA results indicated that there existed a significant effect of practice number on completing time for all driving tasks. Practice made the driving time gradually shorter, but this improvement became less and less as the times of practice increased. Generally speaking, there was not a significant improvement in the performance after 20th practices (during the fourth week).

Next, the learning curve of each participant associated with each driving task was fitted according to the Wright's model. The average coefficient of determination (R^2) was 0.76 (min–max: 0.51–0.95) for up/down hill task, 0.84 (min–max: 0.47–0.94) for 3-point-turn task, 0.86 (min–max: 0.69–0.95) for S-curve task, 0.79 (min–max: 0.23–0.93) for reversing-into-garage task, and 0.76 (min–max: 0.25–0.91) for parallel-parking task.

The theoretical time to complete the first practice (T_1) and learning rate (ϕ) of each participant was further adopted for ANOVA, which revealed that the effect of driving task was significant on both T_1 ($F(4,156) = 260.4$, $p < 0.001$) and ϕ ($F(4,156) = 12.2$, $p < 0.001$). The post hoc of Newman-Keuls test indicated that three groups could be classified for T1: up/down hill (mean = 91.3 s, s.d. = 11.2) and parallel-parking (mean = 94.8 s, s.d. = 14.7) tasks, following 3-point-turn (mean = 105.7 s, s.d. = 16.1) and reversing-into-garage (mean = 111.6 s, s.d. = 16.9) tasks, and the longest was S-curve task (mean = 222.7 s, s.d. = 37.2). As to the learning rate, the post hoc result according to the Newman-Keuls test demonstrated that the learning rates of S-curve task (mean = 0.8717, s.d. = 0.0331) was not significantly different from that of reversing-into-garage task (mean = 0.8752, s.d. = 0.0296), the learning rates of parallel-parking task (mean = 0.8815, s.d. = 0.0357) was not significantly different from that of 3-point-turn (mean = 0.8924, s.d. = 0.0273), and up/down-hill task (mean = 0.9156, s.d. = 0.0308) had the greatest learning rate.

Finally, the values of among 40 participants were averaged within each practice for each task, and the overall Wright's learning curves model for each driving task was fitted. All R^2s were significantly high with a range of 0.88–0.97. This implied that these learning curves of trunk driving tasks were able to be fitted by power function very well. Specifically, the learning rate was 0.9162 for up/down-hill, 0.8912 for 3-point-turn, 0.8802 for parallel-parking, 0.8736 for reversing-into-garage, and 0.8698 for S-curve.

The trainees' workloads were assessed by the NASA-TLX twice, one on the 10th and the other on the 28th practice. The scores were tested by means of ANOVA with factors of driving task and measured time. The results indicated that all main effects and two-factor interactions were significant on weighted NASA-TLX score. As the Fig. 3 shown, the second measure (on 28th practice) was significantly lower than the first measure (on 10th practice) for all evaluated tasks. This implied that practice was also able to reduce the overall workloads. Additionally for the task effect, averagely speaking, S-curve task had the highest

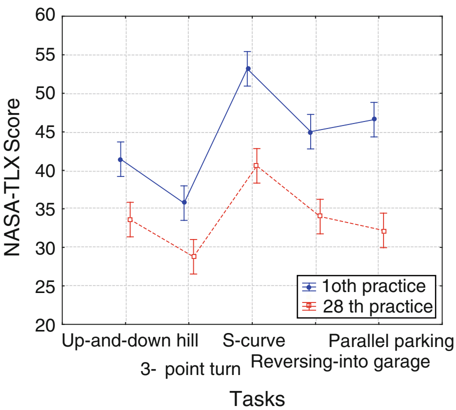


Fig. 3 The weighted NASA-TLX scores of five driving tasks for two measurements

workload, 3-point-turn task had the lightest workload, and the rest three were not significantly different from each other. After practices, Fig. 3 also indicated that there were more reduction in workload for the tasks of S-curve, reversing-into-garage, and parallel-parking.

4 Discussions

The learning rate above 0.9 means pure motor skill, and the learning rate for a hybrid task containing cognitive and motor skill would be ranged 0.7–0.9. Learning can also be separated into two categories, cognitive learning and motor learning. Purely cognitive learning tasks have been shown to have a learning constant (learning rate) of $\sim$0.70, while the learning constant for purely motor learning tasks is $\sim$0.90 (Dar-el et al. 1995). Therefore, it implied that the task of up/down hill task was like a task with pure motor skill, and the rest with learning rates less than 0.9 needed more cognitive processes.

On the other hand, there was a negative correlation between T_1 and Φ for S-curve task ($r = -0.693$, $p < 0.01$), up/down-hill task ($r = -0.393$, $p < 0.05$), 3-point-turn task ($r = -0.812$, $p < 0.01$), reversing-into-garage task ($r = -0.854$, $p < 0.01$), and parallel-parking task ($r = -0.729$, $p < 0.01$).

As to the conclusion of Dar-El et al. (1995), a smaller learning rate seems to need more cognitive processes, which could spend more time. A new dual-phase model for learning industrial tasks is presented, based on the combined effects of cognitive and motor processes. The model proposes that cognitive elements dominate learning during the early cycles, whereas motor elements dominate the learning process as the number of repetitions becomes large. The implication is that the observed learning slope is a variable whose value gradually increases as experience is gained. Experimental studies are described whose results support the behavior of the dual-phase learning model.

It was found that longer the experience of holding the license of light vehicle led to a shorter T1 ($r = -0.324$, $p < 0.05$) of S-curve task. The learning rate for S-curve was 0.8698, the lowest among five tasks. The S-curve task also had the largest workload measured by NASA-TLX, say 53.2 and 40.6 for the first and the second measurement. The S-curve task could need more cognitive process due to the lower learning rate and the larger workload. Therefore, more experienced trainees were able to finish this task in shorter time.

On the other hand, older the trainee, smaller the learning rate for up/down hill task ($r = -0.393$, $p < 0.05$). The learning rate was 0.9162 for up/down hill, the largest among all five tasks. The workload measured by NASA-TLX for this task was 41.5 and 33.6 for the first and the second measurement, respectively. This workload among five tasks was in the middle place.

5 Conclusions

Practice made the driving time gradually shorter, but this improvement became less and less as the times of practice increased. The learning curve associated with each driving task was well fitted according to the Wright's model. This implied that these learning curves of trunk driving tasks were able to be fitted by power function very well. Specifically, the learning rate was 0.9162 for up/down-hill, 0.8912 for 3-point-turn, 0.8802 for parallel-parking, 0.8736 for reversing-into-garage, and 0.8698 for S-curve. Finally, the significantly lower second measurement of NASA-TLX implied that practice was also able to reduce the overall workloads.

References

Dar-el EM, Ayas K, Gilad I (1995) A dual-phase model for the individual learning process in industrial tasks. IIE Trans 27(3):265–271

Konz SA, Johnson S (2000) Work design: industrial ergonomics: Holcomb Hathaway

Reid SA, Mirka GA (2007) Learning curve analysis of a patient lift-assist device. Appl Ergon 38(6):765–771

Sahami S, Sayed T (2010) Insight into steering adaptation patterns in a driving simulator. Transp Res Rec J Trans Res Board 2185(1):33–39

Sahami S, Sayed T (2013) How drivers adapt to drive in driving simulator, and what is the impact of practice scenario on the research? Transp Res Part F Traffic Psychol Behav 16:41–52

Sahami S, Jenkins JM, Sayed T (2009) Methodology to analyze adaptation in driving simulators. Transp Res Rec J Transp Res Board 2138(1):94–101

Prognostics Based Design for Reliability Technique for Electronic Product Design

Yingche Chien, Yu-Xiu Huang and James Yu-Che Wang

Abstract Techniques that can effectively reduce failure rate, control life span and predict product life are highly expected in modern electronic products. Design for Reliability (DFR) technique introduced in this study, applies various robust design and system reliability modeling methods to evaluate whether reliability target can be met in product development stage. However, DFR technique often faces challenges mainly on insufficient accuracy of system reliability prediction. Prognostics and Health Management (PHM) technique applies failure precursors and their impact on product real failure to improve accuracy of reliability prediction in design phase. This study integrates DFR and PHM techniques for reliability prediction. Hard disk drive is selected as a case study for PHM application in design phase. A failure precursor of drive is selected and its statistical distribution of time-to-failure-precursor is established. Applying conditional reliability and residual mean-time-to-failure, remaining useful life (RUL) estimation is proposed. The prognostic based DFR developed in this study plays a key role in predicting product reliability during development stage as well as catastrophic failure prevention in maintenance stage.

Keywords Design for reliability · Prognostics and health management · Failure precursor · Remaining useful life

Y. Chien (✉) · Y.-X. Huang
Chung Yuan Christian University, Chung-Li, Taiwan, Republic of China
e-mail: cyc@cycu.edu.tw

Y.-X. Huang
e-mail: moumouhh@gmail.com

J. Y.-C. Wang
HP Taiwan, Taipei, Taiwan, Republic of China
e-mail: jimswung@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_158,

1 Introduction

Design for Reliability techniques have been proved by many companies worldwide as a set of effective tools to achieve desired product functions and reliability objectives with low cost and short development cycle time.

DFR process offers a series of proactive actions on how to define a market winning reliability target, allocation of reliability target, prediction of reliability at early design phase by reliability modeling, critical components selection and qualification, derating review based on operating and environmental stresses, design Environmental Stress Tests (EST) for design verification, warranty and spares planning, integrated hardware and software reliability modeling for interface design and design optimization, etc.

With clear hand shake at each development process gates, implementation results of DFR process can be assured and design faults can be detected and removed to prevent expensive field failures. Enhanced DFR technique focuses on application of PHM methods for failure precursors identification and RUL prediction during product development phase. Thus, a fast and product oriented reliability prediction can be generated in development phase. The result can be compared with prediction results by parts count method generated early in development phase for prediction accuracy improvement. Investigation causes of failure precursors leads to find root causes of real failures early in design phase and improves product reliability.

2 Literature Review

In 1990, AT&T Bell Laboratories published a book, "Reliability by Design" which explores the approaches on reliability assurance in product life cycle and marked the beginning of new era of Design-for-Reliability. The reliability prediction methodology and system reliability model are two key techniques for the DFR. In 2006, *Telcordia Technologies* published the SR-332, Issue 2 document, "Reliability Prediction Procedure for Electronic Equipment". This document and other component failure rate standards based on company proprietary enable parts-count method for system reliability prediction in design phase.

Around year 2000, Prognostics and Health Management technology emerged as a promising approach for reliability prediction and logistic management. The technology is promoted by Dr. Michael Pecht and his research team, the Center for Advanced Life Cycle Engineering (CALCE), University of Maryland, USA.

PHM plays as a new paradigm in the fields of reliability, maintenance, and logistics. According to the introduction of the technology by CALCE, prognostics is a process of predicting a product's remaining useful life under expected future use by assessing the degradation or deviation of current health from expected state of health. PHM enables users, maintainers, and manufacturers to dynamically understand the state of product health and thereby helps them make informed and timely life cycle management decisions.

3 DFR and PHM Methodologies

3.1 Prognostics Based DFR Approach

The DFR process framework is built for effective reliability management. The framework can be represented by six-step process: (1) Identification of reliability requirements based on marketing and competition, (2) Product functionality design, (3) Component specification verification based on reliability requirements, (4) Design verification on schematic level for comparison with reliability objectives, (5) Design validation on system reliability by real product testing, and (6) Lessons learned from failures for design guidelines update and next generation product reliability improvement.

The DFR process consists inter-process gates for control and appraisal on project reliability status. For each gate, a development project team is responsible for complying to company's gate pass requirements and making pass/fail decision of the project as it proceed to each gate.

Prognostics based design-for-reliability starts from identifying failure precursor during product development phase. Test units with failure precursor to characterize their statistical distribution including mean-time-to-failure-precursor. Establish relationship of return rates between units with and without failure precursor for estimating MTTF of real failure after reveal of failure precursor. Prediction of new product reliability based on corresponding failure mode for the failure precursor can use sum of mean-time-to-failure-precursor and MTTF of real failure after precursor presented.

RUL of product can be estimated after the product health monitor on failure precursor during product life cycle using conditional reliability and residual MTTF based on distribution of failure precursor occurrence time. Result of product health monitor can be applied for preventive action on catastrophic failure.

3.2 Remaining Useful Life Estimate

Time-To-Failure-Precursor of a product can be analyzed for fitting some probability distribution. We define conditional probability as the probability of a product for successful operating t hours with no failure precursor detected after passing product health monitor for the precursor at time T_0. The conditional reliability can be expressed as,

$$R(T_0 \rightarrow T_0 + t|T_0) = R(T_0 + t|T_0) = \frac{R(T_0 + t)}{R(T_0)} = e^{-\int_{T_0}^{T_0+t} \lambda(t')dt'} \quad (1)$$

Furthermore, the first derivative of the conditional reliability (Eq. 2) shows that the conditional reliability is a decreasing function of T_0, if the failure rate is an increasing function. Similarly, if the failure rate is a decreasing function, the conditional reliability will be an increasing function of T_0. (Ebeling 2010)

$$\frac{dR(T_0 + t|T_0)}{dT_0} = R(T_0 + t|T_0)[\lambda(T_0) - \lambda(T_0 + t)] \quad (2)$$

$$MTTF(T_0) = \int_0^{\infty} R(T_0 + t|T_0)dt = \frac{1}{R(T_0)} \int_{T_0}^{\infty} R(t')dt' \quad (3)$$

where $t' = T_0 + t$

The residual *MTTF* denoted as $MTTF(T_0)$, can be defined as Mean-Time-To-Failure-Precursor after passing product health monitor on failure precursor at time T_0. It can be derived from the conditional reliability function in Eq. (1). Calculation of residual *MTTF* is shown in Eq. (3). It is the expected time to reveal failure precursor after last product health check with no failure precursor found. The $MTTF(T_0)$ is dependent on time T_0 and can be treated as remaining useful life of the product on failure precursor occurrence.

Our next step is to develop expected time for real failure occurrence given the product found with failure precursor. This expected time for real failure is denoted as $MTTF_2$ and will be used for taking preventive action to avoid unalarmed failure.

$$\begin{aligned} &RUL \text{ of product after health monitor at time } \mathrm{T}_0 \text{ with no failure precursor found} \\ &= MTTF(T_0) + MTTF_2 \end{aligned} \quad (4)$$

At time $T_0 = 0$, product is ready for release, the *RUL* in Eq. (4) can be regarded as *MTTF* of product based on the failure precursor.

3.3 Relationship of MTTF of Product Carry No Failure Precursor and MTTF of Product Carry Failure Precursor

Considering to conduct a reliability test on two groups, each group consists of same product type. Units in the first group units have been checked before the test and found no failure precursor. Units in the second group have failure precursor before the test. It is reasonable to assume that the second group has *K* times higher return rate in *h* hours test period compared with that from the first group. For simplification, we assume that both groups are in their useful life period. The following relation hold.

$$1 - R_2(h) = K[1 - R_1(h)], \quad \text{where } h \text{ is test hours} \tag{5}$$

$$R_1(h) = \text{reliability of product with no failure precursor} = e^{-\lambda_1 h}$$

$$R_2(h) = \text{reliability of the product with failure precursor} = e^{-\lambda_2 h}$$

where

$$\lambda_1 = \text{failure rate of product with no failure precursor}$$

$$\lambda_2 = \text{failure rate of product with failure precursor}$$

Solving Eq. (5) in terms of λ_1 and λ_2,

$$\lambda_2 = (-1/h)\, ln[1 - K(1 - e^{-\lambda_1 h})] \tag{6}$$

Since $MTTF_1 = 1/\lambda_1$ and $MTTF_2 = 1/\lambda_2$,
the ratio of $MTTF_1$ and $MTTF_2$ the Accelerating Factor can be derived from Eq. (6).

$$Accelerating\,Factor = \frac{MTTF_1}{MTTF_2} = \frac{\lambda_2}{\lambda_1} = \frac{-1}{\lambda_1 h} \ln\left[1 - \mathrm{K}(1 - \mathrm{e}^{-\lambda_1 h})\right] \tag{7}$$

It can be shown numerically, ratio of $MTTF_1/MTTF_2$ in Eq. (7) is greater than 1 with the scale depending on the value of *K*.

4 Case Study

A PHM study uses data from a group of hard disk drives (HDD) in desk top computers located in a computer lab. According to various studies on HDD, failure precursors of drives may include scan error, degrading data transmission rate, read/

write error, high internal temperature inside a drive, etc. Each of the precursor corresponds to their failure mode. The scan error is selected as the failure precursor for this study for its important role in HDD failure and its easy to identify from a built-in personal computer internal monitor program, Self-Monitoring Analysis and Reporting Technology (SMART). Scan error can be caused by bad sector(s) on hard disk or malfunction of magnetic head. For simplification, this research assumes that bad sector is a sole contributor to scan error. Bad sector refers to damage on some sectors in hard disk.

(A) Estimate of residual MTTF based on a failure precursor

Based on the investigation of 38 personal computers in a lab., time-to-failure-precursor of four (4) HDDs with scan error were obtained from the SMART monitoring record. The censored test hour records of the rest of 34 HDDs are also available.

Applying median rank method for regression analysis on the test records and using reliability software program, ReliaSoft, show that the scan error follows a two parameter Weibull distribution with shape parameter, β and scale parameter, η as

$$\beta = 1.62$$
$$\eta = 7418.5 \text{ h}$$
$$\gamma = 0$$

In general, random variable, T distributed as a 3—parameter Weibull,

$$f(T) = \frac{\beta}{\eta}\left(\frac{T-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{T-\gamma}{\eta}\right)^{\beta}}$$

$$R(T) = e^{-\left(\frac{T-\gamma}{\eta}\right)^{\beta}} \tag{8}$$

$$MTTF = \gamma + \eta\Gamma\left(\frac{1}{\beta} + 1\right) \tag{9}$$

.

From Eq. (3),

$$MTTF(T_0) = \frac{1}{R(T_0)}\int_{T_0}^{\infty} R(t')dt'$$

$$= \frac{1}{R(T_0)}\left[\int_0^{\infty} R(t')dt' - \int_0^{T_0} R(t')dt'\right] = \frac{1}{R(T_0)}\left[MTTF - \int_0^{T_0} e^{-\left(\frac{T-\gamma}{\eta}\right)^{\beta}} dT\right] \tag{10}$$

Assume that a drive has been scan tested by the SMART program at time T_0 of 0 h (new product), 2190 h (after 3 months use), 4380 h (after 6 months use) and 8760 h (after one year use) respectively, the residual MTTF can be calculated using Eq. (10) where the value of *MTTF* can be found from Eq. (9) and $\Gamma((1/\beta)+1)$ is a Gamma function.

$$MTTF(0\text{ h}) = MTTF = \frac{1}{R(0)}\left[7419\cdot\Gamma\left(\frac{1}{1.62}+1\right)\right] = 6644\text{ h}$$

Using numerical method to find the integral value,

$$MTTF(2190\text{ h}) = \frac{1}{R(2190)}\left[6644 - \int_0^{2190} e^{-\left(\frac{T}{7419}\right)^{1.62}} dT\right] = 5244\text{ h}$$

Similarly,

$$MTTF(4380\text{ h}) = 4429\text{ h}$$

(B) Estimate of *MTTF* based real failure after failure precursor diagnosed

Pinheiro et al. (2007) investigated more than 100,000 units of HDD in servers installed at Google for impact of scan error on HDD reliability. The result showed that drives having one or more scan errors are 39 times more likely to fail within 60 days than drives with no scan errors. Field test result also showed HDD annual return rate is 6 % approximately.

Calculation shows that $MTTF_2$, the MTTF for drives with failure precursor (scan error) is 49 times shorter than $MTTF_1$, the MTTF for drive with no failure precursor. Notice that the failure defined here is real failure modes based on product specifications.

$$MTTF_1 = \frac{1}{\lambda_1} = 141{,}583\text{ h} = 16.1\text{ years}$$
$$MTTF_2 = \frac{1}{\lambda_2} = 2{,}889\text{ h} = 0.33\text{ years}$$

(C) Remaining Useful Life (RUL) based on PHM monitoring result

From eq. (4),

$$\begin{aligned} &RUL\text{ of HDD based on scan error}\\ &= MTTF(0) + MTTF_2 = 6644 + 2889 = 9533\text{ h}\end{aligned}$$

The RUL based on scan error can be converted to failure rate of scan error for HDD. If more major failure modes in addition to scan error can be monitored and assumes that their occurrences are mutually exclusive, a total HDD failure rate

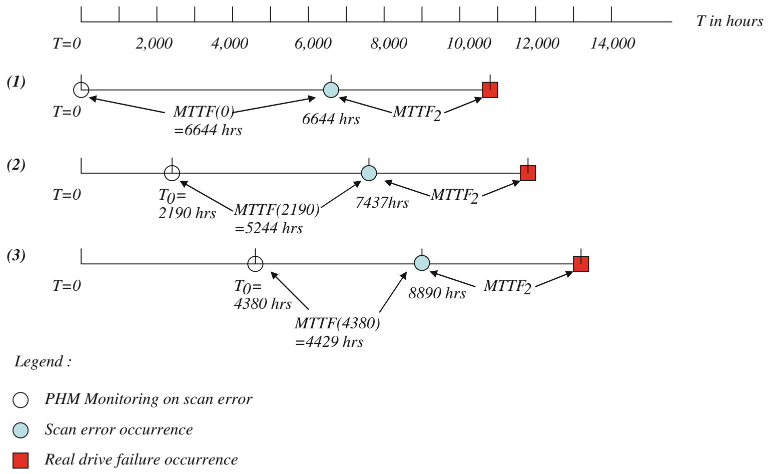


Fig. 1 Residual MTTF of failure precursor and MTTF of real failure for units carrying failure precursor

based on failure precursors can be obtained by summing up all failure rates of each failure mode.

The $MTTF_2$ can be regarded as an action window for taking necessary arrangements such as spare preparation and/or data duplication to prevent impact of unexpected real failure caused by the drive.

Figure 1 shows the relation for product health monitoring at age of (1) Start operation, (2) 3 months and (3) 6 months. It shows that the expected time for scan error occurrence is decreasing as the health monitoring time is increased (product getting older). The average time that a real HDD failure will occur after scan error revealed is $MTTF_2$.

5 Conclusion

This study provides method of application of PHM technique in reliability prediction during product development phase. Using failure precursor to predict product reliability establishes a product-oriented approach as compared with parts count method using generic approach. The failure precursor approach is also a sensitive way to detect product health status which leads to predict real failure occurrence.

Further study on establishing relation between RUL and damaging level for each failure mode can provide more precise basis for predicting product MTTF under different operational and environmental stresses.

Acknowledgments This work is supported by the National Science Council of Taiwan. The authors are also gratefully acknowledge the review from the reviewers.

References

Ebeling CE (2010) An introduction to reliability and maintainability engineering, 2nd edn. Waveland Press, Canada

Pinheiro E, Weber W-D, Barroso LA (2007) Failure Trends in a Large Disk Drive Population, 5th USENIX Conference on File and Storage Technologies, pp 17–29

A Case Study on Optimal Maintenance Interval and Spare Part Inventory Based on Reliability

Nani Kurniati, Ruey-Huei Yeh and Haridinuto

Abstract An engine fuel supply subsystem for particular type of aircraft plays an important role in providing, controlling, and distributing the fuel during engine operation. Failure on this subsystem will affect the readiness of the aircraft for operations. Therefore, for system experienced an aging characteristic or wear-out period, determining of the optimal preventive maintenance and optimal preventive replacement interval by considering the total cost of maintenance per unit time is important. In order to support the replacement activity, available number of spare parts required and must be well controlled to avoid either over stock or shortage. In this study, we attempt to determine the preventive maintenance interval and preventive replacement interval and its required inventory spare parts as well. We deliberate the cost structure, failure field data, and the reliability along the designing and managing the maintenance activity. We also examine the implication of the designed maintenance interval on reliability and availability of the system.

Keywords Reliability · Ware-out period · Maintenance interval · Replacement interval · Spare part inventory

N. Kurniati (✉) · R.-H. Yeh
National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: d10001804@mail.ntust.edu.tw; nanikur@ie.its.ac.id

R.-H. Yeh
e-mail: rhyeh@mail.ntust.edu.tw

N. Kurniati
Institute of Technology Sepuluh Nopember (ITS), Surabaya, Indonesia

Haridinuto
Department of Personnel Administration, Indonesian National Air Force, Jakarta, Indonesia
e-mail: haridinuto@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_159,

1 Introduction

Generally, there are several main systems in the aircraft include engine, hydraulics, air frame, and propeller. Among those systems, engine is the most important system responsible for operations as well as the main parameter determine whether an aircraft worth to fly or delayed due to failure. Inside the engine, there is important subsystem, called engine fuel supply, responsible to provide, control, and distribute the fuel to the engine during operations. The engine fuel supply is critical subsystem but has failure prone and needs to get more attention than the others.

For system experienced an aging characteristic or wear-out period as well as has potentially disastrous consequences of failure would suggest affording preventive maintenance (PM) rather than corrective maintenance (CM). In a particular aircraft type operated for more than 20 years, approaching to the end of life or wear-out periods, corrective action only is not an economical choice since the frequency of failure is high due to aging. It may also incurs cost of resulting in failure of the neighboring device, cost for more extensive repairs and maintenance overtime cost, cost for a large material inventory of repair parts required. These are costs we could minimize under different maintenance strategy rather than corrective action.

The PM's objective is to increase the reliability of the system over the long term by staffing off the aging effect (Lewis 1991). By simply expending the necessary resources to conduct maintenance activities intended by the equipment designer, equipment life is extended and its reliability is increased.

Maintenance activity can't be avoided from cost consequences (Ebeling 1997). If the maintenance activity done frequently with shorter interval period of time, the maintenance cost will increase however the cost due to failure will decrease. Conversely, the maintenance cost will decrease if we reduce the number of maintenance activities by a longer PM interval. Nevertheless, the cost of breakdowns may extremely increase for more complex failures. Therefore, minimizing the total cost for a certain period or the total cost per unit time is more preferable as maintenance decision basis.

Many studies on scheduling maintenance and spare-part problems have been done. Sherif (1982) studied a state-of-the-art review of the literature related to optimal inspection and maintenance schedules of failing systems. Huiskonen (2001) addressed the question of managing spare part logistics by discussing the basic principles affecting the strategic choices and related choices in different areas.

In this study, we attempt to determine the preventive maintenance interval and preventive replacement interval and its required inventory spare part as well. We deliberate the cost structure, failure field data, and the reliability along with the designing and managing the maintenance activity.

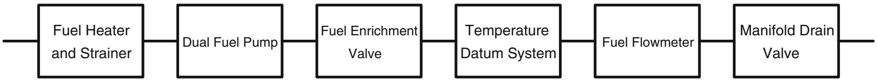


Fig. 1 Reliability block diagram for component of the engine fuel supply

2 Case study

In a particular aircraft, the engine fuel supply consists of several main components as provide in the diagram block. Examining the failure field data extensively for the following calculation, under following assumptions:

- Consider the failure time only, disregard the failure cause and consequences.
- The failure of items are independent and identical
- All items are repairable and replaceable (there is no discardable item)
- No delay due to resources, maintenance crew or equipment (Fig. 1)

Based on the collected failure data (time to failure, TTF) for several years, we determine the failure distribution of each component and consider the Weibull distribution of failure. Based on this failure distribution, we may determine the reliability function, the availability function, and further calculation to determine the preventive maintenance interval and preventive replacement. The failure distribution for consecutive components as block diagram provides are Weibull (4.42; 378.12), Weibull (4.12; 424.90), Weibull (4.81; 316.90), Weibull (3.46; 358.01), Weibull (2.95; 175.81), and Weibull (3.69; 348.13)

3 Determining the Preventive Maintenance Interval

The feature of the components considering maintenance time and numbers of maintenance labor both for corrective and preventive action. The maintenance labor cost is IDR 17,518 per hour person, and the cost due to failure or the consequence cost for 1 h of maintenance action refers to the operation lost for one flying hour with cost IDR 50,000,000 per hour. So we can get the maintenance cost by multiplying the summation of total labor cost and the cost due to failure with the time required to perform the maintenance action. The CM cost (C_f) is larger than the PM cost (C_p) since the time required to perform CM longer than for PM.

Define one cycle (t_p) is the length of interval between two consecutive PM. During time t_p, we may accommodate any corrective maintenance occur and one preventive maintenance action. The optimal PM interval is the length of interval t_p that minimize the total cost for one cycle. The total cost $C\left(t_p\right)$ for one cycle t_p given as (Jardine 1973):

Table 1 Feature and the length of PM interval for component of the engine fuel supply

Component	Corrective action		Preventive action		t_p (flying hour)
	CM time (h)	CM labor (prs)	PM time (h)	PM labor (prs)	
Temperature datum system	24	3	4	3	161
Fuel heater and strainer	8	2	1	2	177
Dual fuel pump	24	2	2	2	175
Fuel Enrichment Valve	4	2	1	2	177
Fuel flow meter	8	2	3	2	175
Manifold drain valve	4	2	1	2	178

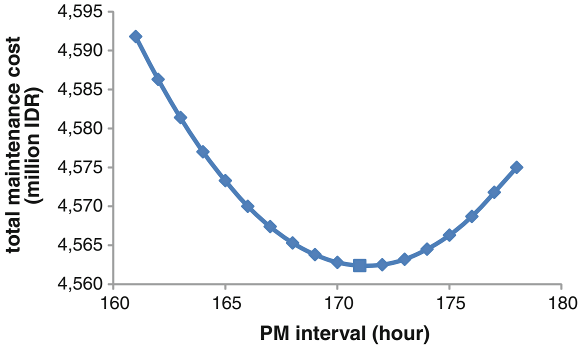


Fig. 2 Total maintenance cost profile under certain PM interval range

$$C(t_p) = \frac{\text{expected failure cost}}{\text{expected cycle length}} + \frac{\text{preventive cost}}{\text{cycle length}} = \frac{C_f(1 - R(t_p))}{\int_0^{t_p} R(t)dt} + \frac{C_p}{t_p} \tag{1}$$

where C_f and C_p are maintenance cost for failure or corrective action and preventive action, respectively. $R(t_p)$ is the reliability function at t_p (Table 1).

Adjustment is needed since the maintenance action for all components may take at the same flying hour. Therefore, we evaluate the total maintenance cost of all components along cycle length range from 161 to 178 flying hours which results in the lowest cost. The resulting PM interval for each component is 171 flying hours.

The comparison between this PM interval and the existing maintenance interval (200 flying hour, Koharmatau 2006) in terms of reliability (provide at Fig. 2) and availability shows that even though the calculated maintenance interval shorter than the existing, we can keep the reliability value better for every components as shown in the Fig. 3. The availability value also have identical pattern as well (Table 2).

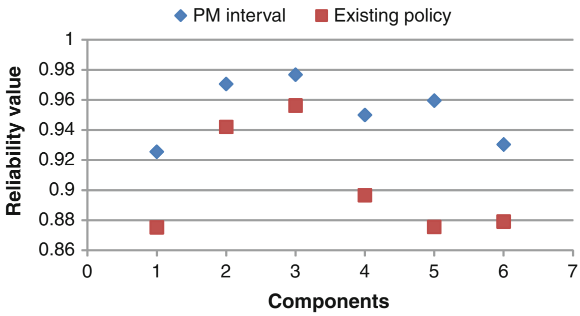


Fig. 3 The comparison of reliability value between the PM interval and the existing interval

Table 2 Analyzing the reliability importance of component of the engine fuel supply

Component	Method			
	Birbaum's measure	Criticality importance	Vessely fussel's	Improvement potential
Temperature datum system	0.6218	0.1701	0.2736	0.0775
Fuel heater and strainer	0.5777	0.0735	0.1271	0.0335
Dual fuel pump	0.5692	0.0547	0.0960	0.0249
Fuel enrichment valve	0.6070	0.1376	0.2267	0.0627
Fuel flow meter	0.6216	0.1697	0.2729	0.0773
Manifold drain valve	0.6191	0.1642	0.2652	0.0748

4 Determining the Preventive Replacement Interval

First, we focus on finding the critical component of the engine fuel supply based on the reliability value. There are several ways to analyze the reliability importance (Heley and Kumamoto Henly and Kumamoto 1992). As shown in Table 3, the most critical component of the engine fuel supply is temperature datum system. Its function is controlling the temperature of fuel before consume by the engine.

The collected time to failure data for several years is taken from maintenance component log book. The calculation of maintenance cost for sub-component is identical to that of maintenance cost for component except that account is taken of the spare part cost. The replacement policy is to perform a preventive replacement once the equipment has reached a specified age t_r plus failure replacement when necessary.

The optimal preventive replacement interval is the length of interval t_r that minimize the total expected replacement cost per unit time, denoted $C(t_r)$, is (Jardine 1973):

$$C(t_r) = \frac{C_p R(t_r) + C_f(1 - R(t_r))}{(t_r + T_p)R(t_r) + \int_0^{t_r} tf(t)dt + T_f(1 - R(t_r))} \quad (2)$$

Table 3 Feature and the length of PR interval for each sub-component

Sub-component	Failure distribution $f(t)$	Maintenance action		t_r
		Time T_p, T_f(h)	Labor (prs)	(flying hour)
Fuel control unit	Weibull (9.49;6072.29)	8	3	4333
TD valve	Weibull (1.75;1615.01)	1	3	4398
Fuel nozzle	Weibull (2.08;2830.87)	3	3	4310
Thermocouple	Weibull (3.39;7422.16)	2	3	3988
TD amplifier	Weibull (1.39;2847.09)	1	2	4362

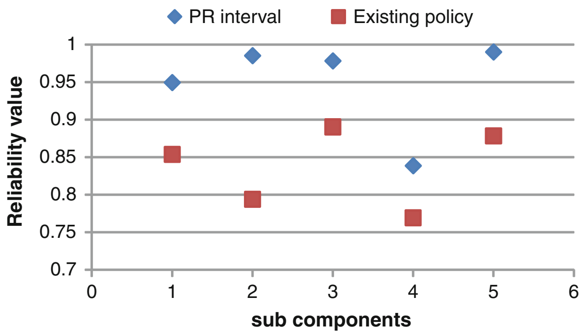


Fig. 4 The comparison of reliability value between the PR interval and the existing interval

where C_f and C_p are replacement costs for corrective and preventive replacement, respectively. $T_f$and $T_p$are times required for corrective replacement and preventive replacement, respectively.

In order to get beneficial meaning in operation, we attempt to find the multiple maintenance intervals closest to the replacement interval. The replacement interval, when we may replace all sub-components, is 4,446 flying hours. The comparison between this PR interval and the existing replacement interval (5,000 flying hour) shows the PR interval will keep the reliability better for every sub-component and availability as well (Fig. 4).

5 Determining the Spare Part Inventory Policy

In order to support the replacement plan, managing the inventory of the spare part is needed. Let s be the replacement interval, the component replaced by a new one after being used for s period or when it fails (Alkaff 1992). The mean time between replacements (MTBR) is $MTBR = \int_0^s R(t)dt$. The average number of spare parts required (N) both due to failure (N_f) and preventive replacement (N_p) during t is $N = t/MTBR$. The proportion of un-failed item after s period is $R(s)$, therefore $N_p = R(s)N$ and $N_f = (1 - R(s))N$ The average number of spare parts required is $N = [tR(s) + t(1 - R(s))]/\int_0^s R(t)dt$. Safety stock ($ss$) during interval s and order

Table 4 Inventory policy for sub-component under different stock out risks

Sub-component	Inventory policy for $\alpha = 0\,\%$				Inventory policy for $\alpha = 5\,\%$			
	N	$N_{\max}$	Ss	ROP	N	$N_{\max}$	ss	ROP
Fuel control unit	2	4	3	3	2	2	1	1
TD valve	2	6	5	5	2	3	2	2
Fuel nozzle	7	10	4	4	7	6	0	0
Thermocouple	22	24	3	3	22	17	0	0
TD amplifier	2	5	4	5	2	2	1	2

lead time (L) is $ss = N_{\max} - N$, where $N_{\max}$ is the maximum number of spare parts required that can be examined as follows. The probability of n times replacement at time t is defined as:

$$P(N(t) = n) = P_n(t) = (H^n(t)/n!)e^{-H(t)} \tag{3}$$

where $H^n(t) = \int_0^t \lambda(t)dt$ is the cumulative hazard rate. Under stock out risk α, $N_{\max}$ is the cumulative $P_n(t)$ for $n = 0.N_{\max}$ that can be found by iterated calculation from $\sum_{n=0}^{N_{\max}} P_n(t) \geq 1 - \alpha$. Reorder point (ROP) is the number of stocks in which the reorder must be taken. The reorder point (ROP) defined as:

$$ROP = ss + D_L \tag{4}$$

where $D_L = L/MTBR$. Finally, the number of spare parts must order (OQ) which is defined as $OQ = N_{\max} - ROP$. The inventory policies of the sub-component of temperature datum systems either for stock out risk at $\alpha = 0\,\%$ and $\alpha = 5\,\%$ are given in Table 4.

6 Conclusions

For a system experienced an aging characteristic or wear-out period, the evaluation for the interval of preventive maintenance or preventive replacement is necessary by examining the recent failure (field) data and its reliability value afterward. We determine the preventive maintenance interval based on minimizing the total expected cost per unit time by considering both preventive and corrective action cost, labor cost, and spare parts if needed. In our case, the comparison between the preventive maintenance interval and the existing interval in terms of reliability and availability shows that even though the calculated interval shorter than the existing, we can keep the reliability and availability better for every item.

To support the replacement action, managing the required spare part is important by considering both reliability and lead time. Providing the order quantity, safety stock, and the reorder point may keep the spare part available for both corrective and preventive replacement.

References

Alkaff A (1992) Teknik Keandalan Sistem. ITS press, Indonesia
Ebeling CE (1997) An introduction to reliability and maintainability engineering. University of Daytona. The Mc Graw Hill, USA
Henly EJ, Kumamoto H (1992) Probabilistic risk assessment reliability engineering design and analysis. IEEE Press, New York
Huiskonen J (2001) Maintenance spare part logistics: special characteristics and strategic choices. Intern J Prod Econ 71:125–133
Jardine AKS (1973) Maintenance, replacement, and reliability. Department of engineering production. University of Birmingham
Koharmatau (2006) Buku Petunjuk Pedoman Pemeliharaan Alutsista (BP3A) Pesawat C-130 Series. TNIAU, Indonesia
Lewis EE (1991) Introduction to reliability engineering. Department of Mechanical and Nulear Engineering Nortwestern University. John Wiley & Sons, USA
Sherif YS (1982) Reliability analysis: optimal inspection and maintenance schedules of failing systems. Microelectron Reliab 22:59–115

Developing Decision Models with Varying Machine Ratios in a Semiconductor Company

Rex Aurelius C. Robielos

Abstract In a semiconductor manufacturing, operators are usually faced with simultaneous activities and therefore it is a requirement that they should have adequate decision making skills. While their main responsibility is to ensure that the machines are continuously running, they are also expected to perform other activities during their assigned working hours. For cases of machine breakdown, one methodology being used is the recognition-primed decision model which is a pattern recognition problem diagnosis procedure. This methodology, however, is appropriate only for single machine breakdown. Thus, a revised decision model is developed to incorporate multiple decision points.

Keywords Recognition-primed decision model · Machine breakdown · Multiple decision points

1 Introduction

In a semiconductor manufacturing environment wherein the system is complex, operators may have difficulties in maintaining a concept of system performance and fitting that concept to the human role within the system. Since most of the activities in the manufacturing floor are assigned to operators, then it is imperative that operators should have the necessary decision making skills. In most cases, simultaneous tasks do occur and operator should have the capability to decide which task is more important and likewise be able to respond to this task appropriately.

R. A. C. Robielos (✉)
Mapua Institute of Technology, Manila, Philippines
e-mail: racrobielos@mapua.edu.ph

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_160,

One methodology being used in a semiconductor industry is the recognition-primed decision model, a problem diagnosis procedure that is usually being done through pattern recognition. One such application of this model is during machine breakdown when there is a need to diagnose the cause of the breakdown. However, the model is appropriate only for single machine breakdown.

This study tries to analyze the different decision points of the operator when simultaneous activities occur due to varying machine ratios. The occurrence of simultaneous machine breakdown would also change the decision making process of the operator. Thus, a revised recognition-primed decision model is developed to include multiple decision points.

2 Man–Machine Task Assignments

Aside from ensuring that the machines are continuously running, operators are also expected to perform various tasks in the manufacturing floor. These activities are the Pre-Post activities, speed delay activities, internal activities, unplanned delay activities and other activities.

(1) **Pre-Post activities**

These are the activities being done by the operator before and after lot processing. There are currently 15 pre and post activities which are grouped according to their Promis Status (database nomenclature system) (Table 1).

Table 1 List of pre and post activities

Promis status	Pre and post activities
NVPACK	Count reconciliation (MIPS)
	Counting of finished lot/new lot
	Counting/checking of endorsed lot (from previous crew)
	Checking of summary versus actual
	Preparing for new lot/completion of fix's
	Printing of barcode and summary
	Labeling of tested units
PDCLEAN	Housekeeping
	For search of missing units
NVSET	Running SUV for new lot (same setup Type 1)
NVRESCR	Rescreen of rejects
NVOQA	Running ILS
	Running Rescr of failed ILS
	For endorsement to technician if still failed at rescr
PEDISPO	For TME's final dispo

(2) **Speed Delay Activities**

These are stoppages encountered during test processing of a lot that falls between the duration of greater than 30 s up to 10 min. These stoppages are commonly caused by 2 reasons:

(a) machine needing assistance because of jams or errors
(b) machine requiring operational assistance

(3) **Internal Activities**

These are activities being done by the operator while the machine is still running. There are 11 identified internal activities under the INUSE Promis Status (Table 2).

(4) **Unplanned Delay Activities**

These are the initial interventions provided by the operator before passing the job to the technician. Usually, these activities would require more than 10 min. Currently, there are 10 possible interventions that are being done by the operator (Table 3).

(5) **Other activities**

These are the activities that may be assigned by the supervisor from time to time (Table 4).

The decision making activities of operator becomes complex the moment that the machine assignment increases to more than one. Machine intensive manufacturing companies would always go into a higher machine ratio since it would bring the manpower expense at the minimum. But when more machines are assigned to operators, we are exposing them in situations that would test their decision making competencies. Thus, the intent of this study is to look at the major decision points and come up with the framework that will guide and help the

Table 2 List of internal activities

Promis status	Internal activities
INUSE	Preparing of untested units for load
	Loading of untested units for Test at the handler
	Unloading of tested units
	Stoppering at tested units
	Bundling of tested units
	Promis transaction (Promis mail viewing of other tester change status)
	Loading of clear tubes at the handler for tested good units
	Make clear lubes for tested good units
	Unloading of tested rejects
	Get stopper and tubes at the rack
	Unloading of used tubes at the handler (untested)

Table 3 List of unplanned delay activities

Promis status	Unplanned delay activities (Events encountered before UDWAIT)
UDHANDL	Handler Jamming
	3 or more time cleaning of jam
UNCNTCTR	Over rejection
UDSYS	Stop the handler
UDEQPT	Check device orientation
UDHANDL	
NVSET/UDSETUP	Failed SUV/SSUV
	Check device orientation
	Run another set of SUV
NVSET	System hang-up
UDSOFT	
UDHANDL	Handler hang-up
NVSET	Set-up of new device
NVSET/UDSETUP	Failed calibration
	Tester reset
NVSET	Unable to load program
	Tester reset
PDCLEAN	Missing unit
	For search of missing units
NVOQA	Failed ILS

Table 4 List of other activities

Promis status	Other activities
INUSE	Operator to get spare of fixtures (contactor, board, suv, etc.) if setup failed
	Operator to get summary report at supervisor room/bay if system encounter hang-ups
	Operator to get and return tubes at tube management if it is her turn

operator. Likewise, instituting a decision framework will definitely redound to the other bottom lines.

As illustrated in Fig. 1, there are 10 possible downtimes that may occur in any given point in time. Since the occurrence and the type of downtimes are random, operator will just have to wait for the machine to stop. Once it stops, operator has to diagnose the problem and then make the necessary course of action. This procedure is actually discussed in the paper by Patterson et al. (2009) wherein he used the recognition-primed decision making model. According to him, this model is composed of three components: one for matching, one for diagnosing, and one for simulating a course of action. Figure 2 depicts the matching and diagnosing components; the former is shown by the box labeled "pattern recognition" and the latter by the box labeled "clarify/diagnose (story building)."

In this model, an individual with expertise identifies a current problem situation as typical and familiar based upon a composite situation stored in memory and,

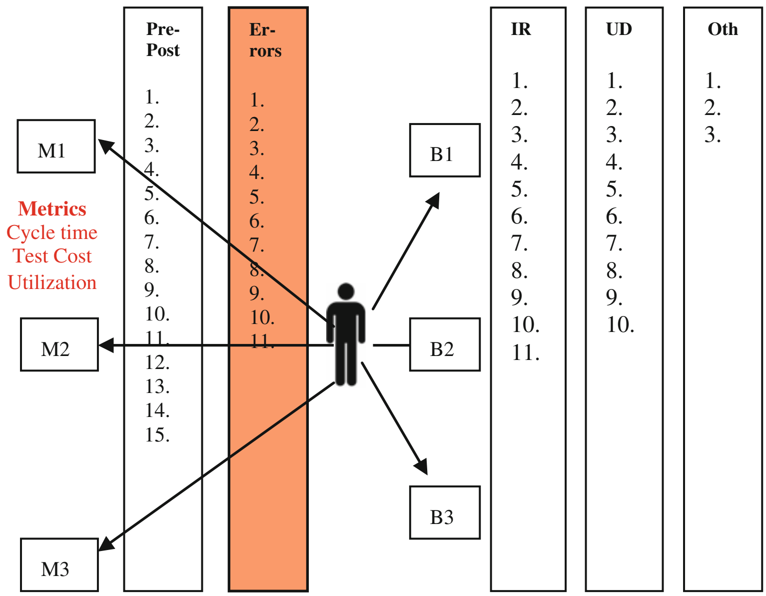


Fig. 1 Man-machine task assignments

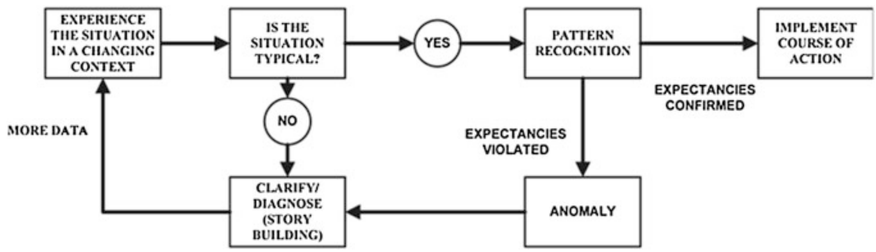


Fig. 2 Diagram of the recognition-primed decision model

with subsequent expectations confirmed, initiates an appropriate course of action, which is typically the first one considered. Klein (1997) also proposed that an individual may mentally simulate a course of action before actually implementing it. If the situation is unfamiliar, however, or if subsequent expectations are violated, then the individual will choose to diagnose and clarify the situation further, which may include story building. This section of the model is usually the case where the problem is beyond the capability of the operator. Thus, this is passed to the Line Technician for possible resolution since the problem is more complicated (Table 5).

If an individual experiences a situation as typical and familiar and recognizes the pattern, he or she decides to implement a course of action if expectancies are confirmed. If the situation is atypical and unfamiliar, or if expectancies are

Table 5 List of possible machine errors

Possible machine errors	Time to repair
Handler jamming	1–3 min
Over rejection	30 s
Failed SUV/SSUV	1 min
System hang-up	10–15 s
Handler hang-up	10–15 s
Set-up of new device	5–10 s
Failed Calibration	2–4 min
Unable to load program	3–5 min
Missing units	5–10 min
Failed ILS	1 min

violated, then the individual decides to clarify and diagnose the situation, which can involve story building.

Assuming that the man–machine ratio is one is to one, the priority of the operator is always the uptime of the machine. Therefore, she has to set aside her other activities whenever a machine breaks down. What complicate the tasks and decision making activity of the operator is when the assigned number of machines increases to more than one.

To illustrate, let us analyze the situation if the man–machine ratio increases to 1 is to 3. Let us start our analysis when the 3 machines are not yet running. Before the units are tested, the operator has to do the pre-activities such as count reconciliation, counting of new lot, preparing for new lot/completion of fixture, etc. After set-up, operator has to ensure that the machine is continuously running. After which, she has to start the pre-activities for Machine 2. There is a possibility that while she is doing the pre-activities for Machine 2, Machine 1 will stop. This is the time that the operator needs to decide which task is more important. Then another set of pre-activities has to be done for machine 3. While operator is doing pre-activities for Machine 3, there is a possibility that Machine 1 and Machine 2 will break down. There are actually many possible combinations that may occur considering that the downtimes of machine are random. Below are just some of the possible scenarios that may occur.

Case 1 Breakdown of Machines

1. All 3 machines simultaneously broke down.
2. 2 Machines broke down, 1 Machine is running

Case 2 Combination of Breakdown and Other Activities

3. Machine 1 broke down, Machines 2 and 3 are running, Operator is doing internal activities
4. Machines 1 and 2 broke down, Machine 3 is running, Operator is doing internal activities

5. Machines 1, 2 and 3 broke down,
   Operator is doing internal activities
6. Machine 1 broke down, Machines 2 and 3 are running,
   Operator is doing pre-post activities
7. Machines 1 and 2 broke down, Machine 3 is running,
   Operator is doing pre-post activities
8. Machines 1, 2 and 3 broke down,
   Operator is doing pre-post activities
9. Machine 1 broke down, Machines 2 and 3 are running,
   Operator is doing unplanned delay activities
10. Machines 1 and 2 broke down, Machine 3 is running,
    Operator is doing unplanned delay activities
11. Machines 1, 2 and 3 broke down,
    Operator is doing unplanned delay activities
12. Machine 1 broke down, Machines 2 and 3 are running,
    Operator is doing other activities
13. Machines 1 and 2 broke down, Machine 3 is running,
    Operator is doing other delay activities
14. Machines 1, 2 and 3 broke down,
    Operator is doing other delay activities

For Man–Machine Ratio of 1:3, here are the possible combinations of decision making activity.

Case 1 Breakdown of Machine

1. Since there are 11 possible downtimes, therefore there are $11 \times 11 \times 11 = 1{,}331$ combinations if 3 machines broke down
2. If 2 machines broke down, then there are $11 \times 11 = 121$ combinations

Case 2 Breakdown and Other Activities

3. There are 15 activities for the Pre-Post activities, 11 for internal Activities and 10 for Unplanned Delay, therefore the minimum combinations will be $15 \times 11 \times 10 = 1{,}650$

If the man–machine ratio increases to 1:4, the possible combinations of decision making activity of the operator will become 14,641.

Case 1 Breakdown of Machine

1. Since there are 11 possible downtimes, therefore there are $11 \times 1 \times 11 \times 11 = 14{,}641$ combinations if 4 machines broke down

The computations above are just estimate of the possible combinations of the decision making activities of the operator if the man–machine ratios are 1:3 and 1:4. The big leap in the values makes it very difficult for the operator to make a good judgment if no system or process is established.

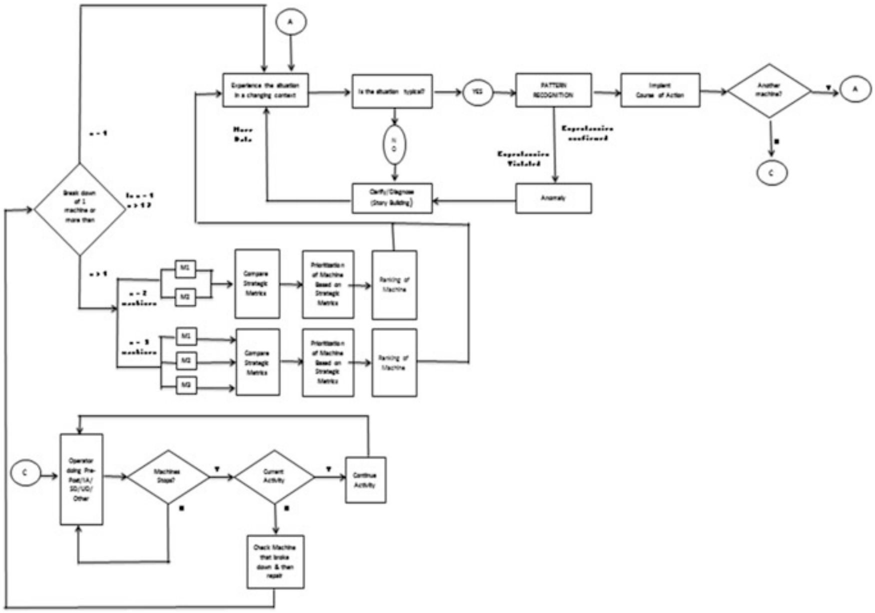


Fig. 3 Extended recognition-primed decision model

With all these activities expected from the operator, it is very important to determine the appropriate man–machine ratio and its corresponding implication on the operator's utilization. While the initial discussion concentrates on the various tasks and how it should be delivered based on the strategic metrics identified, the purpose of coming up with a man–machine ratio is to guide the company on what should be the optimal way of utilizing company's resources and at the same time still meet the various strategic metrics.

3 Conclusion

It is evident that the decision making activities of operators depend on machine assignment. As the number of machine increases, the decision making activity of the operator increases exponentially. Thus, operator should be provided with a framework in order to help them in their decision making process. An Extended Recognition-Primed Decision Model is developed to incorporate multiple machine assignment (Fig. 3).

References

Klein G (1997) The recognition-primed decision (RPD) model: looking back, looking forward. In: Zsambok CE, Klein G (eds) Naturalistic Decision Making. Lawrence Erlbaum Ass, Mahwah

Patterson R et al (2009) Modeling the dynamics of recognition primed decision model. Paper presented at the 9th International Conference on Naturalistic

New/Advanced Industrial Engineering Perspective: Leading Growth Through Customer Centricity

Inside Out to Outside In Through Expert Systems

Suresh Kumar Babbar

Abstract The expert-system-based automated process planning systems are prevalent in Manufacturing and become state of the art tool of successful Industrial Engineers. The author attempted to utilize the concepts of New/advanced Industrial Engineering to apply the capabilities of information technology to redesign business processes in educational institution to reduce the cost, time, and improve quality of its processes by embedding the knowledge of its best decision makers/experts in a "Teaching/learning expert system including scholarship authorization" as part of overall Director Academics Software. The author proposes a concept of software realization of an expert system by assembling experts experience in Personal Computer as knowledge base on the hypothesis that 'knowledge never dies', once we adopt the knowledge of some experts and use it in our system, this knowledge works more efficient than a simple work routine. Director Academics is a tool designed and created for Head of institutions. Here author explored his work in the field of Expert System development, especially what he experiences by working in the Institute and what he learns while he worked under professors. The proposed paper is based on the Rule Based and Case Based Reasoning. In the last author explored his and his senior's experiences.

Keywords Case based · Rule based · Reasoning academic · Expert system · New/advanced industrial engineering

S. K. Babbar (✉)
Bahra University, School of Mechanical Engineering, Solan,
Himachal Pradesh 173215, India
e-mail: sures193@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_161,

1 Introduction

Teams striving to achieve excellence need to apply the proficiencies of information technology to redesign business processes (Yesser 2007) that should lead to growth especially in developing countries like India through customer centricity. Great problems in these countries like shortage of skilled manpower provide great opportunities for Industrial Engineers. Currently we are living in the age of dynamic evolution and in this situation the requirement of customer thereby industries/service organizations changes at a much faster speed. It becomes imperative for organizations to reorganize around customers rather than products for resilience (Gulati 2009). In the present scenario the organizations faces more complex problems for conventional approaches. To illustrate it, when we contrast Case Based Reasoning (CBR) (Watson 1995, 1999; Kolodner 1993) with Rule Based System, we see that the methodology for building and refining Knowledge Base (KB) is more sophisticated than the syntactic checks performed by the Rule Based method. The augmentation of Rule Based System with Case Based Reasoning allows us to handle exceptions gracefully, without making a rule set overly complicated.

A rule, by definition, is meant to capture generalization; it loses its power if it is heavily qualified. It attempts to handle the problems within the framework of mathematical logic has not yielded practical results. Case Based Reasoning provides a mechanism for domain-dependent inference that fills a gap in our proposed toolkit. In the proposed case, we would demonstrate the strength of CBR and its advantages to integrate the CBR with the present systems prevalent with industry/service organizations and challenge the status quo that "Artificial Intelligence (Winston 1982) (AI) software is mostly platform dependent and implemented in environment that no one outside of AI communities uses". Further this paper presents the Case Based Reasoning, as an alternative approach to purely rule-based method, to build a decision support system. Software development for the given problem enables the system to tackle problems like high complexity, low experienced, new staff and changing industrial/service conditions and environment around them.

In the present scenario the purely rule-based method has its limitations like; requirement of explicit knowledge in detail of each domain hence takes years to build Knowledge Base (KB). Case Based Reasoning uses facts in the form of specific cases to solve a new problem, and the proposed solution is based on the similarities between the new problem and the available cases. In this paper we present a Case Based Reasoning which provides decision support for all domains unlike rule-based inference models which are highly domain knowledge specific. Experiments with real data clearly demonstrate the efficiency of the proposed method that has built-in capability to improve productivity of finding and implementing alternatives.

The proposed solutions given in this paper is based on Expert Systems (ES), to solve complicated practical problems of the world especially in developing countries like India that are becoming more and more widespread nowadays. Expert systems are being developed and deployed worldwide in innumerable applications, mainly because of their explanation capabilities.

2 New Industrial Engineering: Information Technology and Business Process Redesign

Business process redesign and information technology are predictable companions, yet industrial engineers have never fully utilized their relationship. The experts argue, in fact, that it has scarcely been exploited at all. But the organizations that have used IT to redesign boundary-crossing, customer-driven processes have benefited immensely. Industrial Engineer needs to change his/her approach from Inside-out to Outside-into reorganize around customers. She/he must achieve resilience within the system for rapid reorganization for customer centricity that should lead to sustainable growth. That growth will take care of Industrial Engineer's core issues of productivity and economy to scale and will not adulterate the strategy of the organization.

Two new tools are renovating organizations for effectiveness to the degree that Taylors once did. These are information technology—the capabilities offered by computers, software applications, and telecommunications—and business process redesign with solving problems for customers—the analysis and design of work flows and processes within and between organizations along with corporate soul of developing with deep customer empathy. Working together, these tools have the potential to create a new industrial engineering (Davenport Thomas and Short James 1990) with focus on customer centricity with high potential to quickly reorganize for resilience. That can change the way the discipline (Industrial Engineering) is practiced and the skills necessary to practice the contemporary Industrial Engineering.

3 What is Case-Based Reasoning?

Case-based reasoning is used to solve problems by remembering a previous similar situation and by reusing information and knowledge of that situation. Let us illustrate this by following flow diagram (see Fig. 1).

A case-based reasoning (CBR) system generally refers to a computer programmed system that identifies a solution to a current problem by examining the descriptions of similar, previously encountered problems and their associated solutions. Matching the current problem with one or more similar previously encountered problems and using the associated solutions of the matching previously encountered problems to suggest a solution to the current problem. In

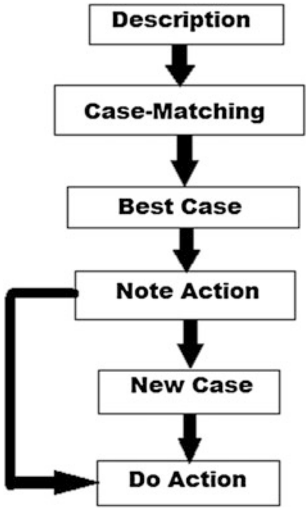


Fig. 1 Flow diagram for case-based reasoning

response to that the receipt of a description of a current problem, a conventional CBR system retrieves the closest matching cases from a case database using a search engine and iteratively asked the user for additional descriptive information until the retrieved case or cases identified by the search engine are sufficiently similar to the current problem to be considered as possible solutions. If a new solution (not previously stored in the case database) is subsequently validated, the validated solution can be stored into the case database and utilized to solve future problems.

4 The Case Base Reasoning Cycle-Interrelationship

CBR cycle-inter-relationship can be represented as the following comparative graph (see Fig. 2). When the number of cases is more, the effort for retrieval and ease of adoption is high or we can say that the effort for retrieval and ease of adoption is directly proportional to the number of cases. But when we see the proportionality between efforts for retrieval and ease of adoption it is reverse, when the ease of adoption is low effort of retrieval is high and vice versa.

5 Working of CBR Based Expert System

In the beginning CBR process number of cases is limited, most of the times we need to modify the solution but as the experience increases, the probability of similar or near similar case would increase. In normal times, a new problem is

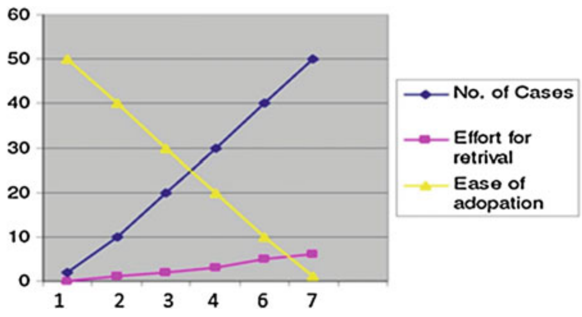
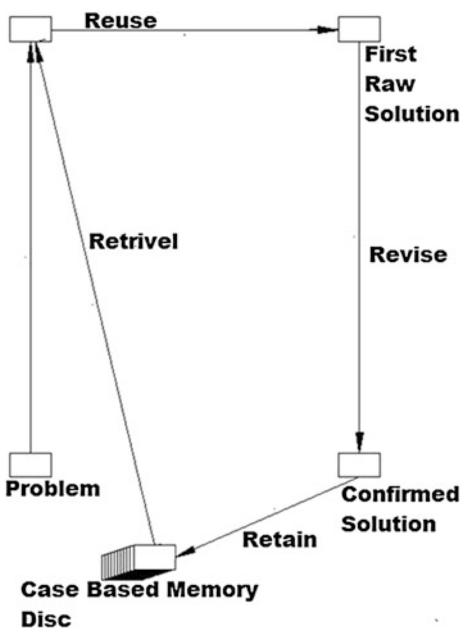


Fig. 2 Proportionality of no. of cases with ease of adoption and effort for retrieval

analyzed against cases in the Knowledge Base and one or more similar cases are retrieved. A solution suggested by the matching cases is then reused and tested for success. Unless the retrieved case is a close match, the solution will probably have to be revised producing a new case that can be retained.

The CBR cycle presented above (see Fig. 3) occurs without human intervention. For example many CBR tools act primarily as case retrieval and reuse systems. Case revision (i.e., adaptation) is often being undertaken by managers of the Knowledge Base. However, it should not be viewed as weakness of CBR that encourages human collaboration in decision support. The following sections will outline how each process in the cycle can be handled.

Fig. 3 CBR cycle



A Case is a piece of knowledge representing with experience. It contains the past solution that is the content of the case and the context in which the solution may be used. Typically a case comprises:

- The problem that describes the state of the world when the case occurred,
- The solution which states the derived solution to that problems, and/or,
- There is a lack of consensus within the CBR community as to exactly what information should be in a case. However, two pragmatic measures can be taken into account in deciding what should be represented in cases: the functionality and the ease of acquisition of the information represented in the case.

6 Advantages of Case Based Reasoning

- It RETRIEVES the most similar case from the galaxy of cases
- REUSE the problem cases to solve the new problem
- REVISE/MODIFY the proposed solution if required and
- RETAIN the new solution as a part of a new case.

7 Advantages of NEW/Advanced Industrial Engineering Approach

It provides quantum leap on the journey of disciplined integration and thus yields major competitive advantage. It prompts Industrial Engineer to shift 120-degree towards an outside-in perspective that otherwise is hardest advance to make.

References

Davenport Thomas H, Short James E (1990) The new industrial engineering: information technology and business process redesign. Sloan Manag Rev 31(4)

Gulati R (2009) Reorganize for resilience. Harvard Business School

Kolodner J (1993) Case-based reasoning. Morgan Kaufman, New York

Watson I (1995) Progress in case based reasoning. Lecture notes in artificial intelligence. Springer, Berlin, p 1020

Watson I (1999) Case-based reasoning is a methodology not a technology. Knowl-Based Syst 12:303–308

Winston PH (1982) Learning new principles from precedents and exercises. Artif Intell 19:321–350

Yesser (2007) Business process redesign methodology. The Saudi e-Government Program 1:1–26

Scheduling a Hybrid Flow-Shop Problem via Artificial Immune System

Tsui-Ping Chung and Ching-Jong Liao

Abstract This paper investigates a two-stage hybrid flowshop problem with a single batch processing machine in the first stage and a single machine in the second stage. In the problem, each job has an individual release time and the jobs are grouped into several batches. To be more practical in real applications, the waiting time between the batch machine and the single machine is restricted. Since the problem is NP-hard, an immunoglobulin-based artificial immune system (IAIS) algorithm is developed to find an optimal or near-optimal solution. To verify IAIS, comparisons with two lower bounds in the second problem are made. Computational results show that the proposed IAIS algorithm is quite stable and efficient.

Keywords Hybrid flowshop · Artificial immune system · Batch processing machine

1 Introduction

In this section, we consider a two-stage hybrid flowshop scheduling problem where there are n jobs to be processed first at stage one and then at stage two. The first stage contains a batch processing machine (BPM) and the second stage contains a single machine. The processing times of job j in stage one and two are p_{1j} and p_{2j}, respectively. Each job has a release time r_j and a corresponding size s_j. The capacity of each batching machine is up to B and the sum of the job sizes in a

T.-P. Chung (✉)
Department of Industrial Engineering, Jilin University, Changchun, China
e-mail: tpchung@jlu.edu.cn

C.-J. Liao
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: cjliao@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_162,

batch must be less than or equal to B. The batch processing time is equal to the maximal processing time of the jobs in this batch, and all jobs of the same batch start and finish together. The waiting time between the BPM and the single machine is restricted by W. The single machine on stage two can process no more than one job at time. The proposed problems have been shown to be NP-hard by Lee and Uzsoy (1999) even in the case when the batch bounded is determined by job sizes in a single BPM.

There are also some research studies that focus on the hybrid flowshop problem with BPM. Xuan and Tang (2007) establish an integer programming model and propose a batch decoupling based Lagrangian relaxation algorithm for a hybrid flowshop problem with batch processing machine in the last stage. Oulamara (2007) deals with the problem of job scheduling in a no-wait flowshop with two batching machines. Bellanger and Oulamara (2009) develop several heuristics with the worst cases analysis for the hybrid flowshop problem where there are several batch processing machines in the second stage. Gong et al. (2010) consider a two-stage flowshop scheduling problem. They propose a priority rule and a worst case with a minimum value of 2. Su and Chen (2010) provide a two-machine flowshop where a batch processing machine is followed by a discrete machine. The objective functions in all the above literature are to minimize the makespan.

For the waiting time constraints in the hybrid flowshop problem with BPM, Su (2003) considers the same problem as ours but with identical job release times for all jobs. A heuristic algorithm and a mixed integer program are proposed. Fu et al. (2011) consider a flowshop scheduling problem with BPM and limited buffer to minimize the mean completion time. A lower bound and two heuristic algorithms are developed.

Mathirajan and Sivakumar (2006) provide a literature review of metaheuristics on the BPM scheduling in semiconductor. Genetic algorithm (GA) is applied by many authors for solving flowshop problem with the batch processing machine (Lu et al. 2008; Chiang et al. 2010; Malve and Uzsoy 2007; Chou et al. 2006). Liao and Huang (2010) propose a Tabu search algorithm for the two machine flowshop problem with batch processing machines. Xu et al. (2012) provide an ACO algorithm and a useful heuristic in the batch processing problem.

In the past few years, AIS has been successfully applied to a large number of combinational optimization problems (Engin and Döyen 2004; Bagheri et al. 2010; Woldemariam and Yen 2010). In this paper, we will improve an immunoglobulin-based AIS algorithm (Chung 2011) called IAIS, for the two BPM problems considered in this paper.

2 Lower Bounds

Two lower bounds, LB_1 and LB_2, are developed here. The final lower bound is determined by $LB = \max(LB_1, LB_2)$, which will be compared with the solution from the proposed algorithm for validation. Xu et al. (2012) provide a lower bound, and we extend it to a lower bound (LB_1). In additional, a new lower bound (LB_2) will also be proposed.

According to Xu et al. (2012), jobs are first indexed in the descending order of release times, so job n is the job with the longest release time. The lower bound based on Xu et al. (2012) is

$$LB_1 = \max_{j \in S_j}\{r_n + p_{1n} + p_{2n}, \min(r_j + p_{1j} + p_{2j} + p_{2n}, r_j + p_{1j} + p_{1n} + p_{2n})\} \\ \text{where } S_j = \{j | r_j + p_{1j} > r_n; s_j + s_n > B\} \tag{1}$$

Property 1 For the considered problem, there exists an optimal schedule where jobs in the same batch are consecutively processed on the machine without idle time in stage 2.

Proof According to Theorem 1 of Su (2003), the makespan of her problem is $\sum x_i + \sum p_{ij}$, which shows that processing jobs in the same batch consecutively at stage 2 can minimize the makespan. For our problem, the makespan is $r_{S_1} + \sum x_i + \sum p_{ij}$ because each batch has a start time and the batch start time is determined by the largest release time of the jobs in the same batch. Thus, Property 1 is also valid in our problem.

According to Property 1, if the single machine at stage 2 is a bottleneck machine, any feasible sequence is optimal. Thus, a lower bound LB_2 can be described as follows.

$$LB_2 = \min_{j \in n}\{r_j + p_{1j}\} + \sum_j p_{2j} \tag{2}$$

3 The Proposed IAIS Algorithm

In this section, the structure of the proposed immunoglobulin-based AIS algorithm (IAIS) is presented. A new encoding and decoding method is proposed here.

In this study, possible schedules are represented by integer-valued strings of length n. The n elements of the strings are the batch numbers and each job belongs to a batch. Then, we sequence the batches by the Earliest Release Time (ERT) order on the BPM. Those strings are accepted as antibodies of the AIS. The algorithm goes up to solution by the evolution of these antibodies. This method is called the batch-based encoding and decoding method. affinity value of each schedule is calculated by function $\text{Affinity}(a) = 1/\text{makspan}(a)$, where a is the considered antibody. From this function, a lower makespan value creates a higher affinity value.

The method of population generation is based on the job's release time. Some notation is presented first. There is a random number $u \sim U(1, 100)$ and a fixed value F. n_b is the number of jobs in the current batch b.

Jobs in a non-increasing order of release times are arranged. The job at the head of the list is selected and placed in the first batch with three constraints as follows.

Constraint 1 The sum of the job sizes in the current batch must be less than or equal to B.

Constraint 2 The sum of the job processing time in stage two must be less than or equal to W.

Constraint 3 $u > F$.

If it does not satisfy any one of the three constraints, a new batch is created. The procedure is repeated until all jobs are assigned to a batch.

3.1 Isotypes Switching

There are four isotype immunoglobulins, IgM, IgG, IgE, and IgA. Each isotype has a different function. If the makespan of a new string in IgM is larger than that of the old one, three isotype immunoglobulins, IgG, IgE, and IgA are randomly selected to be the next mutation method.

Table 1 Comparison results of IAIS algorithm ($n = 20$)

		IAIS		
Instance	LB	C_{max}	Gap	Time
J2S1O1-1	393	434	10.43	2.37
J2S1O1-2	355	391	10.14	2.12
J2S1O1-3	384	464	20.83	2.85
J2S1O1-4	366	414	13.11	2.43
J2S1O1-5	362	366	1.10	2.60
Ave.			11.13	2.47
J2S2O1-1	431	506	17.40	1.81
J2S2O1-2	530	585	10.38	1.83
J2S2O1-3	568	617	8.63	2.32
J2S2O1-4	544	566	4.04	1.86
J2S2O1-5	568	609	7.22	2.21
Ave.			9.53	2.01
J2S1O2-1	476	514	7.98	2.41
J2S1O2-2	476	489	2.73	2.20
J2S1O2-3	466	507	8.80	2.55
J2S1O2-4	410	442	7.80	2.30
J2S1O2-5	401	435	8.48	2.17
Ave.			7.64	2.32
J2S2O2-1	515	590	14.56	1.76
J2S2O2-2	576	596	3.47	1.87
J2S2O2-3	628	647	3.03	2.05
J2S2O2-4	529	572	8.13	2.13
J2S2O2-5	558	610	9.32	2.01
Ave.			7.70	1.96

In IgG, the pairwise mutation is used. For a sequence s, let i and j be randomly selected two positions in the sequence. A neighbor of s is obtained by swapping these two jobs. In IgA, an index value is given to each job calculated by r_j/b. The job with the smallest value is assigned to batch $b-1$ if $b>1$. The job with the largest value is assigned to batch $b+1$. In IgE, for an antibody, let i be a randomly selected position in the sequence. There is a random number $u \sim U(1,100)$ and a fixed value G. If $u < G$, let i be assigned to batch $b+1$; otherwise, to batch $b-1$.

3.2 Elimination

According to the limited space of repertoire, the antibodies are deleted except the best antibody of the current generation. The new antibodies are generated randomly and are replaced with the deleted one.

Table 2 Comparison results of IAIS algorithm $(n = 50)$

			IAIS	
Instance	LB	C_{max}	Gap	Time
J3S1O1-1	837	951	13.62	18.25
J3S1O1-2	650	740	13.85	27.07
J3S1O1-3	891	960	7.74	27.08
J3S1O1-4	717	853	18.97	18.88
J3S1O1-5	766	854	11.49	20.83
Ave.			13.13	22.42
J3S2O1-1	1,229	1,439	17.09	15.19
J3S2O1-2	1,257	1,291	2.70	14.97
J3S2O1-3	1,323	1,380	4.31	14.03
J3S2O1-4	1,389	1,456	4.82	12.32
J3S2O1-5	1,182	1,267	7.19	11.72
Ave.			7.22	13.65
J3S1O2-1	1,055	1,097	3.98	36.51
J3S1O2-2	975	999	2.46	15.03
J3S1O2-3	1,145	1,204	5.15	17.83
J3S1O2-4	1,007	1,065	5.76	14.87
J3S1O2-5	1,110	1,123	1.17	16.21
Ave.			3.71	20.09
J3S2O2-1	1,219	1,456	19.44	16.34
J3S2O2-2	1,297	1,414	9.02	17.00
J3S2O2-3	1,333	1,423	6.75	21.54
J3S2O2-4	1,380	1,468	6.38	13.29
J3S2O2-5	1,202	1,278	6.32	12.84
Ave.			9.58	16.20

4 Computational Results

In this section, we present the results of computational experiments. On an Intel Core 2 CPU (3.0 GHz) with 2.0 GB RAM, all the algorithms were coded in C^{++}.

The benchmark problems of Xu et al. (2012) are used as the data set in the first stage of the proposed problem. The waiting time of each job is limited by $W = 40$, and the processing times of jobs in the second stage are generated by the distributions of $O1 = U(1, 25)$ and $O2 = U(1, 40)$. The generated benchmark problems can be downloaded from http://web.ntust.edu.tw/~ie/index.html. Preliminary tests were conducted to find good parameter settings: $A = 10,\ D = \lfloor n/4 \rfloor, C = 10$ and $F = 10$.

The performance of the algorithms is calculated by Eq. (3). Each instance is run ten times to obtain the best $C_{\max}$ and the average CPU time for IAIS. The computational results for $n = 20, 50, 100$ are summarized in Tables 1, 2, and 3, respectively.

Table 3 Comparison results of IAIS algorithm ($n = 100$)

			IAIS	
Instance	LB	$C_{\max}$	Gap	Time
J4S1O1-1	1,503	1,715	14.11	60.01
J4S1O1-2	1,555	1,686	8.42	60.01
J4S1O1-3	1,441	1,722	19.50	60.01
J4S1O1-4	1,445	1,666	15.29	60.01
J4S1O1-5	1,672	1,805	7.95	60.01
Ave.			13.06	60.01
J4S2O1-1	2,536	2,674	5.44	60.01
J4S2O1-2	2,618	2,656	1.45	40.13
J4S2O1-3	2,521	2,574	2.10	46.59
J4S2O1-4	2,497	2,543	1.84	47.42
J4S2O1-5	2,587	2,616	1.12	56.68
Ave.			2.39	50.17
J4S1O2-1	2,008	2,110	5.08	60.01
J4S1O2-2	2,139	2,154	0.70	60.01
J4S1O2-3	2,075	2,100	1.20	58.44
J4S1O2-4	2,287	2,287	0.00	57.78
J4S1O2-5	1,846	1,988	7.69	60.01
Ave.			2.94	59.25
J4S2O2-1	2,528	2,797	10.64	59.39
J4S2O2-2	2,620	2,646	0.99	47.48
J4S2O2-3	2,526	2,611	3.37	51.70
J4S2O2-4	2,542	2,617	2.95	53.92
J4S2O2-5	2,623	2,639	0.61	57.68
Ave.			3.71	54.03

$$Gap = \frac{Best\ C_{\max} - LB}{LB} \times 100\% \quad (3)$$

From Table 1, the average Gap of IAIS is 9.00 with the maximum of 20.83, and the average computation time of IAIS is 2.19 s. From Tables 2 and 3, the average Gaps of IAIS are 8.41 and 5.52, respectively.

5 Conclusions and Future Research

In this paper, we have examined a two-stage hybrid flowshop problem with a single BPM in the first stage. The problem has the objective of minimizing the makespan, and is NP-hard problem. To evaluate the performance of the IAIS algorithm, it has been tested on the benchmark problems. Computational results have shown that the proposed IAIS algorithm is quite stable and efficient.

Future research may be conducted to exploit the effectiveness of IAIS to other scheduling problems, such as flowshop with multiple batch processing machines with various constraints and objectives. It is also interesting to investigate the performance of IAIS to other combinatorial optimization problems.

References

Bagheri A, Zandieh M, Mahdavi I, Yazdani M (2010) An artificial immune algorithm for the flexible job-shop scheduling problem. Future Gener Comp Sy 26(4):533–541

Bellanger A, Oulamara A (2009) Scheduling hybrid flowshop with parallel batching machines and compatibilities. Comput Oper Res 36(6):1982–1992

Chiang TC, Cheng HC, Fu LC (2010) A memetic algorithm for minimizing total weighted tardiness on parallel batch machines with incompatible job families and dynamic job arrival. Comput Oper Res 37(1):2257–2269

Chou FD, Chang PC, Wang HM (2006) A hybrid genetic algorithm to minimize makespan for the single batch machine dynamic scheduling problem. Int J Adv Manuf Technol 31(3–4):350–359

Chung TP (2011) Heuristics for single- and multi-stage identical parallel machine scheduling problems, Dissertation, National Taiwan University of Science and Technology

Engin O, Döyen A (2004) A new approach to solve hybrid flowshop scheduling problems by artificial immune system. Future Gener Comp Sy 20(6):1083–1095

Fu Q, Sivakumara AI, Lib K (2011) Optimisation of flow-shop scheduling with batch processor and limited buffer. Int J Prod Res 50(8):2267–2285

Gong H, Tang L, Duin CW (2010) A two-stage flow shop scheduling problem on a batching machine and a discrete machine with blocking and shared setup times. Comput Oper Res 37:960–969

Lee CY, Uzsoy R (1999) Minimizing makespan on a single batch processing machine with dynamic job arrivals. Int J Prod Res 37(1):219–236

Liao LM, Huang CJ (2010) Tabu search heuristic for two-machine flowshop with batch processing machines. Comput Ind Eng 60(3):426–432

Lu LF, Zhang LQ, Yuan JJ (2008) The unbounded parallel batch machine scheduling with release dates and rejection to minimize makespan. Theor Comput Sci 396(1–3):283–289

Malve S, Uzsoy R (2007) A genetic algorithm for minimizing maximum lateness on parallel identical batch processing machines with dynamic job arrivals and incompatible job families. Comput Oper Res 34(10):3016–3028

Mathirajan M, Sivakumar AI (2006) A literature review, classification and simple meta-analysis on scheduling of batch processors in semiconductor. Int J Adv Manuf Technol 29(9–10):990–1001

Oulamara A (2007) Makespan minimization in a no-wait flow shop problem with two batching machines. Comput Oper Res 34(4):1033–1050

Su LH (2003) A hybrid two-stage flowshop with limited waiting time constraints. Comput Ind Eng 44(3):409–424

Su LH, Chen JC (2010) Sequencing two-stage flowshop with nonidentical job sizes. Int J Adv Manuf Technol 47(1):259–268

Woldemariam KM, Yen GG (2010) Vaccine-enhanced artificial immune system for multimodal function optimization. IEEE Trans Syst Man Cybern Part B: Cybernetics 40(1):218–228

Xu R, Chen H, Li X (2012) Makespan minimization on single batch-processing machine via ant colony optimization. Comput Oper Res 39(3):582–593

Xuan H, Tang L (2007) Scheduling a hybrid flowshop with batch production at the last stage. Comput Oper Res 34(9):2718–2733

Modeling and Simulation on a Resilient Water Supply System Under Disruptions

X. Liu, J. Liu, S. Zhao and Loon Ching Tang

Abstract We address the resilient water supply system against disruptions in megacities. The study is aimed at developing a quantitative approach for assessing the resilience of water supply system to disruptions. In this context, we propose a decision model incorporates two determinants of system resilience both in robust level and recovery time, and discuss their relationship towards the occurrence of disruptions. Furthermore, a simulation-based model is proposed that incorporates resilience into the proper performances of water supply system, which leads to the impacts of the loss caused by those disruptions. We also present a case study in which the resource scheduling strategies are taken into account to increase the resilience level of water supply system, such as the level of inventory, pipeline-dispatched water, and dispatched water by transportation.

Keywords Disruption · Resilience · Robust · Water supply · System dynamics

X. Liu (✉) · S. Zhao
Department of Industry Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Min-Hang District 200240 Shanghai, People's Republic of China
e-mail: x_liu@sjtu.edu.cn

S. Zhao
e-mail: Sixiang.zhao@hotmail.com

J. Liu
Sino-US Global Logistic Institute, Shanghai Jiao Tong University, 1954 Huashan Road, Xu-hui District 200030 Shanghai, People's Republic of China
e-mail: Liujian007@sjtu.edu.cn

L. C. Tang
Department of Industrial and Systems Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260, Singapore
e-mail: isetlc@nus.edu.sg

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_163,

1 Introduction

The challenges facing today's megacities are daunting, and water management is one of the most serious concerns. The rapidly escalating demands for water, conflicts, shortages, waste, and degradation of water resources make us to rethink its emerge threatens as well as the need to make water systems more resilient (WHO 2009; UN-Habitat 2012). Although the concept of resilience is considered as multidimensional and multidisciplinary, the concept of resilience is becoming more widely recognized the act of rebounding or springing back, and able to quickly return to normal operations from events (Haimes 2009; Aven 2011).

A resilience water system can be defined in this study as the ability to recover its functions to a certain level from the impacts of disruptions, which is consisting of the robustness, redundancy, resourcefulness, and rapidity (Bruneau et al. 2003). Resilience has been applied in water resource system performance evaluation (Hashimoto et al. 1982), water resource system under impact of climatic change (Fowler et al. 2003), water distribution networks (Todini 2000) and sustainability indicators in urban water supply (Milman and Short 2008). Few papers have focus on building a quantitative resilience metric in megacities water supply system.

In this paper, we formulate a water supply system model under disruptions using system dynamics. Then, we provide a decision-making platform for simulating the system resilience of water supply system in different scenarios.

2 Model of Water System Resilience

2.1 Definition of Water System Resilience

Water system resilience under disruption offers significant advantages to promote ability of system function to prepare and response quickly, reduce losses of system. A general method of water resilience system under disruption is presented in Fig. 1.

In Fig. 1, horizontal axis represents the recovery time, and the vertical axis represents the utility function $F(t)$ (units in percentage). We assume well performance of system function is 100 %, while entire disrupted is zero. The robustness is represented by x, so the function loss of system could be represented as $1 - x$. The loss of resilience can be divided into three stages: The first stage ($t_1 \leq t \leq t_2$) is the hazard diffusion process after initial failures, which mainly reflects the absorptive capacity of the system as the degree to which it absorbs the impacts of initial damage and minimizes the consequences, such as cascading failures; The second stage ($t_2 \leq t \leq t_3$) is the delay stage, which reflects that the resource would be effective only after an inevitable delay; The third stage ($t_3 \leq t \leq t'$) is the recovery stage. t' is the most satisfied recovery time integrating

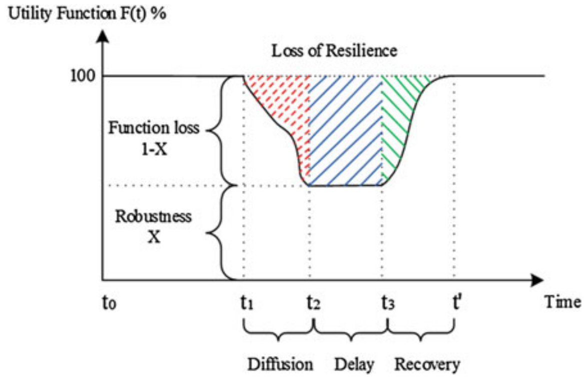


Fig. 1 Quantitative measure method for the loss of water system resilience

cost and demand factors. The loss of resilience can be calculated by the following equation:

$$LR(x,t) = \frac{\int_{t_1}^{t_2}(1-x)dt + (1-x)(t_3-t_2) + \int_{t_3}^{t'}(1-x)dt}{T} \quad (1)$$

Based on the previous definition, it's easily to get the resilience as follow:

$$R(x,t) = 1 - LR(x,t) \quad (2)$$

2.2 Water System Resilience Under Different Strategies

In a water system, the resilience is varying with different strategies during disruptions, such as resource allocation, scheduling, probability of consequence, and information uncertainty, et al. In this context, the 3-Dimensional water system resilience method can be shown as Fig. 2 by adding the strategy axis for resource

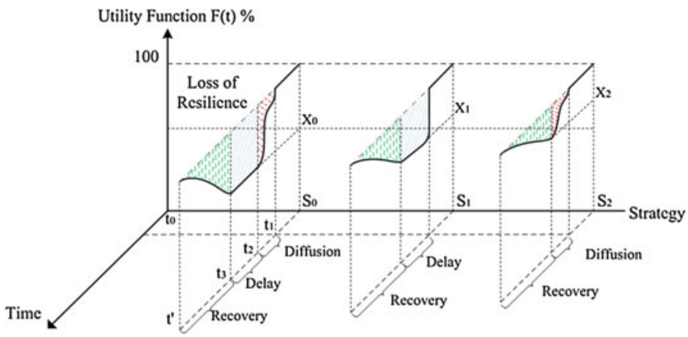


Fig. 2 Water system resilience under different strategies

axis. The key point is how to make the strategies during the different stages to minimize the total loss of system resilience.

3 System Dynamic Model of Water Supply System

The system dynamic as powerful tool could effectively modeling and simulation the strategies for water supply system. In this section, we construct system dynamic model to describe the system resilience of water supply system under disruption, also the state of system can be captured by different strategies to achieve the resilience levels.

3.1 Forming of the Causal Loop Diagram

For a water supply system, system resilience means in this study the satisfaction rate (SR) of water supply system, is often used to assess resilient of water supply. As stated above, system resilience of water supply system is to minimize the total loss area over the time horizon. In another word, the problem could be convert into maximize the satisfaction rate of water supply system. The SR depends on the total resilience level $R(x, t)$ and adjusting different strategies. The conceptual and causal diagram for water supply system under disruption is show in Fig. 3.

The causal loop diagram is described by causal and effect relationship, using the "+" "−" means that the two variables change in the same or opposite direction, the signs B represents negative feedback loop that means balance, equilibrium and stasis. System dynamics model of water supply consists of five major sub-systems: (B4) water reservoir construction; (B3) water demand management; (B1) dispatched-water by transportation water; (B2) pipeline-dispatched water; (B5) water demand and usage. Where (B4) represents the expending the water reservoir strategies caused by water supply shortage for short term; (B1), (B2), (B3) represent the different strategies under disruption for short term.

3.2 Stock Flow Diagram of Water Supply System

Based on the causal loop diagram, stock-flow diagram of water supply system is developed as Fig. 4. In normal condition, a balance between supply rate and usage rate keeps adequate water supply and a normal water level of reservoir. When loss of supply happens and exceeds its absorption capacity, water dispatch is needed to cover the supply shortfall.

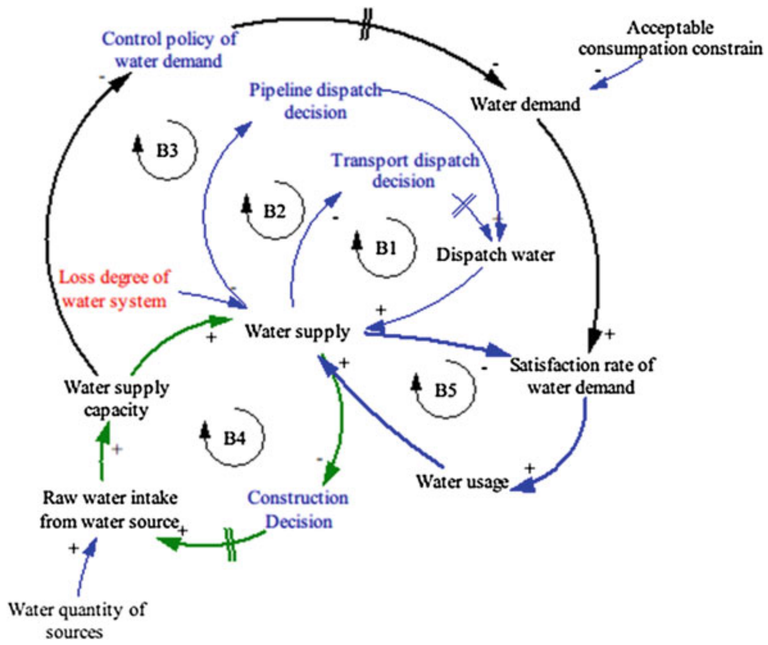


Fig. 3 Causal loop diagram for water supply system under disruption

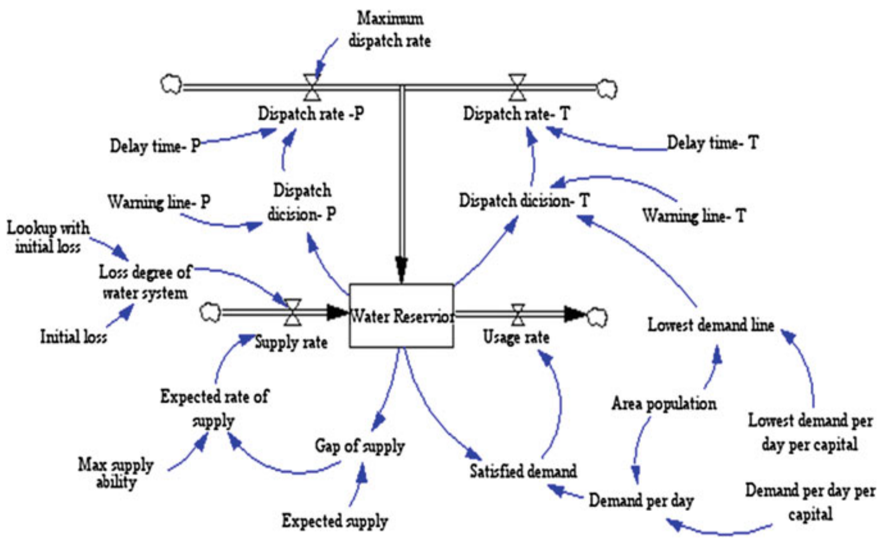


Fig. 4 Stock flow diagram for water supply system under disruption

4 Case Study

Chenhang reservoir is an important reservoir in Shanghai, which covers more than 3 million population's water demand. The reservoir capacity is designed to be 9.14 million m^3, and effective reservoir is 9 million m^3. Chenhang reservoir is facing threatens rising caused by salt tide. The objective is to improve its supply capacity and maximize the satisfaction rate of water supply under different strategies using the proposed model.

4.1 Initial Conditions and Assumptions

We assume effective reservoir as inventory that is one of decision variables of system output. Supply capacity is 1.6 million m^3/day as business as usual according to engineer design, and accounts for about 16.2 % of total supply capacity. Due to the impact of climate change, the quality of water intakes from Yangtze revers are often not up to standard from December in last year to the April in next year. The most extremely case is that continuous time of salt tide is approximately 24 days based on the history data record from Shanghai Water Authority. Assume that the water reservoir is equal to inventory, then the supply capacity is primary depend on the inventory, pipeline-dispatched water, and dispatched water by transportation during this period. So the initial loss, continuous time, supply capacity, and initial inventory level can be obtained.

4.2 Simulation Results and Discussions

Three scenarios are assumed in the sensitivity test by assigning three kinds of loss, continuous time, warning line of pipeline-dispatched. The results can be obtained and demonstrated the Table 1.

The dispatch rate of pipeline water and dispatch rate of transportation water would depend on the setting of the warning line of pipeline-dispatched and

Table 1 The result of salt tide scenario for Chenhang reservoir

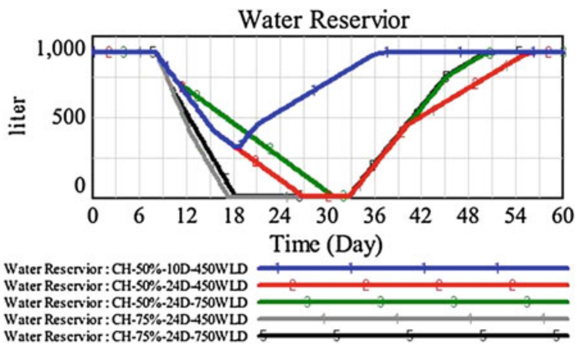
Case	Loss	CT	WL (P)	Dispatch (P)	Dispatch (T)	SR
Unit	%	Day	Million m^3	Million m^3	Million m^3	%
1	50	10	450	180	0	95
2	50	24	450	750	6	76.77
			750	108	150	90.84
3	75	24	450	810	325	60.7
			750	1,050	350	65

warning line of transportation-dispatched that triggered by the lowest demand line correspondently. The dispatching strategies toward specific targets are simulated and demonstrated by satisfied demand via adjusting different parameters so that the system resilience could be calculate by the changes of satisfied demand. Assume that system resilience meet the customer demands when satisfaction rate reach 95 %, the simulation result for water reservoir, dispatch rate of pipeline water, dispatch rate of transportation water and satisfaction rate are show in the following 4 Figures.

From the above 4 Figures, one can find:

1. Assume the initial loss level is 50 %, and warning line of pipelined dispatch is 450 m^3. Figure 5 shows that water reservoir of scenario 1 is not significant influence for system resilience when continuous time is 10 days; while continuous time is 24 days, the water reservoir will continuously decline. The improve redundancy of design reservoir could enhance the robustness level that withstand disruption to water supply system.
2. Assume the initial loss level is 50 %, and continuous time is 24 days, the Fig. 6 provide the estimate level on the change in dispatch rate of pipeline water with different trigger strategies of pipeline supply. The simulation results show that the dispatch rate of pipeline water is closely related to the warning line of pipelined dispatch. Comparing Fig. 7 with Fig. 8, it is illustrated that the way of dispatch rate for pipeline water is prior to the dispatch rate for transportation water based on cost considerations. The improve redundancy of scheduling capacity could enhance the robustness level that withstand disruption to water supply system in short term.
3. Assume the continuous time is 24 days, we compare scenario 2, 3, 4, 5 under different initial loss and warning line of pipelined dispatch, the Fig. 8 shows the estimate level for satisfaction rate when the corresponding strategies are taken. Compare 75 % initial loss (scenario 4 and 5) with 50 % initial loss (scenario 2 and 3), the degree of initial loss and reduce the probability to disruption is more crucial to the system resilience.

Fig. 5 Water reservoir



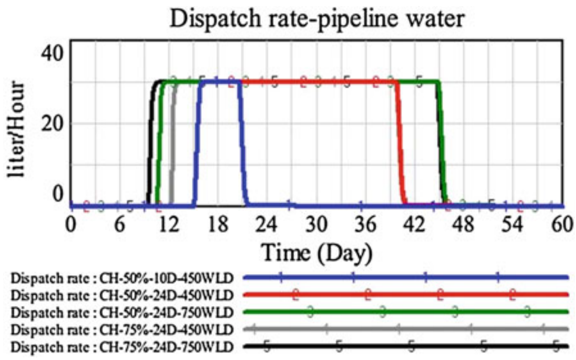


Fig. 6 Dispatch rate of pipeline water

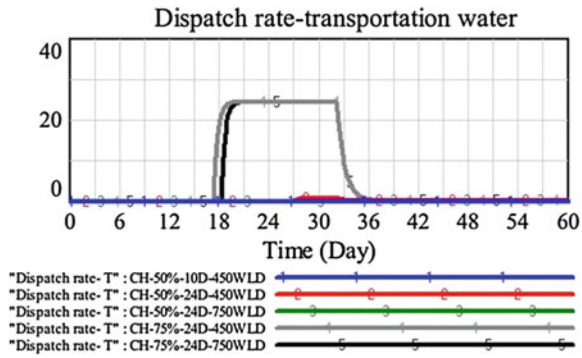


Fig. 7 Dispatch rate of transportation water

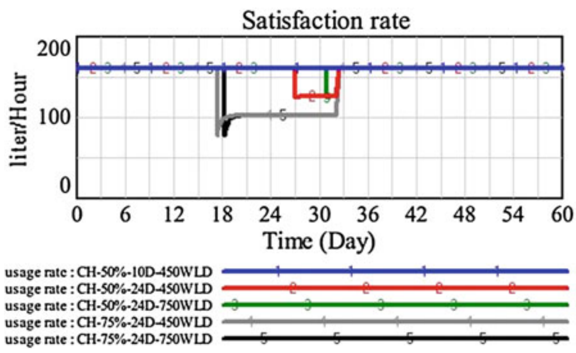


Fig. 8 Satisfaction rate

5 Conclusion and Further Research

We have developed a system dynamics model of resilience water supply system with strategies consideration under disruptions. The general properties of the system resilience are very depended on the robustness and recovery time. Based on the uncertainty of initial loss, continuous time, strategies taken consideration, we have extended both the theoretical and system dynamics models to simulate the scenarios happened in Shanghai. The resilience of water supply system has been extended by analysis of robustness, uncertainty, and adoptive supply ability.

Acknowledgments This research is supported by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE), and NSFC (91024013, 91024131), the authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Aven T (2011) On some recent definitions and analysis frameworks for risk, vulnerability, and resilience. Risk Anal 31(4):515–522

Bruneau M, Chang SE, Eguchi RT et al (2003) A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra 19(4):733–752

Fowler HJ, Kilsby CG, O'Connell PE (2003) Modeling the impacts of climatic change and variability on the reliability, resilience, and vulnerability of a water resource system. Water Resour Res 39(8):0

Haimes YY (2009) On the definition of resilience in systems. Risk Anal 29(4):498–501

Hashimoto T, Stedinger JR, Loucks DP (1982) Reliability, resiliency, and vulnerability criteria for water resource system performance evaluation. Water Resour Res 18(1):14–20

Milman A, Short A (2008) Incorporating resilience into sustainability indicators: an example for the urban water sector. Global Environ Change 18:758–767

Todini E (2000) Looped water distribution networks design using a resilience index based heuristic approach. Urban Water 2(2):115–122

UN-Habitat (2012) State of the World's Cities 2012/2013: Prosperity of Cities. http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3387. Accessed 10 Apr. 2013

WHO (2009) Vision 2030: The resilience of water supply and sanitation in the face of climate change. http://www.who.int/water_sanitation_health/publications/9789241598422/en/. Accessed 13 April 2013

A Hybrid ANP-DEA Approach for Vulnerability Assessment in Water Supply System

C. Zhang and X. Liu

Abstract Vulnerability reflects the potential of disrupting the whole system to some extent when the system is exposed to hazard. One of the most important issues of the indicator-based vulnerability assessment problem is to determine the weights of vulnerability indicators, especially when they are correlated with each other in multiple dimensions (i.e., physical, functional and organizational). In this paper, a framework for assessing vulnerability of critical infrastructure system is identified and applied to the evaluation in a water supply system. A complete critical infrastructure system vulnerability index is developed, which contains dimensions of "protection and defense", "quick response after disaster", "maintenance and recovery capacity" and "possible damage to system". A quantitative method, integrating analytic network process (ANP) and game cross-efficiency data envelopment analysis (DEA) model, is proposed to analyze the vulnerability of interdependent infrastructures. Finally, the assessed vulnerability level of each infrastructure in water supply system is graded into four classes.

Keywords Vulnerability · Assessment · Data envelopment analysis · Analytic network process

C. Zhang (✉) · X. Liu
Department of Industry Engineering and Logistic Management, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
e-mail: xiaochongzi@sjtu.edu.cn

X. Liu
e-mail: X_liu@sjtu.edu.cn

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_164,

1 Introduction

Since the interconnections (both physical and logical) between modern infrastructures become more complex, lifeline systems are more vulnerable to disasters. So it is important for the government to select critical elements of the system and protect them with highest priority. However, how to assess the vulnerability of these elements is still a huge challenge for researchers.

Vulnerability is an important attribute of critical infrastructure systems. The concept of vulnerability is still evolving and has not yet been established. Different researchers have different definitions on vulnerability. TurnerII et al. (2003) defines it as the degree to which human and environmental systems are likely to experience harm due to a perturbation or stress, Aven (2011) defines it as the manifestation of the inherent states of the system that can be subjected to a natural hazard or be exploited to adversely affect that system. Aggregating the existing definitions (TurnerII et al. 2003; Barbat and Carreño 2010), we define vulnerability in this study as follows: vulnerability reflects the potential of disrupting the whole system to some extent when the system is exposed to hazard.

There are various approaches for characterizing vulnerability. The first one is a multi-dimensional indicator framework which needs weights assignment, such as expert decision and analytic network process (ANP) (Aven 2011; Grubesic and Matisziw 2007; Piwowar et al. 2009). The second one is network modeling approaches (Qiao et al. 2007; Scaparra and Church 2008a, b), which is mainly based on the network topology of infrastructures, such as maximal flow model, shortest path model and network flow model. The third one is probabilistic modeling (Sultana and Chen 2009; Doguc and Ramirez-Marquez 2009), which is usually used when analyzing inter-dependencies and cascading failures.

In this paper, a hybrid ANP and Cross-Efficiency DEA approach is proposed to solve this multi-criteria assessment problem. The remainder of this paper is organized as follows. In Sect. 2, the indicator system for vulnerability evaluation and value functions of selected indicators are described. Section 3 presents the proposed hybrid ANP-DEA approach for vulnerability assessment. Section 4 illustrates the proposed evaluation framework via a case study. Finally Sect. 5 concludes this paper.

2 Indicators for Vulnerability Assessment

Four dimensions are considered for constructing the vulnerability index in this study: (1) Protection and Defense (reflecting the exposure of system to disasters); (2) Quick Response after disaster; (3) Maintenance and recovery capacity; (4)

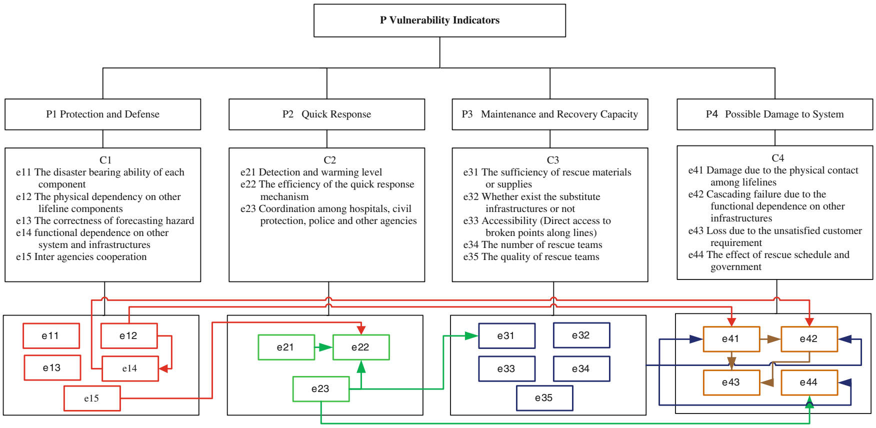


Fig. 1 The ANP decision structure for vulnerability evaluation

Possible damage to system (Ezell 2007). The vulnerability indicators are demonstrated in Fig. 1.

Values of qualitative indicators are acquired by ranking or categorizing performed by experts. For clearness, selected parameters need to be explained especially. "Functional or logical interdependency" values are obtained from the correlation matrices of infrastructures and "the sufficiency of rescue materials" are calculated using the following function: "the realistic storage of rescue materials/ the expected storage of rescue materials".

3 The Proposed Methodology

The vulnerability evaluation processes are shown in Fig. 2.

3.1 Bounds of weights for each indicator by ANP

Variables:

1) CI_i ($i = 1, 2, \ldots, n$) means the ith in infrastructure to be evaluated;
2) The total number of DMs (Decision makers) involved in the evaluation is K and $k = 1, 2, \ldots, K$ expresses the kth expert;
3) The weight of the ith cluster, the jth element of the kth expert is represented by $\hat{w}_{ijk}$ ($i = 1, 2, \ldots, 4$, $j = 1, 2, \ldots, 4$, $k = 1, 2, \ldots, K$).

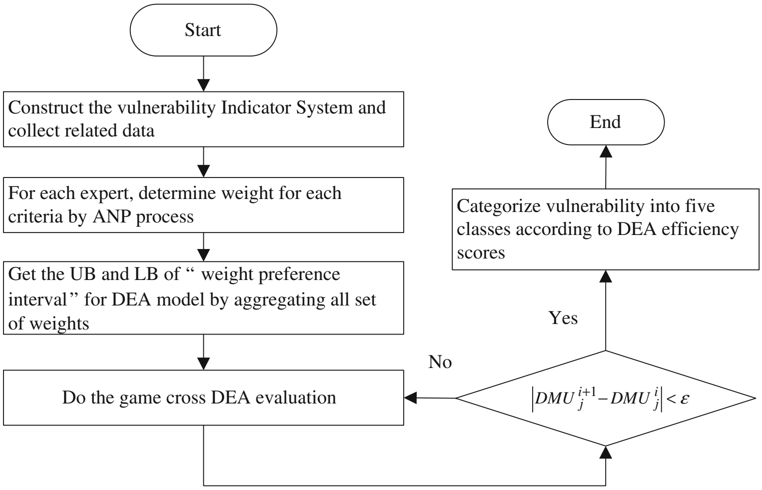


Fig. 2 Hybrid ANP-DEA vulnerability evaluation process

Analytic network process (ANP) is used for determining the upper and lower limit of weights. It is a relatively simple and systematic approach that can be used by decision makers (Khadivi and Fatemi Ghomi 2012). It allows both interaction and feedback within clusters of elements and between clusters. Such feedback well captures the complex effects of interplay in human society, especially when risk and uncertainty are involved. The Decision structure of this process is shown as Fig. 1 and Super Decision 1.6.0 can be used to complete the ANP process for each expert and get the weight of each parameter, referred to as $\hat{w}_{ijk}$ ($i = 1, 2, \ldots, 4$, $j = 1, 2, \ldots, 4$, $k = 1, 2, \ldots, K$).

Then, to eliminate the impact of subject bias of single expert, weights from all DMs should be aggregated. By calculating the mean value $\bar{w}_{ij}$ and variance E_{ij}^2, the LB and UB of weight interval can be given, as is shown in Eq. 1.

$$\hat{w}_{ij} \in [\bar{w}_{ij} - 1.96\delta_{ij}, \bar{w}_{ij} + 1.96\delta_{ij}] = [\hat{w}_{ij\min}, \hat{w}_{ij\max}] \quad (1)$$

3.2 DEA Game Cross-Efficiency Model

Charnes et al. (1978) proposed the initial DEA model (CCR model) for evaluating the relative efficiencies of a set of decision making units (DMUs). The application of DEA as an alternative multi-criteria decision making (MCDM) tool has been gaining more attentions in the literatures because it can find optimal weights for all relevant inputs and outputs of each DMU in a relatively objective and fair way (Wu et al. 2009). The DEA game cross-efficiency model, which was proposed by Wu and Liang (2012), can obtain unique game cross-evaluation scores which constitute a Nash equilibrium point. This model is used for evaluating the vulnerability index here.

In the model, the input and output indicators are represented by m_i and s_j respectively. The indicators which have positive correlations with vulnerability are defined as "output" while others are defined as "input". The ith input and rth output of DMU_j are represented as x_{ij} and y_{rj} respectively.

The steps of this DEA game cross-efficiency method are listed as follows.

Step 1: Add the bound of weights to the initial CCR model as constraints and solve the model.

The bounds of input and output indicators in DEA model are represented by [w_{imin}, w_{imax}] and [μ_{imin}, μ_{imax}] separately, and the constraint set of each indicator in this step is derived from LB and UB. The game cross DEA model is illustrated as model 2. Let $t = 1$, $\alpha_j = \alpha_j^1 = \bar{E}_j$, and solve the model.

$$max \sum_{r=1}^{s} \mu_r y_{rd} = \theta_d$$

$$s.t \sum_{i=1}^{m} w_{ij}^d x_{il} - \sum_{r=1}^{s} \mu_{rj}^d y_{rl} \geq 0 l = 1, 2, \ldots, n$$

$$\sum_{i=1}^{m} \omega_i x_{id} = 1, \tag{2}$$

$$\begin{aligned} & w_i - \frac{w_{i\min}}{w_{1\min}} w_1 \geq 0, \ w_i - \frac{w_{i\max}}{w_{1\max}} w_1 \leq 0, \\ & \mu_i - \frac{\mu_{i\min}}{\mu_{1\min}} \mu_1 \geq 0, \ \mu_i - \frac{\mu_{i\max}}{\mu_{1\max}} \mu_1 \leq 0, \\ & \omega_i \geq 0, i = 1, 2, \ldots, m, \ \mu_r \geq 0, r = 1, 2, \ldots, s. \end{aligned}$$

Model 2 is solved n times (one for each d) for each alternative i, thus each DMU corresponds to a set of optimal weights: w^*_{1d}, w^*_{2d},…,w^*_{md}, μ^*_{1d}, μ^*_{2d}, …, μ^*_{sd}. Calculate the game cross-evaluation score for each DMU by Eq. 3.

$$\bar{E}_j = \frac{1}{n} \sum_{d=1}^{n} E_{dj} = \frac{1}{n} \sum_{d=1}^{n} \left(\frac{\sum_{r=1}^{s} \mu_{rd}^* y_{rj}}{\sum_{i=1}^{m} w_{id}^* x_{ij}} \right) \quad d, j = 1, 2, \ldots, n \tag{3}$$

Table 1 Organizational structure of water system

Organizational structure of water system													
Raw water system			Transmit		Treat and store				Distribution				Control
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Raw water resources	Reservior	Power supplies	Pipelines	Power supplies	Tanks	Settling pond	Facilities	Power supplies	Distribution network	Valves	Pump station	Power supplies	SCADA

Table 2 Score of vulnerability evaluation

Infrastructure no.	1	2	3	4	5	6	7
Vulnerability index	0.805	0.870	0.506	0.557	0.966	0.983	0.955
Infrastructure no.	8	9	10	11	12	13	14
Vulnerability index	0.893	0.456	0.680	0.958	0.964	1	0.442

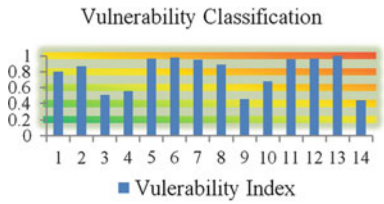


Fig. 3 The grade of infrastructure

Step 2: Add a new constraint, as is shown in Eq. 4, to the DEA model and solve this model again. Then, define $\alpha_j^{t+1} = \frac{1}{n}\sum_{d=1}^{n}\sum_{r=1}^{s}\mu_{rj}^{d*}(\alpha_d^t)y_{rj}$, where $\mu_{rj}^{d*}(\alpha_d^t)$ represents the optimal value of μ_{rj}^{d}.

$$\alpha_d \times \sum_{i=1}^{m} w_{ij}^{d} x_{id} - \sum_{r=1}^{s} \mu_{rj}^{d} y_{rd} \leq 0 \tag{4}$$

Step 3: If $|\alpha_j^{t+1} - \alpha_j^t| \geq \varepsilon$ for some j, where ε is a specified small positive value, then let $\alpha_j^t = \alpha_j^{t+1}$ and return to Step 2, else if $|\alpha_j^{t+1} - \alpha_j^t| < \varepsilon$ for all j, then stop and α_j^{t+1} is the final game cross-evaluation score given to DMU_j. Finally rank the vulnerability according to the final efficiency scores.

4 Numerical Example

In this section, we examine a numerical example using the above hybrid ANP-DEA method to illustrate its validity in evaluating vulnerability for water supply system. Assume that City X locates at earthquake-prone regions, now the vulnerability of its water system against earthquake need to be assessed for prevention of disasters. As is shown in Table 1, the organizational structure of water system is composed of 14 infrastructures which need to be evaluated.

The data and specific calculation process are omitted due to the limited space, only the final DEA efficiency score of each DMU is presented in Table 2.

During the process, two virtual infrastructures, which are used as the benchmark for the most and the least vulnerable infrastructures are introduced into the analysis. In this study, the UB and LB of the vulnerability index are 1 and 0.2 and accordingly, the vulnerability is categorized into four levels. Figure 3 shows the ultimate ranking of each infrastructure.

5 Conclusions

A hybrid ANP-DEA approach for infrastructure vulnerability assessment is proposed in this paper. The difficulty of infrastructure vulnerability evaluation mainly comes from the complexity of lifeline system and the multi-dimensional nature of vulnerability. The incorporation of ANP and DEA game cross efficiency method make the evaluation more objective and fair. Since disasters are always dynamic process and evaluation indicators may keep changing with the evolvement of disasters, the suggestion for future researches is that a dynamic model can be considered for treating the uncertainties and dynamics.

Acknowledgments This research is partly supported by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) and the NSFC (91024013, 91024131).

References

Aven T (2011) On some recent definitions and analysis frameworks for risk, vulnerability, and resilience. Risk Anal 31:515–522

Barbat AH, Carreño ML (2010) Seismic vulnerability and risk evaluation methods for urban areas. A review with application to pilot area. Struct Infrastruct Eng 6:17–19

Charnes A, CooperWW Rhodes E (1978) Measuring the efficiency of decision-making units. Eur J Oper Res 2:429–444

Doguc O, Ramirez-Marquez JE (2009) A generic method for estimating system reliability using Bayesian networks. Reliab Eng Syst Saf 94:542–550

Ezell BC (2007) Infrastructure vulnerability assessment model (I-VAM). Risk Anal 27(3):571–583

Grubesic TH, Matisziw TC (2007) A typological framework for categorizing infrastructure vulnerability. GeoJournal 78:278–301

Khadivi MR, Fatemi Ghomi SMT (2012) Solid waste facilities location using of analytical network process and data envelopment analysis approaches. Waste Manage (Oxford) 32:1258–1265

Piwowar J, Châtelet E, Laclémence P (2009) An efficient process to reduce infrastructure vulnerabilities facing malevolence. Reliab Eng Syst Saf 94:1869–1877

Qiao J, Jeong D, Lawley M, Richard JPP, Abraham DM, Yih Y (2007) Allocating security resources to a water supply network. IIE Trans 39:95–109

Scaparra MP, Church RL (2008a) A bilevel mixed-integer program for critical infrastructure protection planning. Comput Oper Res 35:1905–1923

Scaparra MP, Church RL (2008b) An exact solution approach for the interdiction median problem with fortification. Eur J Oper Res 189:76–92
Sultana S, Chen Z (2009) Modeling flood induced interdependencies among hydroelectricity generating infrastructures. J Environ Manage 90:3272–3282
TurnerII BL, Kasperson RE et al (2003) A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci USA 100:8074–8079
Wu J, Liang L (2012) A multiple criteria ranking method based on game cross-evaluation approach. Ann Oper Res 197:191–200
Wu J, Liang L, Chen Y (2009) DEA game cross-efficiency approach to Olympic rankings. Omega 34:909–918

An Integrated BOM Evaluation and Supplier Selection Model for a Design for Supply Chain System

Yuan-Jye Tseng, Li-Jong Su, Yi-Shiuan Chen and Yi-Ju Liao

Abstract In a supply chain, the design of a product can affect the activities in the forward and reverse supply chains. Given a product requirement, the components of the product can be designed with different specifications. As a result, the bill of material and the manufacturing activities will be different. Therefore, in different design alternative cases, there can be different decisions of supplier selection for producing the product. In this research, a new model for supplier selection and order assignment in a closed-loop supply chain system is presented. First, the design information of the design alternative cases are analyzed and represented in the form of a bill of material model. Next, a mathematical model is developed for supplier selection and order assignment by evaluating the design and closed-loop supply chain costs. Finally, a solution model using the particle swarm optimization method with a new encoding scheme is presented. The new model is developed to determine the decisions of design evaluation and supplier selection under the constraints of capacity and capability to achieve a minimized total cost objective. In this paper presentation, an example product is illustrated. The test results show that the model and solution method are feasible and practical.

Keywords Supply chain management · Closed-loop supply chain · Product design · Bill of material · PSO

1 Introduction

To design a product, there may be different ways to design the detailed specifications of the components and product. In order to satisfy the product requirement, different design alternative cases can be utilized to design the product. In the

Y.-J. Tseng (✉) · L.-J. Su · Y.-S. Chen · Y.-J. Liao
Department of Industrial Engineering and Management, Yuan Ze University, Chung-Li, Taoyuan, Taiwan
e-mail: ieyjt@saturn.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_165,

different design alternative cases, the components of the product can be designed with different shapes, dimensions, different materials, and other specifications. If the components and product are designed differently, the bill of material (BOM) of the product will be different. As a result, the downstream manufacturing activities will be affected. Therefore, the different design alternative cases can affect the decisions in the supplier selection and order assignment. It is necessary to evaluate how the different design alternative cases affect the supply chain.

In a product life cycle, the supply chain that performs the common activities such as manufacturing, assembly, transportation, and distribution can be described as a forward supply chain. In the reverse direction, the reverse supply chain performs the activities to process a product at the end of the product life cycle. The activities in a reverse supply chain can include recycle, disassembly, reuse, remanufacturing, and disposal.

If several design cases are available, the different design alternative cases can affect the decisions in supplier selection in the closed-loop supply chain. It is necessary to consider the design alternative cases prior to the actual production of the product. The different design alternatives cases can be modeled and analyzed based on different objectives to determine the best design. In addition, the order assignment and supplier selection can be analyzed and evaluated for the design.

In this research, the information of design of the components and the product is represented as BOM information. In the forward supply chain, the information of the components and product are represented as a BOM model. In the reverse supply chain, the components and product are represented as a reverse bill of material (RBOM) model. A design for closed-loop supply chain model is developed to find the suitable design case and the suitable suppliers in an integrated way (Fig. 1).

In the previous research, the problem and models of supplier selection have been discussed in the papers of Kasilingam and Lee (1996) and Humphreys et al. (2003). A literature review of supply chain performance measurement was presented in Akyuz and Erman (2010). The topics of reverse logics and closed-loop supply chains have been presented in French and LaForge (2006) and Kim et al. (2006). In Schultmann et al. (2006) and Alshamrani et al. (2007), the problems of close-loop supply chain were modeled and discussed. In Sheu et al. (2005) and Lu et al. (2007), the models for green supply chain management were presented. In Ko and Evans (2007), a genetic algorithm-based heuristic for the dynamic integrated forward and reverse logistics network was developed. In Yang et al. (2009), an optimization model for a closed-loop supply chain network was presented. In Kannan et al. (2010), the closed loop supply chain model was modeled and solved using a genetic algorithm approach. Based on the review, the product design and the supplier selection in the closed-loop supplier chain have not been evaluated in an integrated way. Therefore, in this research, a model for integrated evaluation of product design and the closed-loop supply chains is developed.

The cost items for the design activities include function, dimension, material, assembly operation, and manufacturing operation. The cost items for the forward supply chain activities include manufacturing cost, purchase cost, and transportation cost. The cost items for the reverse supply chain activities include recycle

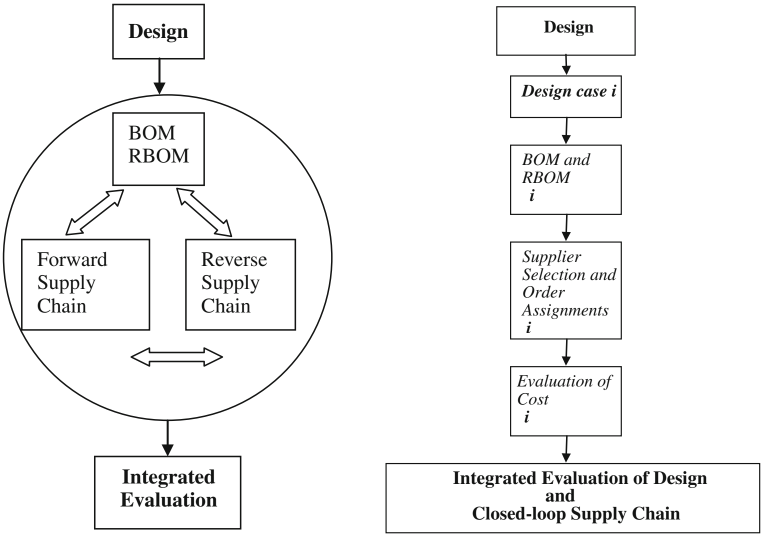


Fig. 1 The concept and model of design for closed-loop supply chain

cost, disassembly cost, reuse cost, remanufacturing cost, and disposal cost. The total cost is the sum of the above cost items. The constraints include the capacity and capability constraints. The mathematical model is developed to select the supplier and determine the order assignment for each supplier under the constraints of capacity and capability to achieve a minimized total cost objective.

In the previous research, the PSO algorithm has been successfully applied to many continuous and discrete optimizations (Kennedy and Eberhart 1997). The research in Banks et al. (2008) reviewed and summarized the related PSO research in the areas of combinatorial problems, multiple objectives, and constrained optimization problems. In this research, the solution method using the PSO approach is utilized. In the presentation, the test results are presented and discussed.

In this paper, Sect. 1 presents an introduction. Section 2 describes the mathematical model and PSO model of design for closed-loop supply chain. In Sect. 3, the implementation and application are illustrated and discussed. Finally, a conclusion is presented in Sect. 4.

2 The Design for Closed-Loop Supply Chain Model

2.1 Bill of Material and Reverse Bill of Material Models for Representation Design of a Product

In this research, the information of design of the components and product is represented in the form of a bill of material (BOM). In the forward supply chain,

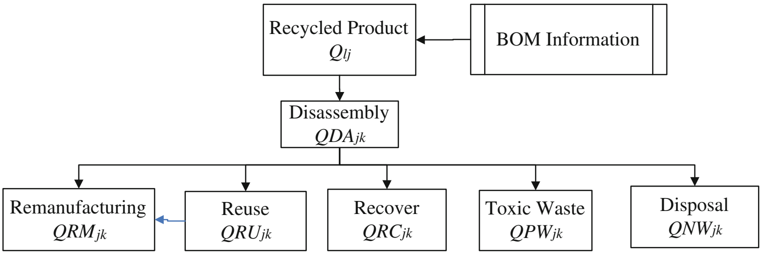


Fig. 2 The format of a reverse bill of material (RBOM)

the information of the components and product are represented as a BOM model. In the reverse supply chain, the components and product are represented as a reverse bill of material (RBOM) model (Fig. 2).

2.2 The Design for Closed-Loop Supply Chain Model

In this research a design for closed-loop supply chain model is presented. A brief description of the notations is as follows.

l An order $l \in L$, $L = L_F \cup L_R$
L All the orders
LF Orders in the forward supply chain
LR Orders in the reverse supply chain
i A plant $i \in I, I = I_p \cup I_o$
I All the plants
j A product $j \in J_l$, J_l represents the products in order l
k A component
x_{li} A 0–1 decision variable representing whether order l is assigned to plant i
TC Total cost
TPC Cost of forward supply chain
TRC Cost of reverse supply chain
TRB Value of reverse supply chain
TUB Value of reuse supply chain
TMB Value of remanufacturing
TCB Value of recovery
TUC Cost of reuse operation
TNC Cost of remanufacturing operation
TCC Cost of recovery operation
TAC Cost of disassembly operation
TWC Cost of disposal operation
TSC Transportation cost
TMC Material cost

TFC Manufacturing cost

The model is briefly described as follows.

$$\text{Min } TC = TPC + TRC - TRB \quad (1)$$

$$TPC = TOC + TSC + TMC + TFC \quad (2)$$

$$TRC = TUC + TNC + TCC + TAC + TWC \quad (3)$$

$$TRB = TUB + TMB + TCB \quad (4)$$

$$TUC = \sum_{l \in L_R} \sum_{i \in I_p} \sum_{j \in J_l} \sum_{k \in K_{lj}} Q_{lj} \times QRU_{jk} \times CRU_{ijk} \times x_{li} \quad (5)$$

$$TNC = \sum_{l \in L_R} \sum_{i \in I_p} \sum_{j \in J_l} \sum_{k \in K_{lj}} Q_{lj} \times QRM_{jk} \times CRM_{ijk} \times x_{li} \quad (6)$$

$$TCC = \sum_{l \in L_R} \sum_{i \in I_p} \sum_{j \in J_l} \sum_{k \in K_{lj}} Q_{lj} \times QRC_{jk} \times CRC_{ijk} \times x_{li} \quad (7)$$

$$TAC = \sum_{l \in L_R} \sum_{i \in I_p} \sum_{j \in J_l} \sum_{k \in K_{lj}} Q_{lj} \times QDA_{jk} \times CDA_{jk} \times x_{li} \quad (8)$$

2.3 The Solution Model Using the Particle Swarm Optimization Method

The PSO algorithm is utilized for finding the solutions in the model. The PSO algorithm is an evolutionary computation method introduced by Kennedy and Eberhard (1997). In the PSO method, a particle is defined by its position and velocity. To search for the optimal solution, each particle adjusts its velocity according to the velocity updating equation and position updating equation.

$$v_{id}^{new} = w_i \cdot v_{id}^{old} + c_1 \cdot r_1 \cdot (p_{id} - x_{id}) + c_2 \cdot r_2 \cdot \left(p_{gd} - x_{id}\right) \quad (9)$$

$$x_{id}^{new} = x_{id}^{old} + v_{id}^{new} \quad (10)$$

This research applies the PSO method to the problem by developing a new encoding and decoding scheme. In the developed encoding scheme, a particle is represented by a position matrix. The elements in the position matrix are denoted as h_{pj}, where p represents a particle and l represents an order. The encoding of the position matrix is as follows

$$PL = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ p \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \cdots & l \end{array} \\ \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1l} \\ h_{21} & h_{22} & \cdots & h_{2l} \\ \vdots & \vdots & \ddots & \vdots \\ h_{p1} & h_{p2} & \cdots & h_{pl} \end{bmatrix}_{P \times L} \end{array} \tag{11}$$

where h_{pj} represents the position matrix of particle p,
where $p = 1, \ldots, E$, and $l = 1, 2, \ldots, L$.

The fitness function represents the objective of the PSO enumeration. The objective as shown in (12) is used as the fitness function.

$$\text{Min } Fitness = \text{Min } TC = TPC + TRC - TRB \tag{12}$$

The position matrix of a particle can be decoded into an order assignment set where each order l is assigned to a suitable plant i to achieve the objective of the fitness function. The assigned plant i can be determined by decoding h_{pj}. The total number of plants I is divided into several numerical zones. The assignment of order l to plant i can be determined by searching the numerical zone where h_{pj} falls in. After the PSO enumeration, the final particle represents an order assignment arrangement set in the closed-loop supply chain.

3 Implementation and Test Results

The mathematical model and the PSO solution model was implemented and tested. An example is modeled and illustrated. Product A is a simplified mobile phone as shown in Fig. 3. The BOM is shown in Fig. 4. The related data are modeled for implementation and testing. The cost items in the forward and supply chain are also modeled. Using the input data of the example product, the mathematical model are modeled and solved using the PSO model. The test results show that the models are feasible and efficient for solving the problem.

4 Conclusions

In this research presentation, the concept of design for closed-loop supply chain is developed. A mathematical model and PSO solution model is presented for integrated evaluation of the design and its closed-loop supply chain. The related BOM and RBOM are developed to represent the design information. The costs in design, forward supply chain, and reverse supply chain are modeled. A mathematical

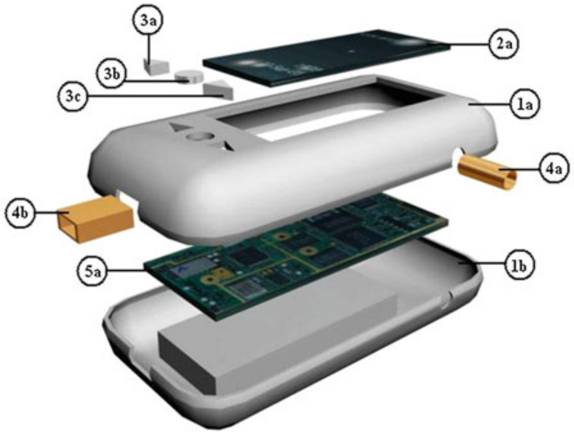


Fig. 3 Product A is a simplified mobile phone used for testing and illustration

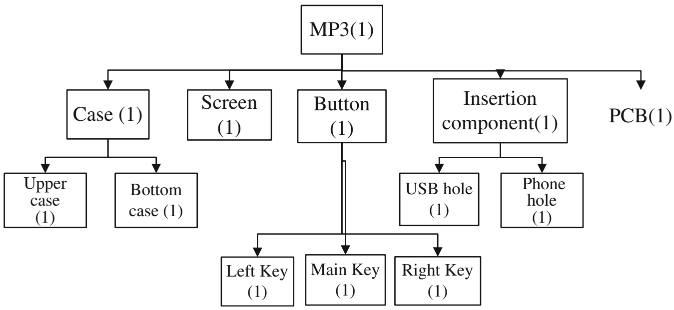


Fig. 4 The BOM of product A

model is presented for use in supplier selection and order assignment. The PSO solution model is presented to find solutions. An example is demonstrated in the presentation. The test results show that the models are feasible and useful for solving the design for closed-loop supply chain problem. Given a design, the order assignment and suppler selection can be analyzed and evaluated to achieve the objective of the fitness function of minimizing total costs of design, forward supply chain, and reverse supply chain. Future research can be directed to explore more detailed value and cost functions of design, and forward and reverse supply chain activities.

Acknowledgments This research is funded by the National Science Council of Taiwan ROC with project number NSC 100-2221-E-155-021-MY3.

References

Akyuz G, Erman ET (2010) Supply chain performance measurement: a literature review. Int J Prod Res 48:5137–5155

Alshamrani A, Athur K, Ballou RH (2007) Reverse logistics: simultaneous design of delivery routes and returns strategies. Comput Oper Res 34:595–619

Banks A, Vincent J, Anyakoha C (2008) A review of particle swarm optimization. Part II: hybridization, combinatorial, multicriteria and constrained optimization, indicative applications. Nat Comput 7:109–124

French ML, LaForge RL (2006) Closed-loop supply chains in process industries: an empirical study of producer re-use issues. J Oper Manage 24:271–286

Humphreys PK, Wong Y, Chan FTS (2003) Integrating environmental criteria into the supplier selection process. J Mater Process Technol 138:349–356

Kannan G, Sasikumar P, Devika K (2010) A genetic algorithm approach for solving a closed loop supply chain model: a case of battery recycling. Appl Math Model 34:655–670

Kasilingam RG, Lee CP (1996) Selection of vendors: a mixed-integer programming approach. Comput Ind Eng 31(1–2):347–350

Kennedy J, Eberhart RC (1997) A discrete binary version of the particle swarm algorithm. In: 1997 Proceedings of international conference systems, man and cybernetics, Piscataway, NJ, 1997

Kim K, Song I, Kim J, Jeong B (2006) Supply planning model for remanufacturing system in reverse logistics environment. Comput Ind Eng 51:279–287

Ko HJ, Evans GW (2007) A genetic algorithm-based heuristic for the dynamic integrated forward/reverse logistics network for 3PLs. Comput Oper Res 34:346–366

Lu YY, Wu CH, Kuo TC (2007) Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. Int J Prod Res 45:4317–4331

Schultmann F, Zumkeller M, Rentz O (2006) Modeling reverse logistic tasks within closed-loop supply chains: an example from the automotive industry. Eur J Oper Res 171:1033–1050

Sheu JB, Chou YH, Hu CC (2005) An integrated logistics operational model for green-supply chain management. Transp Res Part E: Logistics Transp Rev 41:287–313

Yang GF, Wang ZP, Li XQ (2009) The optimization of the closed-loop supply chain network. Transp Res Part E: Logistics Transp Rev 45:16–28

Estimation Biases in Construction Projects: Further Evidence

Budi Hartono, Sinta R. Sulistyo and Nezar Alfian

Abstract Construction projects are characterized by their unique and temporary features. Very limited data, if any, would be available and readily transferable for the analysis of subsequent projects. Hence most project analysts would depend on intuitions and gut feelings to make judgment and estimations. This experimental study is a follow-up study on investigating the possible existence of systematic estimation errors (biases in estimations) in an Indonesian context. It is focused on the two suspected types of biases; the anchoring accuracy and overconfidence biases in project time duration estimates. Two groups of estimators (experienced, n = 20 vs. non-experienced, n = 20) were involved in the study. A hypothetical project case based on an actual construction project was developed. The estimators were then individually requested to provide duration estimates (for each project activity and overall) for the project case. The estimates were then compared against the actual duration of the project. The result of suggests that anchoring bias is not statistically observable for both non-experienced and experienced estimators. This study finds that overconfidence bias is identifiable when making the range estimation of the project duration.

Keywords Construction project · Judgmental bias · Duration estimate · Experiment

B. Hartono (✉) · S. R. Sulistyo · N. Alfian
Industrial Engineering Program, Mechanical and Industrial Engineering Department, Universitas Gadjah Mada, Jl. Grafika 2, Yogyakarta, Indonesia
e-mail: boed@gadjahmada.edu

S. R. Sulistyo
e-mail: sintarahmawidya@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_166,

1 Introduction

Project is a temporary group of activities designed to create a unique product, service, or result (PMI 2000). Due to the unique and temporary characteristics, the availability of the historical data becomes limited or not easily accessible. This brings various problems to the analysts in project planning process, including time and cost estimations.

Subjective expert judgment becomes a viable option for the project planners and analysts to estimate time and cost. The subjective expert judgment uses the cognitive aspect of decision making process which according to studies (Bazerman 1998; Hastie and Dawes 2001) prone toward systematic errors or biases.

According to Tversky and Kahneman (1974), bias which affects judgment process is specific and systematics. Specific means the natural error; whereas systematic means the errors made by the research subjects is statistically consistent hence they are predictable (Mak and Raftery 1992). In many occasions, decision makers use some simplifying strategies in estimation or decision-making, called heuristics to make the process faster and require lower cognitive loads (Tversky and Kahneman 1974).

Duration estimation for project activities is an essential stage in project planning. An estimation biases in the process, if any, could result in inaccuracy of the overall project planning which in turn could affect the project overall performance.

Various past studies had been administered with the aims of identifying systematic errors or biases in estimation within general management as well as in project management context [e.g. (Cleaves 1987; Flyvbjerg 2003, 2006; Flyvbjerg et al. 2002, 2004a, b, 2005)]. For the specific context of Indonesian projects, Nugroho (2011) identified the possible existence of accuracy, anchoring, and overconfidence biases of project duration estimates. The study was administered by means of experiments using mini-projects of building Lego® blocks. The study found that anchoring biases were not observable while the accuracy biases and over confidence biases are both statistically observable from the subjects. Saputra (2012) and Aji (2012) respectively conducted follow-up experiments with Lego® software to observe possible biases for estimators with a different level of experiences. Result shows that accuracy bias and overconfidence biases are observable, while anchoring bias is not identifiable among the experienced respondents. Handayani (2012) attempted to identify the same estimation biases by means of a survey. In this study, data was collected from real IT projects from various companies. Respondents were required to estimate the project duration and activities' times prior to the project execution. Actual project durations were collected after the project completion. The survey method provides a more realistic setting for the study and could indicate a better external validity if compared to the experiments. Results identified two biases: overconfidence and anchoring. The main drawback of the survey study is that the project size and complexity varies across companies and estimators. Accordingly, project size and complexity which may affect the estimation accuracy cannot be controlled.

This reported, follow-up study utilizes an experimental approach by using a real project case on which the estimators are required to provide their estimations. This study attempts to address the two drawbacks on the previous pertinent studies. By using a case adopted from a real construction project, the study could provide a more realistic setting than those experimental studies using mini projects of building Lego® blocks. Furthermore, since all estimators were exposed to the same case, size and complexity of the project are controllable and hence provides more conclusive results compared to the survey study.

2 Research Method

The subjects of the experimental study are classified into: experienced and non-experienced respondents (n = 20 for each). The experience group comprises contractor practitioners with a minimum experience of five (5) years in managing similar projects. They were mid-level manager who were actively involved in the decision making process in project bidding. On the other hand, the un-experienced group comprises vocational school teachers and students with some knowledge exposures but no experience in project management.

A hypothetical construction project is developed on the basis of a real construction (housing) project. Some pertinent documents such as: the engineering drawing, the plot plan, the project activity list and the bills of materials are developed. By referring to the documents, individual respondents were required to provide time estimates for each project activities as well as the estimates for the total project duration. The order of tasks for each respondent was randomly sequenced to eliminate noises.

3 Results

3.1 Anchoring Biases

Anchoringg refers to a cognitive bias in which an individual's judgment or estimation is strongly tied to some arbitrary (or irrelevant) value or reference point or anchoring stimuli (Tversky and Kahneman 1974). As a consequence, the estimation value would be statistically correlated to the irrelevant value.

In the study, anchoring stimuli was given by asking the respondents to response the following questions prior to their assignment to provide project estimation: "how much time needed to work on a small grocery store?". Figure 1 shows the value of the responses on anchoring stimuli against the value of project duration estimation across the experienced respondents.

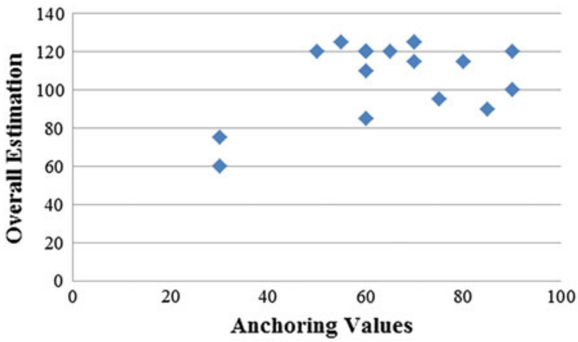


Fig. 1 Anchoring versus overall estimation for experienced respondents (n = 15)

Table 1 indicates the correlation test for both groups of experienced and non-experienced estimators. It was suggested from the statistical analysis that no significant correlation between anchoring responses and project estimation is observable. Hence in this study anchoring effect is not observable for both groups.

3.2 Accuracy Biases

The second point to observe is possible accuracy biases. There are two sets of estimation data used in this analysis, overall project estimation and activity based project estimation, for both respondents. Overall project estimation is the estimation of the total project duration which is derived from the estimators at once. Activity-based project estimation is the estimation of the total project duration which is derived from the sum of the estimation of individual activities in the lowest level of the work breakdown structure.

Error in accuracy is computed by using Eq. (1).

$$\textit{Errors in accuracy}\ (\Delta) = \textit{the project estimation} - \textit{the actual duration} \tag{1}$$

The one sample *t* test is used to analyze the possible existence of systematic errors in accuracy of the estimation The hypotheses are indicated by Eqs. (2) and (3).

$$H_0 : \mu_\Delta = 0;\ \text{there is no systematic error} \tag{2}$$

$$H_1 : \mu_\Delta \neq 0;\ \text{there is a systematic error} \tag{3}$$

The summary of the one sample t-test result is depicted in Table 2.

Table 1 Anchoring effect results

	Experienced	Inexperienced
Spearman correlation coefficient	0.041 (*p*-value = 0.864)	0.221 (*p*-value = 0.350)
Interpretation	Anchoring effect is **not** observable	

3.3 Overconfidence Biases (Range Estimates)

The third point to be observed in this study is to identify the possible existence of overconfidence biases for range estimates. Observation was administered by giving task to the respondents to make the range of estimation (the min and the max) for the project duration with a 90 % confidence level. The actual overall project time is then used to calibrate the data range estimation which have been made. A range estimate by an estimator is considered a hit if the actual project duration is located within the minimum and maximum values of project duration estimations.

Figure 2 shows the results for experienced respondents. Analysis indicates that the hit ratio is 65 % for experienced and 20 % for inexperienced respondents respectively which are much lower than the designated 90 % confidence level. The low hit ratio indicates that most of the estimated ranges were too narrow indicating overly-confident estimators.

4 Comparisons with Past Studies and Concluding Remarks

Tables 3 and 4 provide the profile and result for four pertinent studies as well as the current study in estimation bias identifications. Across the studies, the results for anchoring biases tend to be negative. All studies could not identify the anchoring biases except for Study A. Study C which utilized two methods of anchoring shows different results. It suggests that anchoring bias is highly affected by the way the anchoring stimuli are administered. This is consistent to the finding by past studies indicating that not all types of anchoring stimuli would yield the same level of anchoring biases (Brewer and Chapman 2002; Chapman and Johnson 1994).

Accuracy biases are observable in most of the cited studies except for the current study of experienced estimators. Experienced estimators in construction industry seem to exhibit less accuracy biases. The fact that the current study is administered within the construction context while the other studies are carried out in IT settings may affect the accuracy biases. Complexity and culture of the specific project domains may matter. However, further studies are required to

Table 2 One sample t-test summary for systematic error in accuracy

One sample t-test	Experienced		Non-experienced	
	t	Sig. (2-tailed)	T	Sig. (2-tailed)
Overall estimates	−0.721	0.48	−4.751	0
	Not observable		**Observable, aggressive**	
Activity-based estimates	5.835	0	3.188	0.005
	Observable, conservative		**Observable, conservative**	

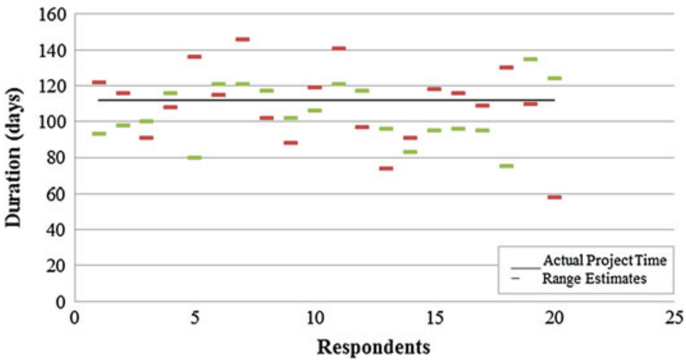


Fig. 2 Estimated ranges by experienced respondents

Table 3 Profile of pertinent studies

	Study A	Study B	Study C	Study D	Current study
Author	Aji (2012)	Saputra (2012)	Handayani (2012)		
Method	Experiment	Experiment	Survey	Survey	Experiment using case from a real project
Domain	IT	IT	IT	IT	Construction
Type of project	Simple, simulated, LEGO software	Simple,	simulated, LEGO software	Complex, real, variety	Complex, real, variety
Real, single case					
Respondents	Non-experience	Experience	Non-experience	Experience	Experienced and Non experienced
Respondent criteria	New for the task	Learning curve	Zero experience	>5 yrs. experience	Zero experience and >5 yrs. experience

examine such determinants affecting estimation biases. Observations for overconfidence biases across all studies provide consistent results. It is found that estimators exhibit similarity on overconfidence biases, regardless the domain (IT, Construction) and the level of experiences.

Table 4 Results of pertinent studies

Study A	Study B	Study C	Study D	Current study	
Non-experienced	Experienced	Non-experienced	Experienced	Non-experienced	Experienced
Anchoring biases					
Observable	Not observable	Mixed	Not observable	Not observable	Not observable
Accuracy biases					
Observable, conservative (for pessimistic estimates)	Observable, conservative	Observable, conservative	Observable, conservative	Observable, aggressive	Not observable
Over confidence biases (range estimates)					
Observable, over confidence	Observable, over confidence	Observable, over confidence	Observable, over confidence	Observable, over confidence	Observable, over confidence

References

Aji RK (2012) judgmental biases on project duration estimations for inexperienced estimators. Mechanical & Industrial Engineering. Universitas Gadjah Mada, Yogyakarta

Bazerman MH (1998) Judgment in managerial decision making. Wiley, New York

Brewer NT, Chapman GB (2002) The fragile basic anchoring effect. J Behav Decis Making 15:65–77

Chapman GB, Johnson EJ (1994) The limits of anchoring. J Behav Decis Making 7:223–242

Cleaves DA (1987) Cognitive biases and corrective techniques: proposals for improving elicitation procedures for knowledge-based systems. Int J Man Mach Stud 27:155–166

Flyvbjerg B (2003) How common and how large are cost overruns in transport infrastructure projects? Transp Rev 23:71–88

Flyvbjerg B (2006) From nobel prize to project management: getting risks right. Proj Manage J 37:5–15

Flyvbjerg B, Holm MS, Buhl S (2002) Underestimating costs in public works projects: error or lie? J Am Plann Assoc 68:279–295

Flyvbjerg B, Glenting C, Rønnest AK (2004a) Procedures for dealing with optimism bias in transport planning: guidance document. The British Department for Transport, London

Flyvbjerg B, Holm MKS, Buhl SL (2004b) What causes cost overrun in transport infrastructure projects? Transp Rev 24:3–18

Flyvbjerg B, Holm MKS, Buhl SL (2005) How (in) accurate are demand forecasts in public works projects?: the case of transportation. J Am Plann Assoc 71:131–146

Handayani D (2012) A survey of judgmental biases in estimating the duration of information technology. Projects mechanical and industrial engineering department. Universitas Gadjah Mada, Yogyakarta

Hastie R, Dawes RM (2001) Rational choice in an uncertain world: the psychology of judgment and decision making. Sage Publications, Inc., Thousand Oaks, CA

Mak S, Raftery J (1992) Risk attitude and systematic bias in estimating and forecasting. Constr Manage Econ 10:303–320

Nugroho FI (2011) Initial study on judgmental biases of project time estimation using experts judgment. Mechanical and Industrial Engineering. Universitas Gadjah Mada, Yogyakarta

PMI (2000) Guide to the project management body of knowledge, 2000 edn. Project Management Institute, Pennsylvania, USA

Saputra BA (2012) Judgemental biases analysis in project time estimation based on individual and group of estimators. Mechanical and Industrial Engineering. Universitas Gadjah Mada, Yogyakarta

Tversky A, Kahneman D (1974) Judgment under uncertainty: heuristics and biases. Science 185:1124–1131

Exploring Management Issues in Spare Parts Forecast

Kuo-Hsing Wu, Hsin Rau and Ying-Che Chien

Abstract According to literature, we know that research in spare parts forecast is a very popular topic in recent years due to the need of higher service level of customer demand. Most approaches in these researches focus on how to forecast spare parts more accurately under various conditions with some mathematical techniques. However, few attentions are paid to the management issues to control or maintain some factors to keep the spare parts forecast useful. For example, Engineering Change (EC) often introduce lots of planed items no longer valid and consume mass efforts trying to continue the spare parts support. This motivates our study. This study starts from service process, spare parts requirement, and spare parts forecast flow. When we come to investigate management issues in spare parts forecast, besides EC, such as issues like different service models for OEM, ODM or Brander, spare parts information correctness and service organization structures are worth exploring.

Keywords Spare parts forecast · Management issues · Spare parts lifecycle

1 Introduction

Spare parts forecast is popular research topic in recent years following the increasing customers' service level demand, especially for those manufacturer which is seeking to improve their service level in coping with customer increasing

K.-H. Wu · H. Rau (✉) · Y.-C. Chien
Department of Industrial and Systems Engineering, Chung Yuan Christian University, Chungli 320, Taiwan, Republic of China
e-mail: hsinrau@cycu.edu.tw

K.-H. Wu
e-mail: 10102405@cycu.edu.tw

Y.-C. Chien
e-mail: cyc@cycu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_167,

demand (Tan et al. 2010), and at the same time, an internal pressure in lower the service cost is pressing in Dutta (2009).

The results of those researches are forecast methodologies for solving different kinds of service environments and conditions. But most of them stand in forecast technical point of view, in general spare parts forecast implementation practice, there are issues other than forecast technical aspect needs to be considered in order the forecast implementation can function as they are expected. Giving an example, in case forecast methodologies use not updated Engineering Change (EC) spare parts price list as the base in forecast, the result of the forecast will not be correct and may with those useless substituted parts, In the worst case with prohibited parts which may introduce not just inventory issue, but also field service issue.

In this study, we aim to explore those issues which may impact the forecast implementation result other than the forecasting technical mechanism itself, those issues are treated as the management issues, because by those methodologies found, mostly they focus in forecast aspect with fixed conditions, and not looking into the surrounding management issues.

2 The Service Process and Spare Parts Forecast

For exploring management issue, it is necessary to look back to the overall service process from the beginning of the service. The service process lifecycle, spare parts support cycle and information requirement for creating forecast methodology will be introduced and reviewed. By the overall review, it starts to explore the possible management issue which leads the well-developed spare parts forecast performance not as expected or simply in vain.

2.1 Service Process Lifecycle

Service process lifecycle describes how a service is formed from offer, setup, maintenance, and reaches the end-point; the service process lifecycle is shown in Fig. 1. Referring to the models of Aurich et al. (2010) and Maxwell and Vorst (2003), we propose the service process lifecycle in five different stages, each stage has its activities that need to be fulfilled; i.e. the requirement for service, a solid

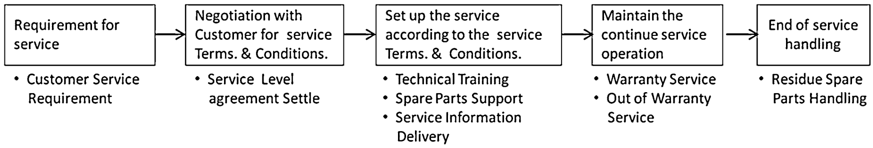


Fig. 1 Service process lifecycle

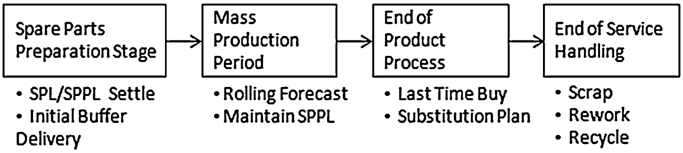


Fig. 2 Spare parts support cycle

customer service requirement has to be provided, and for the rest of the stages which have their own activities to be fulfilled as shown in the Fig. 1.

2.2 *Spare Parts Support Cycle*

As shown in service process lifecycle, spare parts support plays a vital position; it backs up the service activities, so, examining spare parts support cycle becoming a necessary. Sanborn et al. (2011) proposed a spare parts life cycle model, Fig. 2 we revised Sanborn's and proposed a model based on parts acquiring characteristics, this model describes the cycle into four stages.

In each stage, similar to service lifecycle there are activities need to be fulfilled, giving example, End of Life (EOL) process starts to secure the continued support for spare parts been described by Pourakbar and Dekker (2012) service agreements oblige it means EOL is a job not avoidable and for resulting this issue two actions will follow; Last Time Buy (LTB) or substitution plan. These two actions all invent different departments, such as sales, purchasing, component engineering, quality assurance, etc. especially LTB is truly a burden either to the vendor or customer, so it always happens that LTB liability becoming a tough issue between vendor and customer negotiation, simply because none of them is willing to bear the responsibility in carrying spare parts inventory. The other activity, spare parts substitution will consume company large resources and often bring internal conflict in resource allocation.

2.3 *Spare Parts Forecast*

By reviewing current paper there is no doubt, there lots of different forecast methodologies had been developed. No matter which spare parts forecast methodology and model, their creation must be based on existing information and assumptions. The information needed for creating forecast as Huiskonen (2001) proposed in four different catalogs, in this study, the information required is separated into catalogs, it can be temporal such as past usage history, and sales forecast, it may also with some condition such as one layer distribution, and one

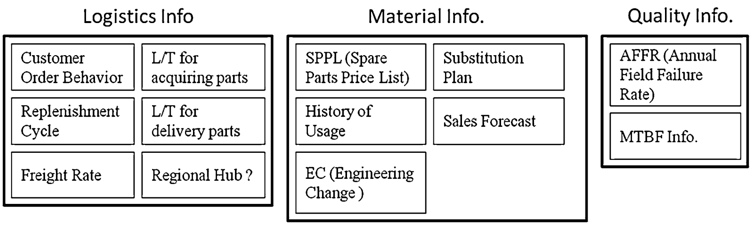


Fig. 3 Information needed for spare parts forecast chart

central hub for the source of distribution, beside those information, Sanders and Larry (1995) also point out human judgment/factor also play its role.

In this study, forecast methodology is not the focus, but information needed and used is the aim. Figure 3 shows the summary of information used in developing forecast methodology. By viewing this chart, some of the information actually came from a complex combination, for example Spare Parts Price List (SPPL) is mixed by balancing between usability (kitting parts), flexibility (EOQ, MOQ), compatibility (substitution), and cost (Huiskonen 2001).

3 The Management Issues

There are many management issues that can impact well developing forecast methodologies; they impact the forecast in two major catalogs: false information and forecast fulfillment. In Fig. 4, it illustrates the relationships between those items, and they all come to the end with forecast malfunction. When we look at the causes, totally 9 different causes are listed, none of them is related to the forecast methodology itself, but any one of them can distort or even cause failure to the forecast implementation objective. Even though there are many factors that may give impacts to the forecast, we focus on the Sales forecast in this section, Engineering Change and service provider will be discussed.

3.1 Sales Forecast

All the forecast methodology must consider the sales forecast in handling the spare parts forecast; a false information input to the forecast methodology will not produce the correct result, because the demand for spare parts in the field will follow the increasing sales and increases. In the study of Michael and O'Connor (2000), they concluded that forecast accuracy is hard to reach even amendments apply. An unreliable sales forecast induce fluctuations in forecast result and such situation makes spare parts hard to catch the real demand, and will cause spare parts to be in either shortage or surplus to the demand.

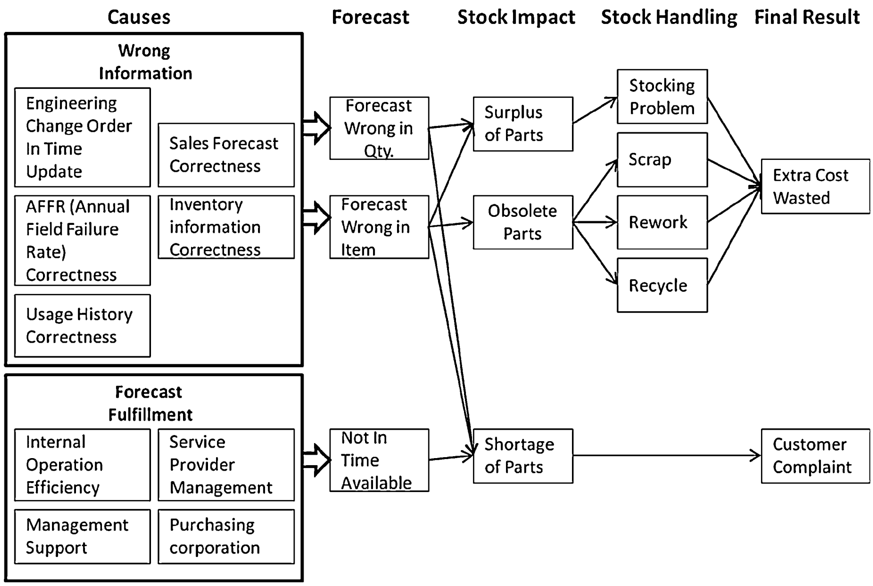


Fig. 4 The causes of forecast malfunction chart

Figure 5 shows the sales forecast formation, a similar approach has been proposed by Danese and Kalchschmidt (2011), they named it forecasting process management, it describes the sales forecast generally comes from the information collected from the second tier or customer's forecast, usage history or demand for existed product (Armstrong et al. 2000), or marketing survey for new launching product, so we can easily imagine that it may contain uncertainties. To amending such unreliable factor, in general practice a confidence level/factor is added to make such forecast into a range. But beside the major information, other aux. information shown in Fig. 5 are also needed to be considered to amend the forecasting such as manufacturing capacity.

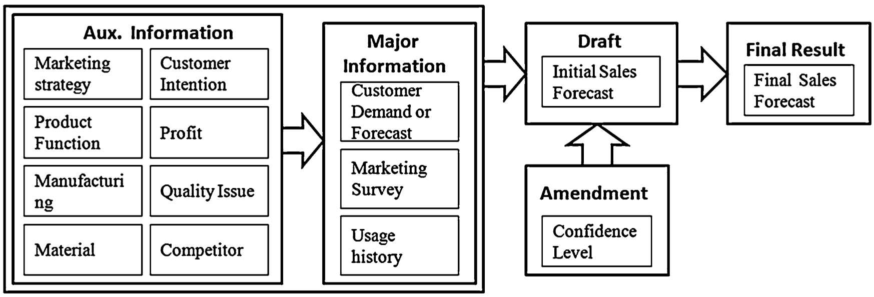


Fig. 5 The formation of sales forecast chart

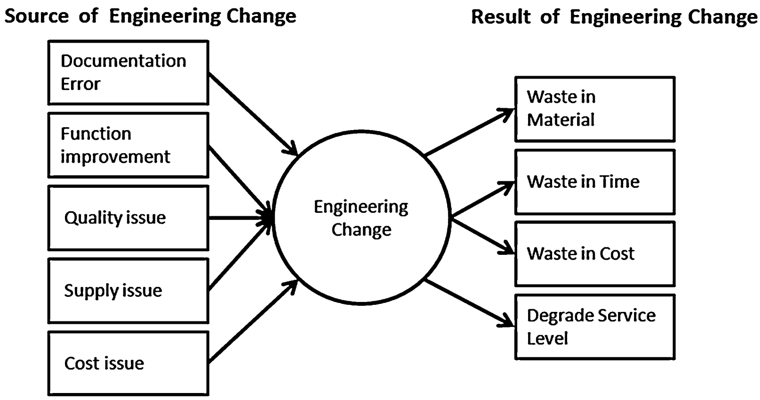


Fig. 6 EC demand and the consequence chart

3.2 Engineering Change Management

Wright (1997) in his paper directly describes the engineering change (EC) resulting EC demands are an evil. EC is an issue which all the companies hate to issue, but it does exist. Since EC implementation means lots of actions will be followed up and to be completed. In reality it just cannot be avoided, especially it is highly unpredictable as it is indicated by Tavcar and Duhobnik (2005) since in real world nothing is perfect, and EC is the action trying to make product perfect no matter in function or in cost. Figure 6 illustrates the EC sources and the consequences.

The reasons demanding for issuing EC may be for resulting quality issue, improving function, correcting documentation error, material supply issue, or saving cost. Huang et al. (2003) provide their view in the source of the EC, and Prabhu et al. conduct a survey in automotive OEM about the EC initiation of the change showing that cost reduction occupies the highest percentage of all cause. In general industrial practice, different departments may request the EC to solve the problem they are facing, example, purchasing may ask for EC to replace current used component with same function with lower cost, Engineering department may ask EC to change some component to enhancing the product function according to the sales request (Fig. 7).

3.3 Service Provider

Service provider may directly or indirectly seriously influence the spare parts forecast result by either lack of capability or wiliness in spare parts forecast fulfillment, and especially in a international company, service provider (self own

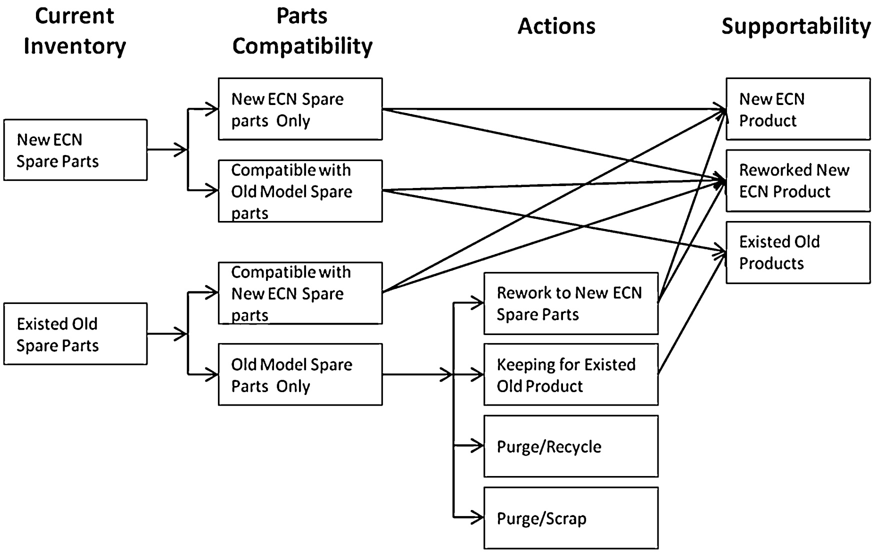


Fig. 7 On hand inventory handling flow chart

or out-sourcing) is part of the service net which spare parts may be stocked (Dekker et al. 2013). It is often seen that company outsources the service delivery to external service provider.

Service delivery can be separated into three categories. Their content can be separated into service operation, spare parts support, and service logistics. The service provider spare parts support model can be arranged either vendor consign or service provider purchases first and charged back after the consumption. This shows the difference of the spare parts ownership, because none will be pleased to hold the spare parts inventory, since spare parts inventory is always be treated as the most important factor impacts the operation and financial performance of the service organization as the survey done by Dutta and Pinder (2012).

How the vendors perform service outsourcing, it is necessary to understand the possible service model in practice, if standing in supplier/vendor point of view, the possible service model is shown in Fig. 8. Since HQ holds communication between spare parts supplier, and supplier will ask for a forecast in order for suppliers to plan and manage the parts availability and delivery. In such cases, even when HQ is not responsible for making forecast, but region office does, a forecast is still a must in planning spares. In the mean time, for a small service organization, own office or outsourcing service provider, it is hard to ask for making good quality forecast, and this even messes the total spare parts supply. We saw such situation often happens in practice.

So without optimal service provider management, this will cause spare parts forecast deterioration, it may be that spare parts surplus and abuse in the first model or shortage parts caused lower service level in second model.

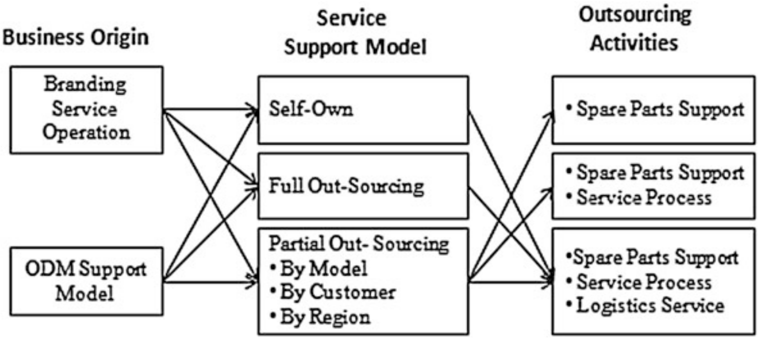


Fig. 8 Service operation model and service activity chart

4 Conclusion

This study discussed the service management issues which impact the spare parts forecast performance from beginning from the review of service process, the spare parts support flow, the spare parts forecast methodology creation requirement, a listed of management issues, and do further 3 issue discussions; sales forecast, EC and service provider.

This study concludes that having well design spare parts forecast methodology does not guarantee expected forecast result, as well as good fulfillment and implementation. Lots of information has to be supported and fed into the forecast mechanism, but without proper management control in securing correctness of the information, the first step of the forecast fails simply because of the output of the forecast is incorrect. There are even more management issues involved in forecast implementation. A continue well management support for the fulfillment in implementation plays vital key to ensure the set forecast result is achieved.

Acknowledgments This work is supported in part by National Science Council of Republic of China under the grants NSC 101-2221-E-033-037-MY3. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers.

References

Armstrong JS, Morwitzb VG, Kumar V (2000) Sales forecasts for existing consumer products and services: do purchase intentions contribute to accuracy. Int J Forecast 16:383–397

Aurich JC, Mannweiler C, Schweitzer E (2010) How to design and offer services successfully. CIRP J Manuf Sci Technol 2:136–143

Danese P, Kalchschmidt M (2011) The role of the forecasting process in improving forecast accuracy and operational performance. Int J Prod Econ 131:204–214

Dekker R, Pinçe Ç, Zuidwijk R, Jalid MH (2013) On the use of Installed base information for spare parts logistics: a review of idea and industry practice. Int J Prod Econ 143:536–545

Dutta S (2009) Delivering customer service via contact center and the web. Aberdeen Group, Boston

Dutta S, Pinder A (2012) Optimizing the service supply chain. Aberdeen Group, Boston

Huang GQ, Yee WY, Mak KL (2003) Current practice of engineering change management in Hong Kong manufacturing industries. J Mater Process Technol 139:481–487

Huiskonen J (2001) Maintenance spare parts logistics: special characteristics and strategic choices. Int J Prod Econ 71:125–133

Lawerance M, O'Connor M (2000) Sales forecasting updates: how good are they in practice? Int J Forecast 16:369–382

Maxwell D, Vorst R (2003) Developing sustainable product and services. J Cleaner Prod 11:883–895

Pourakbar M, Dekker R (2012) Customer differentiated end-of-life inventory problem. Eur J Oper Res 222:44–53

Sandborn P, Prabhakar V, Ahmad O (2011) Electronic part life cycle concepts and obsolescence forecast. IEEE Trans Compon Packag Technol 51:707–717

Sanders NR, Ritzman LP (1995) Bringing judgment into combination forecasts. J Oper Manage 13:311–321

Tan AR, Matzen D, McAloone TC, Evans S (2010) Strategies for designing and developing services for manufacturing firms. CIRP J Manuf Sci Technol 3:90–97

Tavcar J, Duhobnik J (2005) Engineering change management in individual and mass production. Rob Comput Integr Manuf 21:205–215

Wright IC (1997) A review of research into engineering change management: implications for product design. Des Stud 18:33–42

Artificial Particle Swarm Optimization with Heuristic Procedure to Solve Multi-Line Facility Layout Problem

Chao Ou-Yang, Budi Santosa and Achmad Mustakim

Abstract The facility layout problem (FLP) has an important effect on the efficiency and the profitability of the manufacturing system from the standpoint of the cost and time. This research has objective to minimize total material handling cost. Multi-line facility layout problems (MLFLP) is FLP that assigns a few facilities in the two or more lines into industrial plant, where the number of the facilities is less than the number of the locations with no constraint for placing the facilities. This study present Heuristic Artificial Particle Swarm Optimization (HAPSO) a hybrid meta-heuristic algorithm to solve MLFLP and it consider the multi-products. The proposed algorithm applied to the case study from other paper. The computational results indicate that the proposed algorithm more effective and efficient to solve the case.

Keywords Multi-line facility layout problem · Estimation distribution algorithm · Particle swarm optimization · Tabu search · Heuristic procedure

1 Introduction

The facility layout problem (FLP) has an important effect on the efficiency and the profitability of the manufacturing system from the standpoint of the cost and time. Multi-lines facility layout problem (MLFLP) assign a few facilities in the two or

C. Ou-Yang (✉) · A. Mustakim
Department of Industrial Management, School of Management, National Taiwan University of Science and Technology, Taipei, Taiwan, R.O.C
e-mail: ouyang@mail.ntust.edu.tw

A. Mustakim
e-mail: mustakimachmad@gmail.com

B. Santosa
Department of Industrial Engineering, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
e-mail: budi_s@ie.its.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_168,

more rows into industrial plant. Where the number of the facilities is less than the number of the locations and the total facilities area is less than total area of industrial plant (Sadrzadeh 2012). This research has objective to mini-mize total material handling cost for MLFLP.

Meta-heuristic and its hybrid algorithm have been proposed by many recent researchers to solve FLP. El-Baz (2004) use Genetic Algorithm (GA) to solve FLP. Miao and Xu (2009) use Hybrid GA and Tabu Search (TS) to solve Multi-row FLP. Zhou et al. (2010) use GA to solve Multi-row FLP. Sadrzadeh (2012) use GA with heuristic procedure to solve MLFLP. Utamima (2012) use Hybrid meta-heuristic to solve single-row FLP. This paper proposes hybrid algorithm Estimation Distribution Algorithm (EDA), Particle Swarm Optimization (PSO), TS and it enchanted by heuristic procedure.

2 Mathematical Model

To determine the material handling cost for one of the possible layout plans, the production volumes, production routings, and the cost table that qualifies the distance between a pair of machines/locations should be known. The following notations are used in the development of the objective function: Fij amount of material flow among machines i and j (i, j, …, M). M is the number of machines. C_{ij} unit material handling cost between locations of machines i and j. D_{ij} rectilinear distances between locations of machines i and j. C total cost of material handling system. The total cost function is defined as:

$$C = \sum_{i=1}^{M} \sum_{j=1}^{M} F_{ij} C_{ij} D_{ij} \tag{1}$$

This research has objective function to minimize C.

3 The Proposed Algorithm

This research want to develop the proposed algorithm to solve multi-rows Facility Layout Problems. The proposed algorithm is combining Particle Swarm Optimization (PSO), Estimation Distribution Algorithm (EDA) and Tabu Search(TS). Figure 1 describes flowchart of the proposed algorithm. The proposed algorithm divided by four main processes. These are Heuristic Procedure, EDA, PSO, and TS. It is enchanted by elitism to keep 10 % of the best particles for next iteration. The proposed algorithm is named as Heuristic Artificial Particle Optimization (HAPSO).

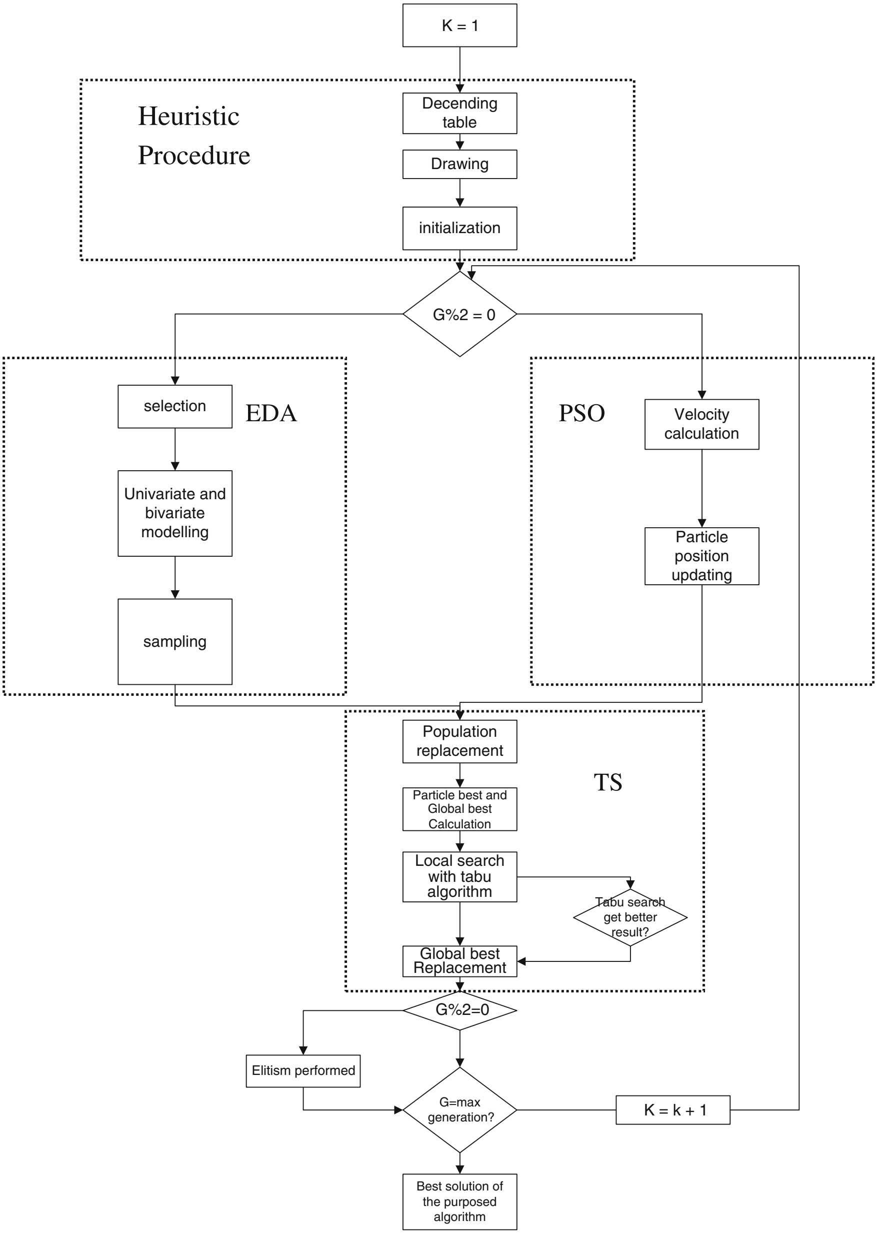


Fig. 1 Flowchart of the proposed algorithm HAPSO

3.1 Heuristic Procedure

This paper adopt (Sadrzadeh 2012) heuristic procedure for generate initial particles for EDA procedure and PSO procedure. For generating the initial particle for this purpose algorithm, this paper uses three steps. The steps are : production descending table, drawing the facilities, generate heuristic feasible initial particles.

3.1.1 Production of Descending Table

Almost all of the FLP researches have objective function minimizing the total material handling. Table 1 is flow data of material between facilities. The cost da-ta is 1 each flow of material. Then firstly Table 1 multiply with cost data. Then the relationship between facilities is obtained. The relationship numbers are arranged from the largest to smallest. Then it called descending table in Table 2

3.1.2 Drawing the Facilities

By using the column of "relationship" in Table 2, a schematic representation created, which is called drawing. The following procedure of drawing are : first, If there are two facilities in the drawing, a link line drawing between them. Second, if there is only one facility in the drawing, another facility with a link line between

Table 1 Flow data of material between facilities

From/to	1	2	3	4	5	6	7	8
1	–	100	0	0	0	0	0	0
2	–	–	0	0	0	45	0	0
3	–	–	–	0	0	0	87	0
4	–	–	–	–	0	33	0	0
5	–	–	–	–	–	0	63	0
6	–	–	–	–	–	–	0	0
7	–	–	–	–	–	–	–	150
8	–	–	–	–	–	–	–	–

Table 2 Descending table

No	Facilities	Arranged number
1	7–8	150
2	1–2	100
3	3–7	87
4	5–7	63
5	2–6	45
6	4–6	33

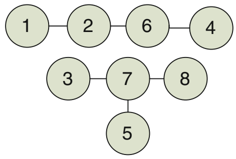


Fig. 2 Drawing the facilities

them is added to the drawing. Third, if there is no facility in the drawing, the two facilities with a link line between them are added to the drawing. The procedure is continued until all facilities assigned to the drawing. From Table 2, the drawing obtained in Fig. 2

3.1.3 Generate Heuristic Initial Particle

From Fig. 2, heuristic initial particles can be obtained by changing the configuration of the drawing and place them in the locations. For example Fig. 3 shows the two created initial particles corresponding in the drawing considered Fig. 2.

3.2 Estimation Distribution Algorithm

Initial particles is obtained from Heuristic procedure. The particles from heuristic procedure are labeled as X^1, X^2, X^3, … and X^N which N is half number of particles that is generated from heuristic procedure. Then univariate and bivariate probabilistic model (Chen et al. 2012) are developed from the initial particles of Heuristic procedure. The solutions generated by two probabilistic models are called as artificial particles.

This research adopted univariate and bivariate probabilistic model from (Utamima 2012). The univariate probabilistic model $\phi_{i\{i\}}$i[i] in Eq. 2 shows the importance of facilities sequence. It represents how many times facility i is placed at position [i] at current generation. $A^k_{i[j]}$ is set to 1 if facility I is placed at position [i], otherwise it is set to 0.

1	2	6	4
	3	7	8
		5	

1	2	6	7	e1	3	7	8	e2	e3	5	e4

4			
6	3	7	8
2	1	5	

4	e1	e2	E3	6	3	7	8	2	1	5	E4

Fig. 3 Heuristic initial particles

$$\phi_{i[i]} = \sum_{k=1}^{N} A_{i[i]}^{k}, \quad i = 1, 2, \ldots, n;\ k = 1, 2, \ldots, N \tag{2}$$

The bivariate probabilistic model ψ_{ij} in Eq. (3) represents how many times facility j is placed after facility j. B_{ij}^{k} has value 1 if facility j is placed next to facility I, otherwise it is set to 0. This proposed algorithm replace the 0 value in $\phi_{i\{i\}}$ and ψ_{ij} with 1/N for maintaining the diversity of the purposed algorithm.

$$\psi_{ij} = \sum_{k=1}^{N} B_{ij}^{k}, \quad i = 1, 2, \ldots\ldots, n;\ k = 1, 2, \ldots, N \tag{3}$$

Let Pi[i](g) in Eq. (4) be the probability value of facility i at position [i]. Selecting facility i which has better probability value than other facility when both probabilistic models statistic information used. For every offspring O^1, O^2, … and O^{2N}, this method according to Utamima to assign the first facility and the rest facilities according to Chen et al. (2012) using Roulette wheel with the probability Pi[i].

$$P_{i[j]}(g) = \frac{\phi_{i[j]}(g) x \psi_{ij}(g)}{\sum_{f \in \Omega} \phi_{i[j]}(g) x \psi_{ij}(g)} \tag{4}$$

where,

[i] 2,3, …, n; i = 1, 2,3, …, n
Ω set of unassigned facilities

3.3 Particle Swarm Optimization

Initial particles from heuristic procedure will be used for Particle Swarm Optimization (PSO) initial particles. Then the velocities are calculated for every particles. In standard PSO, the velocity is added to the particles on each dimension to update the particles. If the velocity is larger, the particle may explore more distant area. Sometimes the particle pass the best solution then cannot find the best solution. So it needs the inertia weight which is reference from is listed below :

$$w = \frac{\max gen - currentgen}{\max gen} \tag{4}$$

Velocity formulation below:

$$V_i(t+1) = wxv_i(t) + r_1 c_1 (x_{pbest} - x_i(t)) + r_2 c_2 (x_{gbest} - x_i(t)) \tag{5}$$

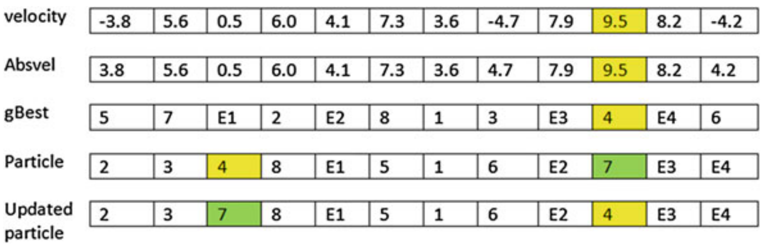


Fig. 4 Steps of update the particles

where V is velocity, w is weight inertia, t is iteration, r_1 and r_2 are random number, c_1 and c_2 are parameter for update the velocity, x_{pbest} is best particle each iteration, x_i current particles, x_{gbest} is the best particle among other particles.

This part use permutation-based particle updating based on concept from (Hu et al. 2003). The steps explain at Fig. 4. Get highest velocity value within particle. Get the corresponding gBest position which has the highest velocity. Find the position of value in current particle. Update the particle position that is to set the value of same position gbest by swapping the value.

3.4 Tabu Search

The best solution from EDA or PSO part each generation is the input for tabu search (TS) part. The procedure for TS is according to Utamima. If the output from the TS is better, so update the best solution.

Then performing the elitism to keep 10 % best particles of total number particles. Elitism try to keep the best solution in next iteration so that better solution can be obtained.

Table 3 Comparison between HAPSO and other approaches

Method	Best (30 runs)	Average	Worst	Succesful hits
Proposed HAPSO	11,632	11,764	11,981	12
Sadrzadeh (2012)	11,662	11,676.1	11,951	28
El-Baz (2004)	11,862	11,871.8	13,373	23
Mak et al. (1998)	12,892	15,087.7	18,657	11
PMX Chan and Tansri (1994)	14,947	18,355.9	20,654	0
OM Chan and Tansri (1994)	22,406	24,301.7	26,926	0
CX Chan and Tansri (1994)	14,717	17,216.5	20,654	0

Fig. 5 Best solution

	9	17	10		
3	20	12	8	18	6
23	24	16	4		15
7	14	2	11	19	5
		21	13	1	22

4 Case Study

This case study which has been introduced by (Kazerooni et al. 1996), 24 fa-cilities are located in a 5 × 6 grid. The number of product is 38 products. The cost needed for handling one unit of the material between the facilities is assumed to be the same. By using a comprehensive search, the determination of the optimal solution amongst the 3.68 × 1,029 feasible solutions is impossible.

HAPSO applied in this case. It start from heuristic procedure then EDA, PSO and the last is TS. We obtain the best result is **11,632**. This result is better than the other papers. Table 3 represents the comparison between HAPSO and other ap-proach from other researches. The results show that HAPSO obtains a more efficient solution as compared to the other approach. Figure 5 shows best solution.

5 Conclusion and Future Research

The proposed algorithm HAPSO can solve MLFLP more efficient than other method. The hybridization of PSO and EDA can avoid the premature conver-gence. It is enchanted by Tabu Search to get better solution from the EDA and PSO. The heuristic initialization make the searching area become near to the op-timal solution. So the PSO, EDA and Tabu can focus to certain area. The result of HAPSO indicate that HAPSO reliable enough for solving the MLFLP with total cost 11,632. It gives better result than other method. Better solution from HAPSO is obtained from the heuristic initialization. Heuristic initialization put the higher "relationship" facilities always together.

Future research of this research can apply this method to different environment of FLP. Develop interface to help decision maker of FLP within HAPSO algo-rithm. HAPSO can be improved again by other approach to get more efficient results because the number of hits still below the expectation.

Acknowledgments This work has been supported by National Science Council under contract NSC 101-2221-E-011-078.

References

Chan KC, Tansri H (1994) A study of genetic crossover operations on the facility layout problem. Comput Ind Eng 26:537–550

Chen YM, Chen MC, Chang PC, Chen SH (2012) Extended artificial chromosomes genetic algorithm for permutation flowshop scheduling problems. Comput Ind Eng 62:536–545

Kazerooni M, Luonge L, Abhary K, Chan F, Pun F (1996) An integrated method for cell layout problem using geneticalgorithms. In: Proceedings of the 12th international conference on CAD/CAM robotics and factories of the future 1996

Mak KL, Wong YS, Chan TS (1998) A genetic algorithm for facility layout problems. J Comput Integr Manuf Syst 1:113–123

El-Baz MA (2004) A genetic algorithm for facility layout problems of different manu-facturing environments. Comput Ind Eng 47:233–246

Hu X, Eberhart R, Shi Y (2003) Swarm intelligence for permutation optimization, a case study on N-Queens problem. In IEEE swarm intelligence symposium. Indianapolis, USA 2003

Miao Z, Xu K-L (2009) Research of multi-rows facility layout based on hybrid algorithm. In: International conference on information management, innovation management and industrial engineering 2009

Zhou N et al (2010) Research on Multi-rows layout based on genetic algorithm. In: 3rd international conference on information management, innovation management and industrial engineering 2010

Sadrzadeh A (2012) A genetic algorithm with the heuristic procedure to solve the multi-line layout problem. Comput Ind Eng 62:1055–1064

Applying a Hybrid Data Preprocessing Methods in Stroke Prediction

Chao Ou-Yang, Muhammad Rieza, Han-Cheng Wang, Yeh-Chun Juan and Cheng-Tao Huang

Abstract Stroke has always been highlighted as big threat of health in the worldwide. Brain image examination and ultrasound are some alternatives to discover stroke disease. Data mining has been used widely in many areas, include medical industry. The uses of data mining methods can help doctors to make prediction of certain diseases. Therefore, in this research, a hybrid model integrating imbalance data preprocessing, feature selection, and back propagation network, decision tree for stroke prediction. The dataset used is brain examination data which collected from 2004 to 2011. However, highly imbalance dataset available can impact the performance of prediction as well as feature selected. The study firstly "rebalance" the dataset by comparing sampling methods; RUSboost and MSmoteBoost. In addition, important features of balance training dataset would be selected by information gain, stepwise regression based feature selection. Towards the end, selected features would be processed using Back Propagation

C. Ou-Yang (✉) · M. Rieza · C.-T. Huang
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: ouyang@mail.ntust.edu.tw

M. Rieza
e-mail: muhd_rieza@hotmail.com

C.-T. Huang
e-mail: M10001015@mail.ntust.edu.tw

H.-C. Wang
Department of Neurology, Shin Kong Wu Ho-Su Memorial Hospital College of Medicine, National Taiwan University, Taipei, Taiwan
e-mail: drhan@ms1.hinet.net

Y.-C. Juan
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei City, Taiwan
e-mail: ycjuan@mail.ncut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_169,

Network and Decision Tree to predict the stroke. These hybrid methods can assist doctor to provide some possibilities information to the patient.

Keywords Stroke · Preprocessing methods · Imbalance data · Feature selection · BPN

1 Introduction

Data preprocessing or preparation is an important and critical step in data mining process and it has a huge impact on the success of a data mining project (Hu 2003). Data mining method has been used widely in medical data diagnosis, include stroke prediction. Brain image examination and ultrasound are some alternatives to discover stroke disease. This paper has been used brain medical data collected from 2004 to 2011.

Because the data distribution is not balance, the existing classification techniques face some difficulties for correctly predicting the minority class. Therefore, imbalance classification becomes major problem. Sampling is a most common method to process the imbalance data sets. Under-sampling and over-sampling are two kinds of modes of sampling. Under-sampling method is used by reducing number of majority class, on the other hand over-sampling used by duplication minority class samples (Liang et al. 2009).

Before any classification method, a feature selection algorithm would be applied in order to reduce the size of search space. The objective of variable selection is threefold: improving the prediction performance of the predictors, providing faster and more cost-effective predictors, and providing a better understanding of the underlying process that generated the data (Guyon and Elisseeff 2003). Feature Selection analysis is classified into three main categories, there are Filter, Wrapper, and Embedded.

Various diagnosis model based on statistic and classification have been proposed as a decision making process. This study proposed hybrid methods by "rebalance" imbalance dataset and perform feature selection in data preprocessing. In the end, back propagation network and decision tree used to diagnose and predict the stroke.

2 Algorithm

2.1 "Rebalance" Algorithm

A. RusBoost

Random Undersampling method balances a data set by removing examples from the majority class. In addition, a boosting method can be performed either by "reweighting" or "resampling" (Seiffert et al. 2010). This paper adopted a proposed method by Seiffert et al. (2010) by combining RUS and Boost in order to resample the training data according to examples assigned weight. The performance of this method presents a simpler, faster and less complex alternative to other method from imbalanced data.

B. MSmoteBoost

Compare to under sampling method, MSmote generate data and increase the sampling weight for the minority class. MSmote is a variant of the smote algorithm, so the basic flow is consistent with Smote (Chawla et al. 2002). This method hybrid with boosting algorithm in order to enable each learner to be able to sample more of the minority class cases, and also learn better and broader decision regions for the minority class (Chawla et al. 2003). Liang et al. (2009) proposed MSmoteBoost to improve performance when training data is imbalance, this techniques is implemented in this study.

2.2 Feature Selection Algorithm

A. Information Gain (IG)

Information gain calculated by using entropy measurement. High entropy means the distribution is uniform, low entropy means the distribution is gathered around a point (Dağ et al. 2012).The range of entropy from 0 to 1. The formula of information gain:

$$Info\,Gain\,(Class, Attribute) = Entropy(Class) - Entropy(Class|Atrribute) \quad (1)$$

$$Entropy(S) = -\sum_{j=1}^{j=m} p_j \log_2 p_j \quad (2)$$

In this paper, the information gain uses ranker method. This algorithm ranks attributes according to average merit. It has an option to assign a cutoff point (by the number of attributes or by a threshold value) to select the attributes (Witten and Frank 2005).

B. Stepwise Regression Analysis (SRA)

Stepwise regression analysis is applied to determine the set of independent variable that most closely affect the dependant variable (Fan et al. 2011). The selected features are generated by running statistical software SPSS 17. In this method, we calculate F value, according to reference (Chang and Fan 2008; Chang and Liu 2008) if F value of a specific variable is greater than the user defined threshold, it is added as significant factor, and otherwise it is removed from the model.

$$SSR = \sum (\hat{Y}_i - \bar{Y})^2 \tag{3}$$

$$SSE = \sum (\hat{Y}_i - Y_i)^2 \tag{4}$$

$$F_j = \frac{MSR(X_j|X_i)}{MSE(X_j|X_i)} = \frac{SSR/1(X_j|X_i)}{SSE/(n-2)(X_j|X_i)}, i \in I \tag{5}$$

2.3 Prediction Algorithm

A. Back Propagation Network (BPN)

Neural network has attracted many researchers to perform any classification. Classification rules are useful for solving medical problems and have been applied particularly in the area of medical diagnosis (Freitus 2002). This paper adopted Back Propagation Network as prediction techniques. A simple BPN consist of 3 layers: input node, hidden node and output node. One of the concern in determining the number of hidden nodes, the most commonly way to set by $(x + y)/2$, $(x + y)/2 \pm 1$, $(x + y)/2 \pm 2$ (Ripley 1993) or $\sqrt{xy}$, $\sqrt{xy} \pm 1$, $\sqrt{xy} \pm 2$ (Kaastra and Boyd 1996) where x is input node and y is output node.

B. C4.5 Decision Tree

This method is one of the most widely used in data mining. C4.5 method for approximating discrete-value function that is robust to noisy data and capable of learning disjunctive expression (Mitchell 1997; Quinlan 1986). There are many algorithm developed in decision tree. However, the main difference between C4.5 and other similar decision tree building algorithms is in the test selection and evaluation process (Ture et al. 2009). C4.5 decision tree algorithm uses modified splitting criteria, called gain ratio. C4.5 selects the test that maximizes gain ratio value (Benjamin et al. 2000).

3 The Proposed Hybrid

In this paper, we propose hybrid methods including data preprocessing and prediction. Data preprocessing start with removing outlier of brain medical data. In addition, the imbalance brain medical data was analyzed by applying sampling techniques (RUSBoost and MSmoteBoost). The sampling method would generate two types of *balance* data sets, and then important feature is selected by Information Gain and Stepwise Regression Analysis. These preprocessing would execute 4 sample dataset (combination of RUSBoost & SRA, RUSBoost & IG, MSmoteBoost & SRA, and MsmoteBoost & IG) as shown in Fig. 1.

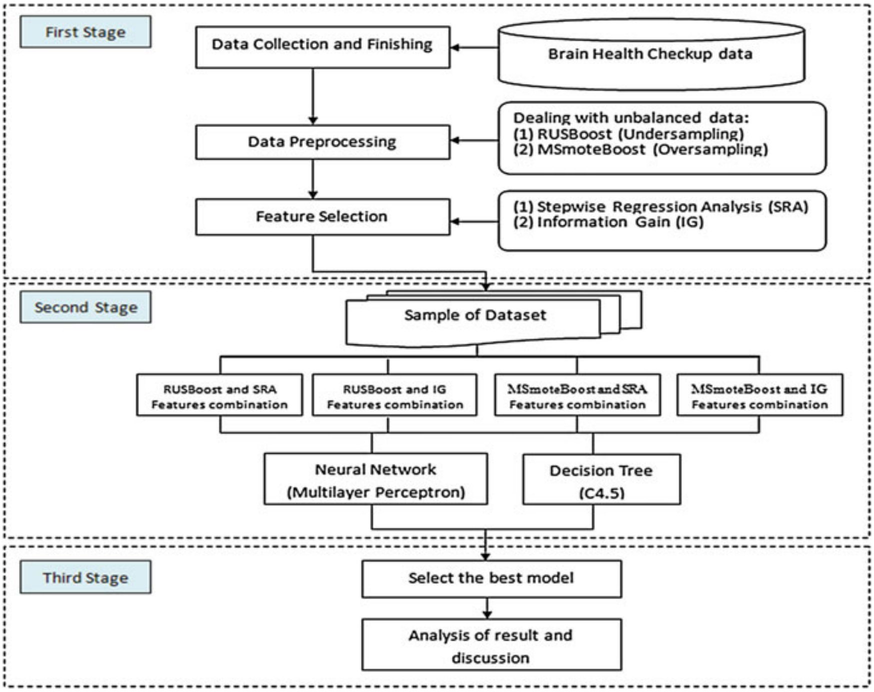


Fig. 1 Hybrid process stage

The combination of data preprocessing would be predicted by neural network and decision tree. All of these combinations have been normalized between range 1 and 0. In the later stage, we could compare 8 outputs from this hybrid method.

4 Experiments

4.1 Data Sets

Our experiments were performed on the brain examination data which collected from 2004 to 2011. The data sets contain 10,037 examples with 24 features and 1 class. The aim of data sets is to predict MRI brain examination for normal (majority class) and stroke (minority class), where 9,495 examples are from majority "normal" class and 542 examples are from the minority "stroke" class (Table 1).

Table 1 Original features of data set

Feature	Range	Feature	Range
Gender	Male/female	Fasting glucose	48–410
Age	12–93	HbA1C	3.3–16.5
Waistline	52.5–139.5	GOT	9–392
Diastolic	37–149	GPT	4–634
Systolic blood pressure	66–237	BUN	5.0–60.0
BMI	12.9–47.3	Creatinine	0.3–5.8
Hypertension	Yes/no	Total cholesterol	88–580
High cholesterol	Yes/no	HDLc	5–135
Diabetes	Yes/no	LDLc	20–442
Heart disease	Yes/no	TC/HDL	1.3–39.2
Anemia	Yes/no	Triglyceride	20–1938
Prothrombin time	8.9–37.0	MRI brain (class)	Stroke/normal
APTT	10.8–72.5		

4.2 Experimental Result and Performance Evaluation

In performance evaluation, we specify the classification accuracy, sensitivity and specificity analysis, and 10-fold cross validation to evaluate proposed method.

Classification Accuracy calculated by using equation:

$$accuracy(t) = (correctCount/transCount) * 100 \tag{6}$$

where *correctCount* is number of correct prediction, *transCount* is total of class label.

$$sensitivity = \frac{TP}{TP + FN}\ (\%) \tag{7}$$

$$specificity = \frac{TN}{FP + TN}\ (\%) \tag{8}$$

where TP = True Positive, TN = True Negative, FP = False Positive and FN = False Negative (Table 2).

As can be seen from above result, MSmoteBoost_SRA_C4.5 combination achieved 95.50, 96.15 and 94.48 for classification accuracy, sensitivity and specific. However, C4.5 predicted lowest accuracy in minority data (RUSBoost_IG features combination). In feature selection techniques, indicate that there is least difference result of predicted accuracy between Information Gain (IG) and Stepwise Regression Analysis (SRA) in each combination for different sampling methods.

For prediction accuracy, comparative between BPN and C4.5 obtained different result while computing under sampling and oversampling dataset. Gap result obtained from BPN Prediction in minority and majority data is less than prediction of C4.5.

Table 2 Result comparison based on classification accuracy, sensitivity and specificity

	Prediction method Preprocessing	BPN			C4.5		
		Classification accuracy (%)	Sensitivity (%)	Specificity (%)	Classification accuracy (%)	Sensitivity (%)	Specificity (%)
Undersampling	RUSBoost and SRA	72.80	72.52	73.08	67.13	71.10	63.17
	RUSBoost and IG	71.39	68.83	73.93	66.28	69.12	63.45
Oversampling	MSmoteBoost and SRA	83.39	78.69	88.08	95.50	96.15	94.48
	MSmoteBoost and IG	85.25	81.36	89.11	95.27	95.79	94.75

5 Conclusions and Discussion

In this paper, we reported data preprocessing techniques able to improve prediction performance of imbalance data set. A hybrid approach of sampling methods and feature selection provide four type combinations include RUSBoost & IG, RUSBoost & SRA, MSmoteBoost & IG, and MSmoteBoost & SRA. The sample data generated of these combinations goes to prediction method (Neural Network and Decision Tree) to classify the correct result.

In the process of running hybrid method, sampling with majority examples provides a better result compare to minority. However, majority examples consumes more time. This indicates that future research would be able to increase the performance of under sampling method and consuming less time while processing the experiment.

Acknowledgments This study has been supported by Shin Kong Wu Ho-Su Memorial Hospital and National Science Council, Taiwan, under contract NSC 101-2221-E-011-078.

References

Benjamin KT, Tom BYL, Samuel WKC, Weijun G, uegang Z (2000). Enhancement of a Chinese discourse marker tagger with C4.5. In Annual Meeting of the ACL Proceedings of the 2nd workshop on Chinese language processing: Held in conjunction with the 38th Annual Meeting of the Association for Computational Linguistics, vol 12. Association for Computational Linguistics, Morristown, NJ, USA, 38–45

Chang PC, Fan C-Y (2008) A hybrid system integrating awavelet and TSK fuzzy rules for stock price forecasting. IEEE Trans Syst Man Cybern Part C Appl Rev 38(6):802–815

Chang PC, Liu C-H (2008) A TSK type fuzzy rule based system for stock price prediction. Expert Syst Appl 34(1):135–144

Chawla NY, Bowyer KKW, Hall LO, Kegelmeyer WP (2002) SMOTE: synthetic minority over-sampling technique. J Artif Intel Res 16:321–357

Chawlalal NV, Lazarevic A, Hall O (2003) SMOTEBoost: improving prediction of the minority class in bosting. In: The 7th European Conference on Principles and Practice of Knowledge Discovery in Databases. Springer, Berlin, pp 107–119

Dağ H, Sayın KE, Yenidoğan I, Albayrak S, Acar C (2012) Comparison of feature selection algorithms for medical Data. In: Innovations in intelligent systems and applications (INISTA), 2012 international symposium on digital object identifier: 10.1109/INISTA.2012.6247011. IEEE, 2012:1-5

Fan C-Y, Chang P-C, Lin J–J, Hsieh JC (2011) A hybrid model combining case-based reasoning and fuzzy decision tree for medical data classification. Appl Soft Comput 11(1):632–644

Freitus AA (2002) A survey of evolutionary algorithms for data mining and knowledge discovery. In: Ghosh A, Tsutsui S (eds) Advances in Evolutionary Computation. Springer, Berlin

Guyon I, Elisseeff A (2003) An introduction to variable and feature selection. J Mach Learn Res 3:1157–1182

Hu X (2003) DB-reduction: a data preprocessing algorithm for data mining applications. Appl Math Let 16:889–895

Hu S, Liang Y, Ma L, He Y (2009) MSMOTE: improving classification performance when training data is imbalanced. In: 2nd international workshop on computer science and engineering (WCSE 2009), Qingdao, China, pp 13–17

Kaastra I, Boyd M (1996) Designing a neural network for forecasting financial and economic timeseries. Neurocomputing 10:215–236

Mitchell MT (1997) Machine learning. McGraw-Hill, Singapore

Quinlan JR (1986) Induction of decision trees. Mach Learn 1:81–106

Ripley BD (1993) Statistical aspects of neural networks. In: Barndoff-Neilsen OE, Jensen JL, Kendall WS (ed.) Networks and Chaos—statistical and probabilistic aspects, Chapman & Hall, London, pp 40–123

Seiffert C, Khoshgoftaar T, Van Hulse J, Napolitano A (2010) Rusboost: a hybrid approach to alleviating class imbalance. IEEE Trans Syst Man Cybern Part A 40(1):185–197

Ture M, Tokatli F, Kurt I (2009) Using Kaplan–Meier analysis together with decision tree methods (C&RT, CHAID, QUEST, C4.5 and ID3) in determining recurrence-free survival of breast cancer patients. Expert Syst Appl 36(2):2017–2026

Witten IH, Frank E (2005) Data mining: practical machine learning tools and techniques, Morgan Kaufmann series in data management systems, 2005

Applying a Hybrid Data Mining Approach to Develop Carotid Artery Prediction Models

Chao Ou-Yang, Inggi Rengganing Herani, Han-Cheng Wang, Yeh-Chun Juan, Erma Suryani and Cheng-Tao Huang

Abstract This paper performs a hybrid method for imbalanced medical data set with many features on it. A synthetic minority over-sampling technique (SMOTE) is used to solve two-class imbalanced problems. This method enhanced the significance of the small and specific region belonging to the positive class in the decision region. The SMOTE is applied to generate synthetic instances for the positive class to balance the training data set. Another method that used is Genetic Algorithm for feature selection. The proposed of this method is to receive the reduced redundancy of information among the selected features. On the other hand, this method emphasizes on selecting a subset of salient features with reduced

C. Ou-Yang (✉) · I. R. Herani · C.-T. Huang
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei 106, Taiwan
e-mail: ouyang@mail.ntust.edu.tw

I. R. Herani
e-mail: inggi.herani@gmail.com

C.-T. Huang
e-mail: M10001015@mail.ntust.edu.tw

H.-C. Wang
Department of Neurology, Shin Kong Wu Ho-Su Memorial Hospital, Taipei, Taiwan, R.O.C
e-mail: drhan@ms1.hinet.net

H.-C. Wang
College of Medicine, National Taiwan University, Taipei, Taiwan, R.O.C

Y.-C. Juan
Department of Industrial Engineering and Management, Ming Chi University of Technology, New Taipei City, Taiwan, R.O.C
e-mail: ycjuan@mail.ncut.edu.tw

E. Suryani
Department of Information System, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
e-mail: erma@is.its.ac.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_170,

number using a subset size determination scheme. Towards the end, selected features would be processed using back Propagation Network (NN) and Decision Tree to predict the accuracy of Carotid Artery Disease. Experimental results show that these methods achieved a high accuracy, so it can assist the doctors to provide some possibilities information to the patient.

Keywords Carotid artery disease · Imbalanced data · SMOTE · Feature selection · GA · Over-sampling · BPN · Decision tree

1 Introduction

Data pre-processing is a data mining technique that involves transforming raw data into an understandable format. Real-world data is often incomplete, inconsistent, imbalanced, and is likely to contain many errors. Data pre-processing is a proven method of resolving such issues. Data pre-processing prepares raw data for further pre-processing.

The class imbalanced problem has been recognized in many real world application. There are many methods to deal with imbalanced problems, includes over-sampling minority class and downsizing majority class (Farquad and Bose 2012). Typically, the approaches for solving the imbalanced problem can divided into two categories: re-sampling methods and imbalanced learning algorithms. Re-sampling techniques are attractive under most imbalanced data. This is because re-sampling adjusts only the original data set, instead of modifying the learning algorithm. In the SMOTE (Synthetic Minority Over-Sampling Technique), the positive class is over-sampled by creating synthetic instances in the feature space formed by the positive instances and their K-nearest neighbors (Gao et al. 2011).

After balancing the data, feature selection is used to select a subset of terms occuring in the training set. A large number of irrelevant and/or redundant features generally exist in the real world datasets that may significantly degrade the accuracy of learned models and reduce the learning speed of the models (Kabir et al. 2011). The traditional approaches in feature selection can be broadly categorized into three approaches: filter, wrapper, and embedded methods. GA (Genetic Algorithm) can reduce redundancy of information among the selected features. Oh the other hand, this method emphasizes on selecting a subset of salient features with reduced number using a subset size determination scheme. Towards the end, to predict the accuracy of data, Back Propagation Network (NN) and Decision Tree (J48) are used.

2 Methodology

2.1 SMOTE

The SMOTE, over-samples the positive class by creating synthetic instances by a specified over-sampling ratio of the minority data size (Gao et al. 2011). The over-sampling denoted as β %, each minority data sample denoted as x_0, and randomly selecting, data points linking x_0 with K-nearest network (K is predetermined), and synthetic instance is denoted as x_s.

$$x_s = x_0 + \delta.\left(x_0^{[t]} - x_0\right) \quad (1)$$

The detailed of SMOTE can be seen as below:

1. SMOTE initialization: Specify the balanced degree β % and the value of K.
2. Create the new training data set $\tilde{D}_N$ by appending the generated positive training data points to the original training data set via the SMOTE.

2.2 Genetic Algorithm

Genetic Algorithms have received significant interest in recent years and are being increasingly used to solve real-world problems. A GA is able to incorporate other techniques within its framework to produce a hybrid that reaps the best from the combination (El-mihoub et al. 2006).

The steps of Hybrid GA can be explained further as follows:

Step 1: Initialize a feature set F of f features, a subset K of k salient features, and a population set P of p strings.
Step 2: Calculate the fitness value of each string p in P using the feed-forward NN training model.
Step 3: Perform the standard crossover operation upon the pair of fitter strings sequentially. The selection of possible fitter strings is made followed by standard rank-based selection procedure with utilizing the predefined crossover probability.
Step 4: Perform the standard mutation operation over the newly generated off-springs. Each bit of every string follows the predefined mutation probability whether it likes to be mutated or not.
Step 5: Perform the local search operation upon an offspring among the all newly generated ones sequentially in order to readjust the number of 1-bits.
Step 6: Replace the strings of lowest rank order in P by the whole generated offsprings.

Step 7: Check the stopping criterion to stop the genetic process. If the criterion is satisfied, then continue; otherwise, go to Step 2.

Step 8: Find the best string from the final generation according to its fitness value that signifies the desired subset of salient features for the given dataset.

2.3 Back Propagation Network

Back Propagation is a common method of training Artificial Neural Networks (ANN). From a desired output, the network learns many inputs. This method is not only more general that the usual analytical derivations, which handle only the case of special network topologies, but also much easier to follow. It also shows how the algorithm can be efficiently implemented in computing systems in which only local information can be transported through the network.

The algorithm of BPN applies the fundamental principle of the gradient steepest descent method to minimize the error function. It compares the outputs of the processing units in the output layer with desired outputs to adjust the connecting weights (Chen et al. 2010). There are three layers inside BPN:

1. Input layer: To demonstrate the input nodes of variables. The input layer receives features of input data and distributes them to hidden layer. The number of input nodes depends on different problems, f(x) = x.
2. Hidden layer: To show the interactions among input layer and output layer. There is no standard rule to define the number of hidden nodes. The usual way to get the best number of nodes is by experiments.
3. Output layer: To indicate the output nodes of variables. The number of output nodes depends on different problems to be solved. where Xi is the input vectors, i = 1, 2, …, m, Yj is the output vectors, j = 1, 2, … ,n and Ht is the hidden nodes, t = 1, 2, …, k.

2.4 Decision Tree

Decision Tree is a decision support tool that uses a model of decision and their possible consequences. These methods are commonly used in operations research, specifically in decision analysis and to help identify a strategy. C4.5 Decision Tree classifier and one-against-all method were combined to improve the classification accuracy for multi-class classification problems including dermatology, image segmentation, and lymphog- raphy datasets (Polat and Güneş 2009).

3 The Proposed Method

In this paper, we proposed methods that include pre-processing and prediction data. The study firstly rebalances the imbalanced dataset by using SMOTE (Synthetic Minority Over-Sampling Technique). After generated the balanced data set, then important features of balance training dataset would be selected by Hybrid Genetic Algorithm Feature Selection. These pre-processing and feature selection can be shown in first stage Fig. 1.

Towards the end, the combination of pre-processing and selected features would be processed using Back Propagation Network (NN) and Decision Tree to predict the best model.

4 Experiments

This study used North Medical Center Brain Health Checkup between 2004 and 2011, seven years of cerebral vascular health and diagnosis data set. It contains general inspection, blood and urine checks, and also professional brain check data (Table 1).

The datasets contain 9.892 unbalanced data, which is 9.578 data is Stroke (majority class) and 314 data is Normal (minority class). This dataset has 21 features that taken from General Inspection and Blood and Urine Checkup (Table 2).

For the evaluation, we specify the classification accuracy, sensitivity, and specificity for proposed methods. The equation of classification accuracy, sensitivity, and specificity (Table 3):

$$fp_{rate} = \frac{FP}{N} \tag{2}$$

$$precision = \frac{TP}{TP + FP} \tag{3}$$

$$accuracy = \frac{FP}{N} \tag{4}$$

$$tp_{rate} = \frac{TP}{N} \tag{5}$$

$$recall = \frac{TP}{P} \tag{6}$$

$$F_{measure} = \frac{2}{1/precision + 1/recall} \tag{7}$$

Additional terms associated with ROC are:

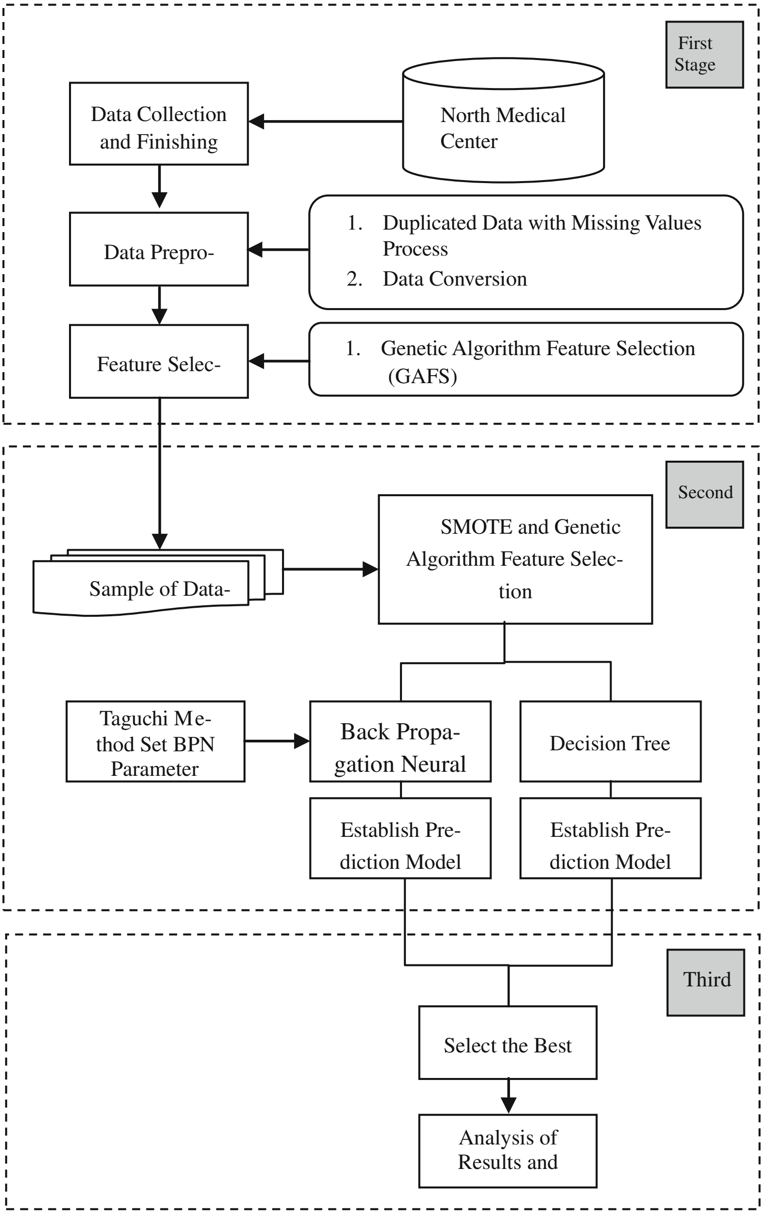


Fig. 1 Framework of the methodology

Table 1 Brain health checkup

Testing category	Test items
General Inspection	Waist circumference, blood pressure (left/right), respiration, pulse, temperature, height, weight, BMI, and past history, habits, and others
Blood and urine checkup	Thrombin original time (prothrombin time), and part coagulation blood live tenderloin time (APTT), and before meals blood glucose, and mashing hemoglobin (HbA1c), and bran amino acid grass acetate go amino enzymes (GOT), and bran amino acid Coke grape go amino enzymes (GPT), and urea nitrogen (BUN), and muscle anhydride (Creatinine), and total cholesterol (Total Cholesterol), and high-density fat protein (HDLc), and low density fat protein (LDLc), and triglyceride (Triglyceride), cysteamine acid (Homocysteine), and others
Professional brain checkup	Neck vascular ultrasound, vascular ultrasound, color wearing a cranial ultrasound, MRI, nasal MRI, MRI brain blood vessels in the brain, EEG brain wave, and others.

Table 2 Important features dataset

General Inspection		Blood Tests	
Name	Scope	Name	Scope
Sex	Male/ female	Prothrombin time	8.9–37
Age of health inspection	12–93	The active part thrombosis time	10.8–115.8
Waist circumference	16–139.5	Fasting glucose	48–410
Diastolic blood pressure	40–146	Glycosylated hemoglobin	3.3–17.1
Systolic blood pressure	73–237	Total cholesterol	76–580
BMI	12.9–47.3	High-density lipoprotein cholesterol	5–125
Hypertension (history)	With/ without	Low-density lipoprotein cholesterol	20–442
Anemia (medical history)	With/ without	Total cholesterol/high-density lipoprotein cholesterol	1.3–39.2
High blood cholesterol (history)	With/ without	Heart disease (medical history)	With/ without
Diabetes (history)	With/ without	Triglycerides	20–1,938

$$\text{Sensitivity} = \text{recall} \tag{8}$$

$$specificity = \frac{TN}{FP + TN} = 1 - fp_{rate} \tag{9}$$

$$\text{Positive predictive value} = \text{precision} \tag{10}$$

where TP = True Positive, TN = True Negative, FP = False Positive and FN = False Negative.

Table 3 Result comparison based on classification accuracy, sensitivity, and specificity

Methodology	Correctly classified					
SMOTE and genetic algorithm feature selection attributes combination	Back propagation neural network			Decision tree (C4.5)		
	Classification (%)	Sensitivity	Specificity	Classification (%)	Sensitivity	Specificity
	80.08	**0.743**	**0.859**	**93.435**	**0.934**	**0.934**

As we can see from the Table 3, SMOTE and Genetic Algorithm Feature Selection achieved **80.08 %, 0.743, 0.859** for classification accuracy, sensitivity and specificity using BPN, and **93.435 %, 0.934, 0.934** for classification accuracy, sensitivity and specificity using Decision Tree.

5 Conclusions & Discussion

Our study in this paper show that activity modeling that is developed using hybrid methods can provide a higher accuracy for predicting Carotid Artery Disease based on patient instances data and features. These hybrid methods include SMOTE that used to solve two-class imbalanced problems, Genetic Algorithm used for receive the reduced redundancy of information among the selected features, and for selected features would be processed using back Propagation Network (NN) and Decision Tree to predict the accuracy.

Genetic Algorithm that is used for independent feature selection provides a good result for the prediction. However, the result of independent feature selection may not so satisfactory than the dependent or interdependent ones. This indicates that future research might be able to increase the accuracy of feature selection method by using other feature selection method.

Acknowledgments This study has been supported by Shin Kong Wu Ho-Su Memorial Hospital and National Science Council, Taiwan, under contract NSC 100-2221-E-011-036.

References

Chen F-L, Chen Y-C, Kuo J-Y (2010) Applying moving back-propagation neural network and moving fuzzy neuron network to predict the requirement of critical spare parts. Expert Syst Appl 37(6):4358–4367

El-mihoub TA, Hopgood AA, Nolle L, Battersby A (2006) Hybrid genetic algorithms: a review. Eng Lett 13:124

Farquad MAH, Bose I (2012) Preprocessing unbalanced data using support vector machine. Decision Supp Syst 53(1):226–233

Gao M, Hong X, Chen S, Harris CJ (2011) A combined SMOTE and PSO based RBF classifier for two-class imbalanced problems. Neurocomputing 74(17):3456–3466

Kabir MM, Shahjahan M, Murase K (2011) A new local search based hybrid genetic algorithm for feature selection. Neurocomputing 74(17):2914–2928

Oh I-S, Lee J-S, Moon B-R (2004) Hybrid genetic algorithms for feature selection. IEEE Trans Pattern Anal Mach Intell 26(11):1424–1437

Polat K, Güneş S (2009) A novel hybrid intelligent method based on C4.5 decision tree classifier and one-against-all approach for multi-class classification problems. Expert Syst Appl 36(2):1587–1592

Comparing Two Methods of Analysis and Design Modelling Techniques: Unified Modelling Language and Agent Modelling Language. Study Case: A Virtual Bubble Tea Vending Machine System Development

Immah Inayati, Shu-Chiang Lin and Widya Dwi Aryani

Abstract The developing of internet worldwide encourages the research in Software Engineering fields in the development of numerous analysis and design methods used in Software Development. Among these methods, Unified Modelling Language (UML) has been known to Software developers as a popular object-oriented tool to analyze and design a system. On the other hand, a less known tool, Agent Modeling Language (AML), is a semi-formal visual modeling language for specifying, modelling and documenting system that incorporate features drawn from multi-agent system theory. This paper presents an overview of UML and AML using the case of Virtual Bubble Tea Vending Machine Software development. This paper also compares UML and AML methods in analyzing phase and designing phase in system development.

Keywords Software engineering · Unified modelling language · Agent modeling language · Virtual bubble tea vending machines

I. Inayati (✉) · S.-C. Lin · W. D. Aryani
Industrial Management, National Taiwan University of Science and Technology,
Keelung Road Sec. 4 no. 43 Daan District, Taipei 106, Taiwan, Republic of China
e-mail: immah.inayati@yahoo.com

S.-C. Lin
e-mail: slin@mail.ntust.edu.tw

W. D. Aryani
e-mail: widyadwiaryani@yahoo.co.id

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_171,

1 Introduction

Modelling is used in many walks of life and is also widely used in science and engineering to provide abstractions of a system at some level or precision and detail. After a model is built, it is then analyzed in order to obtain a better understanding of the system being developed. According to Object Modelling Group (OMG) "Modelling is the designing of software applications before coding" (Gomaa 2011).

Many modelling techniques can be used to develop a system or a software. Those models have their own notations and diagrams to make a better understanding of a system. Object based modelling and agent based modelling are two such techniques that have been used widely. This paper will present the analyzing and design phase of the development of Virtual Bubble Tea Vending Machine (VBTVM) system using two modellings: the object based modelling (using the UML diagram) and the agent based modelling (using Gaia method).

1.1 Object Oriented and Agent Oriented Modelling

Object oriented modelling methods apply object oriented concepts to the analysis and design phase of the software lifecycle. The emphasis is on identifying real-world objects in the problem domain and mapping them to software objects.

Agent oriented modeling applies agent based concept to the analysis and design phase of software lifecycle. Agent is a computer system that is capable of independent action on behalf of its user or owner (Wooldridge 2004). This model is normally used to specify, model and document systems by applying the concept of *Multi-Agent Systems* (*MAS*) theory.

1.2 Unified Modelling Language and Agent Modelling Language

Unified Modelling Language (UML) is a standard language for writing software blueprints. Booch et al. (2005). It is a visual language that provides a way for people to visualize, construct, and document the artifacts of software system (Bennt et al. 2005).

There are three important characteristics inherent in UML, i.e., sketches, blueprints and programming languages. As a sketch, UML can serve as a bridge to communicate some aspects of the system. Thus all members of the team will have the same picture of a system. UML can also serve as a blueprint for a very complete and detailed. With this blueprint will be known to compile detailed information program code (forward engineering) or even to read and interpret the program back to the diagram (reverse engineering).

The Agent Modeling Language (AML) is specified as an extension to UML 2.0 in accordance with major OMG modeling frameworks (MDA, MOF, UML, and OCL). The ultimate objective of AML is to provide software engineers with a ready-to-use, complete and highly expressive modeling language suitable for the development of commercial software solutions based on multi-agent technologies (Trencansky and Cervenka 2005). There were many Methodology using this way of Modelling and Gaia is one of them.

Gaia Methodology is intended to allow an analyst to go systematically from a statement of requirements to a design that is sufficiently detailed so it can be implemented directly (Wooldridge 2004). The objective of the Gaia analysis process is the identification of the roles and modeling the interactions between them (Dennis et al. 2012).

The Analysis phase starts with the definitions of the *global organization goal* which includes the decomposition of the global organization into sub-organizations. The next step is to build the *environmental model* that lists all resources in which one agent can access. The *preliminary role model* is built to capture the basic skills. In this model, a role is represented with an abstract and semiformal description (Blanes et al. 2009).

2 Proposed Model of UML and AML for Virtual Bubble Tea Vending Machine

2.1 Method Used in Modelling Analysis and Design Phase for Bubble Tea Vending Machine Using UML

Figure 1 is the Unified Modelling Language (UML) diagram used to analyze and Design Virtual Bubble Tea Vending Machines. Not all the UML diagram used in this development, as shown below:

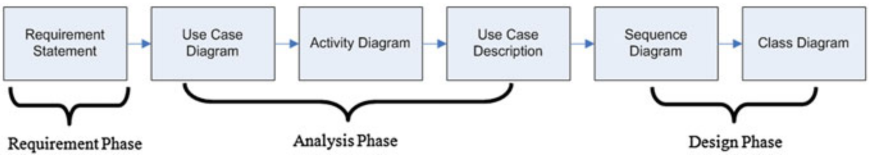


Fig. 1 UML model virtual bubble tea vending machines

2.2 Method Used in Modelling Analysis and Design Phase for Bubble Tea Vending Machine Using AML

Figure 2 illustrates the Agent Modelling Language (AML) using Gaia model. This model will be used in analyzing and designing Virtual Bubble Tea Vending Machine.

3 Preliminary Results and Discussion

Among the three stages of developing proposed model of UML and AML for Virtual Bubble Tea Vending Machine, the authors have completed the first 2 stages, which include the requirement phase and the analysis phase. The analysis phase that has been done are Use case diagram and Activity diagram for UML Diagram and Role model and Interaction model for AML (Gaia) Method.

3.1 Requirement Statement for Virtual Bubble Tea Vending Machine

Table 1 shows our proposed Requirement statement for virtual Bubble Tea Vending Machine. This Requirement will be continued with the Analyzing and Designing steps with two methods, Agent Based and Object Based.

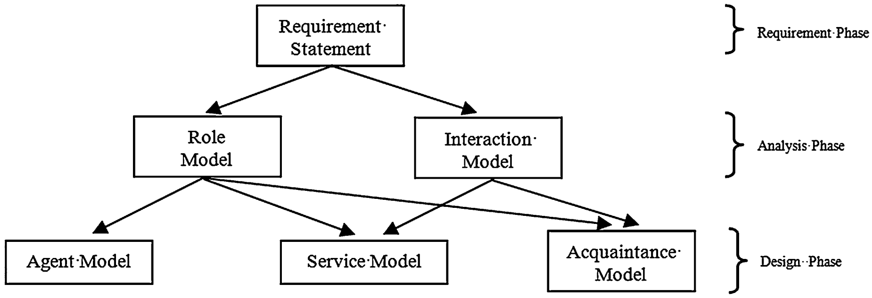


Fig. 2 Gaia model for virtual bubble tea vending machines

Table 1 Requirement statement of bubble tea vending machine

No	Requirement
1	System can identify different user
2	System can save the data of user (including name and email)
3	System facilitate a log management system
4	System can give service to a registered user on a non registered user
5	User can see Bubble tea catalog
6	System can receive 2 kinds of payment: cash and easy card
7	System can give change to cash payment
8	System have to ask user the Bubble tea he/she wants to buy before payment

3.2 Method Used in Modelling Analysis and Design Phase for Bubble Tea Vending Machine Using UML

Figure 3 (revised from Bennet et al. 2005) shows the UML diagrams in Analysis phase based on the requirement statements in the previous phase. The Diagram completed currently are Use case diagram and Activity diagram.

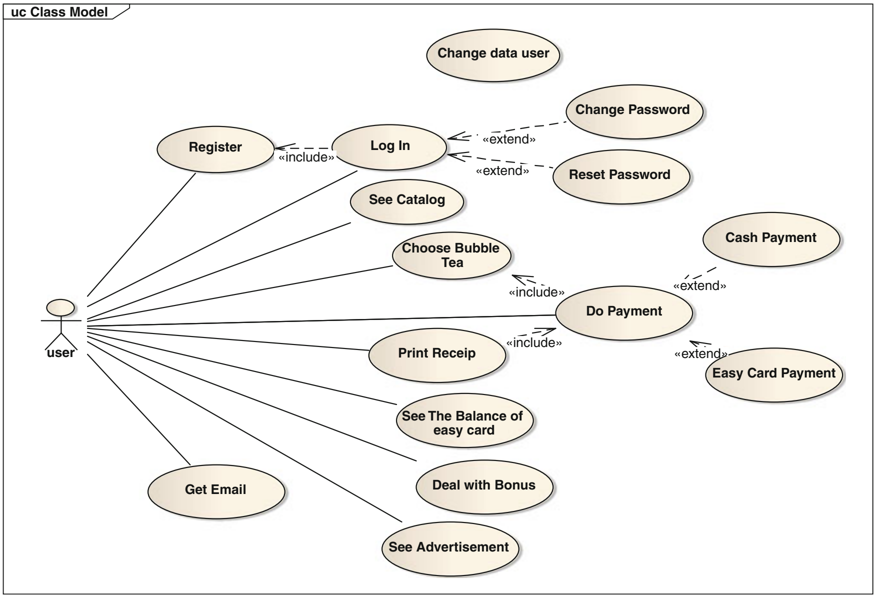


Fig. 3 Use case diagram for virtual bubble tea vending machine system

3.2.1 Use Case Diagram

As can be shown in Fig. 3, Use case diagram shows actors, use cases, and the association among them. Use cases attempt to capture the functional requirements of the system by describing the different ways in which an actor (essentially a type of user) can interact with the system (Hunt 2000). This diagram shows the "user" actor that can access 10 use cases. *Extends* association in the diagram means that actor can choose between some use case and *include* association means that before doing one use case other use cases needed to be accomplished first.

3.2.2 Activity Diagram

Activity diagram is one of the five diagrams used in UML for modeling the dynamic aspects of the system. An activity diagram is essentially a flow chart, showing flow of control from activity to activity. In this development, the activity diagram describes the detail activity of each use case. The picture above shown the activity diagram that show the detail activities of "Choose Bubble Tea" use case (Fig. 4).

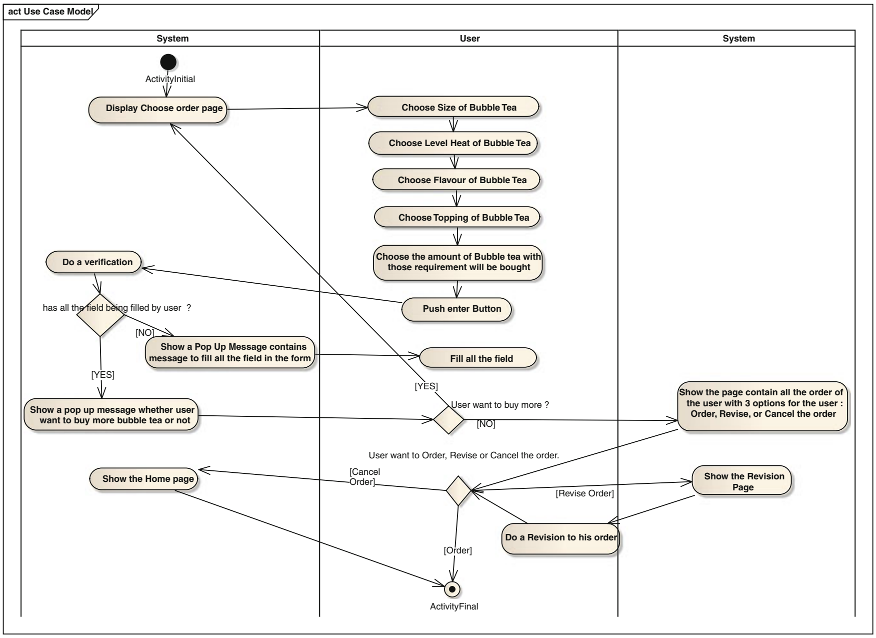


Fig. 4 Activity diagram for virtual bubble tea vending machine system

3.3 Method Used in Modelling Analysis and Design Phase for Bubble Tea Vending Machine Using AML

The Organization

The first phase in Gaia analysis is to determine whether multiple organizations have to coexist in the system and become autonomous interacting MASs (Jain and Dahiya 2011). In our system, the organizations can be easily identified as:

- The one that takes care Transaction
- The one that Make the Bubble Tea

3.3.1 Environmental Model

The environment is treated in terms of abstract computation resources, such as variables or tuples, made available to the agents for sensing. The environment model for the Bubble Tea Vending Machine can be depicted as (Table 2):

Role Model

In the Bubble Tea Vending Machine System, the roles can be identified as:

1. Bubble_manager
2. Register
3. Authorization
4. Solve_query
5. Order_manager
6. Display
7. Bubble_producer
8. Bonus_manager
9. Payment _manager
10. Send_email

Bubble_manager role keeps all the information about bubble_catalogue. The *register* role is responsible to register new buyer. The buyer will give his/her name, password and email address. If the buyer is new, then the registration process is handled by this agent, otherwise the request is sent to *authorization* agent. The Authorization role is used to get the username and password from the user. The details are matched with the database. Once the *Authorization* is done, a message is passed to the *solve_query* agent. The *solve_query* agent then takes the query

Table 2 Environmental model of bubble tea vending machine

bubble_catalog	The list of Bubble tea provided
bubble_recommended	The list Bubble tea recommended for the user
buyer_order	The item Bubble tea that is ordered by the buyer
buyer_detail	The data of buyer

Table 3 Role model of bubble tea vending machine

Role schema: order_manager
Description:
This preliminary role involves keeping the order of each buyer before it is being paid. It uses the data structures called bubble_catalogue that contains information of the detail of bubble tea needed to be produced. The details are: the size, the heat level, the taste, and the topping of bubble tea. This role also change the data of buyer
Protocols and activities
add_bubble_order, change_bubble_order, change_buyer_bonus
Liveness:
Bubble_order = (add_bubble_order, change_bubble_order)

from the user and solves it. After it is solved, the agent will send a message to the *display* role, which will display the Order page. The Buyer will then choose his/her Bubble tea order.

The *order_manager* role will enable user to make a choice to the bubble tea with detailes of the size, heat level, flavor, topping, and the number of bubble tea. After the *order_manager* role is done, *bubble_producer* produces the bubble tea. *Bonus_manager* role enables buyer to choose the bonus options. *Payment_manager* role will help buyer to choose pay options. *Send_email* role enables system to send email to buyer advertised information such as product promotion, new product launch, and lottery winner of promoted products.

4 Result and Future Work

This paper discusses the differences between Unified Modelling Language and Agent Modelling Language in Analyzing phase. Since UML is based on object, it begins with Use Case which explains what the system does. On the other hand, the Gaia model, an Agent Modelling Language, is based on agents and it begins with the role of organization.

Our future work will encompass the design phase and the final implementation phase as well so we can make a more thorough comparison based on rules and guidelines, notation, techniques used, system developed, and the complete documentation (Table 3).

References

Bennet S, Skeleton J, Lunn K (2005) Schaum's outlines UML, 2nd edn. Mc Graw Hill, Singapore pp 5–10

Blanes D, Insfran E, Abrahão S (2009) RE4Gaia: a requirements modeling approach for the development of multi-agent systems. Springer, Berlin Heidelberg ASEA 2009, CCIS 59, pp 245–252

Booch G, Rumbough J, Jacobson I (2005) The unified modelling language user guide, 2nd edn. Addison Wesley, United States, p 267

Dennis LA, Boissier O, Bordini RH (2012) A Gaia-driven approach for competitive multi-agent systems. Springer, Berlin Heidelberg, pp 208–216

Gomma H (2011) Software modelling and design. Cambridge University Press, New York, p 3

Hunt J (2000) The unified process for practitioners. Springer, London, p 63

Jain P, Dahiya D (2011) Architecture of a library management system using Gaia extended for multi agent systems. ICISTM 2011, CCIS 141, pp 340–349

Trencansky I, Cervenka R (2005) Agent modeling language (AML): a comprehensive approach to modeling. Informatica 29:391–400

Wooldridge M (2004) An introduction to multiagent system. Wiley, LTD, England, pp 228–230

Persuasive Technology on User Interface Energy Display: Case Study on Intelligent Bathroom

Widya Dwi Aryani, Shu-Chiang Lin and Immah Inayati

Abstract Computing products for creating persuasive technology are getting easier to use with innovations in online video, social networks, and metrics, among others. As a result, more individuals and organizations can utilize different media to influence people's behaviour via technology channels. In-home displays (IHDs) are one of these trendy and powerful media that have the potential to communicate energy usage feedback and to persuade energy saving action to householders. By providing real-time information on energy consumption, IHDs can persuade householders to change into target behaviour. IHDs user interface design plays a significant role in the success of persuading user behaviour change. This paper presents a laboratory study to investigate how the user interface design of IHDs might persuade people to save energy. A model was proposed, questionnaires, including open-ended questionnaire and closed-ended questionnaire, were created at a first phase of the lab study to gather information regarding user preference among 35 information displays and icon displays. In the second phase study, two user interface prototypes, one with target behaviour feedback and one without, will be developed to investigate user's behaviour change in intelligent bathroom with regard to energy conservation.

Keywords Persuasive technology · Intelligent bathroom · Energy consumption · In-home displays

---

W. D. Aryani (✉) · S.-C. Lin · I. Inayati
Industrial Management, National Taiwan University of Science and Technology, Keelung Road Sec. 4 no. 43 Daan District, Taipei 106, Taiwan, Republic of China
e-mail: widyadwiaryani@yahoo.co.id

S.-C. Lin
e-mail: slin@mail.ntust.edu.tw

I. Inayati
e-mail: immah.inayati@yahoo.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_172,

1 Introduction

Energy conservation of household has being an interesting topic within applied social and environmental psychological research for number of decades (Abrahamse et al. 2005). People's interaction with indoor environment plays a significant role in energy consumption (Yao and Zheng 2010). Studies such as (Doukas et al. 2007) further pointed out that the requirements for necessary thermal comfort, visual comfort and indoor air quality assurance are increasing. There is a need to efficiently manage energy inside building and to support building energy conservation. This effort aims to assure the operational needs with the minimum possible energy cost.

The major barriers to efficient energy management are mismatching and delaying feedback information to the building energy management system (Yao and Zheng 2010). Energy consumption feedback is typically provided in form of monthly bills report. Studies have shown that implementing real-time feedback information inside an ordinary house has reduced individual household electricity consumption by 4 to 12 % (Ehrhardt-Martinez et al. 2010). By providing real-time feedback information, user will be aware of the correlation between their everyday behaviour and energy consumption (Abrahamse et al. 2005). This awareness will persuade user to change behaviour with regards to energy consumption. Presenting real-time feedback information by monitoring and display technologies has more potential for achieving energy savings than giving information alone.

Display technologies can be supported with an interactive computing design to change people's attitude and behaviour. This kind of interactive computing design has been known as persuasive technology. Persuasive technology can take on many forms from mobile phones to smart devices. In this research, we use intelligent bathroom user interface as our case study. Our persuasive system was developed based on the "Functional Triad", a framework for thinking about the roles that computing products play from the perspective of the user (Fogg 2003). The functional triad proposes that interactive technologies can operate in three basic ways: as a tool, as a media, and as a social actor.

This research focused on social actor role because, as Fogg (2003) acknowledged, humans apply the same persuasive principle to influence others. The fact that people responds socially to computer products has significant implications for persuasion. As a social actor, computing product can persuade people to change their attitudes or behaviours by rewarding them with positive feedback, modelling a target behaviour or attitude, or providing social support (Fogg 2003).

The objective of this research is to investigate whether computing product as a social actor has a significant implication in persuading people and hence yields to people's attitude and behaviour change. Figure 1 illustrates our study's research framework.

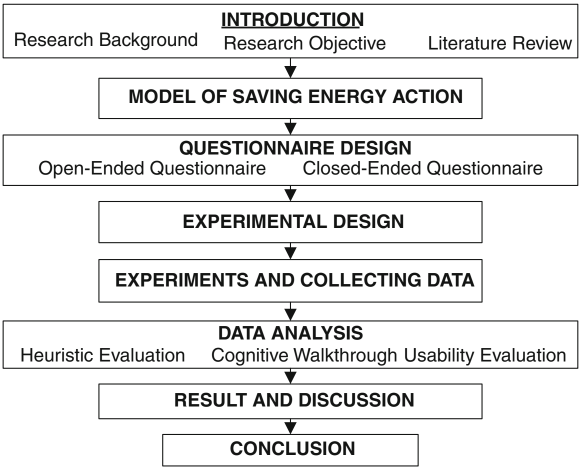


Fig. 1 Research framework

2 Model of Saving Energy Action

Figure 2, a revised model based on EBM Consumer Decision Process-Model (Engel et al. 1995), shows how users are being triggered to choose saving energy actions, a decision making process that user will go through. This model is adapted because it describes in detail the system of internal and external forces that interact and affect how the user thinks, evaluates, and acts.

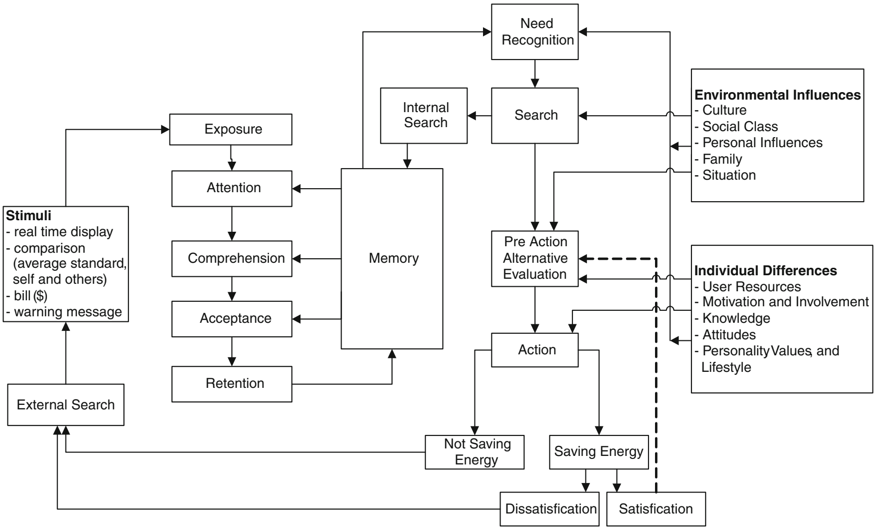


Fig. 2 Model of saving energy action

EBM model proposed five stages that consist of need recognition, information search, pre-action alternative evaluation, action, and post action evaluation. We consider need recognition is a stage when user realized to minimize the energy used which occur as effect from information searching. In action stage, user starts to evaluate the alternative action and decide whether to choose saving energy or not, in terms of expected benefits and narrowing choice to the preferred one. If user chooses not to save energy, the decision process will go back to information searching process. If user chooses to save energy, there will be a post action evaluation whether user is satisfied or dissatisfied. Satisfied user will do action repetitively while dissatisfied user's decision making process will go back to an external search. Satisfaction in this research is shown by how user responds when they had minimised or efficiently used the household appliances.

Model of Saving Energy Action is reciprocal with the three principal factors in Fogg Behaviour Model (FBM) (Fogg 2009) which become a way to understand the drivers of human behaviour. The target behaviour in this research refers to save energy action. Motivation and ability in FBM are represented by Individual Differences while ability becomes one of user resources in our proposed model. Meanwhile, triggers are represented by stimulation in form of real time display, comparison information, bill, and warning message.

3 Implementation of Persuasive Technology in Energy Display

In first phase of our study, questionnaires were developed to gather user preferences for user interface design. The first questionnaire, an open-ended questionnaire, was distributed to five participants, 3 females and 2 males, with ages ranging from 23 to 40 years old. Participants are graduate students specializing in human factors and all participated voluntarily. Participants were interviewed individually to answer his/her preferences regarding energy display information and icon displays. It took an average of 30 min to complete the questionnaire.

A second questionnaire, closed-ended questionnaire, was employed based on the results of the first questionnaire to gather more precise assessments of the information display (35 contents) and icon display (35 icons). Likert-type seven point scales ranging from very important, important, slightly important, neutral, slightly unimportant, unimportant, and very unimportant were applied. Questionnaire was distributed via online questionnaire system and a total of 123 responses were collected with age ranging from 19 to 42 years old and with various occupations.

In the second phase, we will design a persuasive user interface based on functional triad roles. Two user interface prototypes will be developed, including one with social actor role and the other one without social actor role. Participants will be asked to finish 15 tasks based on three different task difficulty levels (easy, medium, and difficult). A post-experiment general satisfaction questionnaire will be distributed as a subjective measure compared to objective measure results gathered during the user interface experiment to examine the effect of persuasive technology.

4 Preliminary Result and Discussion

Summarized results from the open-ended questionnaire reveal that an intelligent bathroom user interface display should provide not only common intelligent bathroom functions such as water temperature or water filling automation, but also provide broader functions such as In-Home Display (IHD), and it would be best to provide smart phones functions. These functions are further breakdown into 35 different functions. The questionnaire also found five alternative icons preferred by the users in information display.

Closed-ended questionnaire further reveals that among 35 information to be displayed in intelligent bathroom, "bathroom indoor air quality" and "home security" are ranked as very important information while "bed temperature", "location recognition", "home appliances automation", "education/learning", "picture", "e-books", and "GPS" are ranked as "neutral". Participants also have chosen the most represented icon for each intelligent bathroom functions. These results were applied to our next phase of implementing our user interface display design.

Since the responses were at least as good as neutral, we plot all of these 35 information displays into user interface design. The first functional triad, *as a tool*, has a goal to make activities in bathroom more user friendly. One example of this is shown in Fig. 3's Lamp setting, users can easily switch lights on and off and adjust the light level by finger touching the icons.

The second functional triad, *as a media*, has two categories, symbolic and sensory. Symbolic media category uses symbols (text, graphics, charts, and icon) to convey information. Sensory media provides sensory information such as audio, video, and even smell and touch sensations. The third functional triad, *as a social actor*, means user will respond to the user interface display as though it were a living being and people will get emotionally involved with user interface display through social actor role. In our user interface design, we adapted this role in giving advice to user to lead to energy saving actions. Figure 4 shows the still under-developing user interface display when the display is placed in standby position for 5 min.

Once the user interface prototypes are completed developed, the respondents will be asked to finish designated tasks in our lab and to what extent the persuasive technology plays a role in our intelligent bathroom user interface will be investigated.

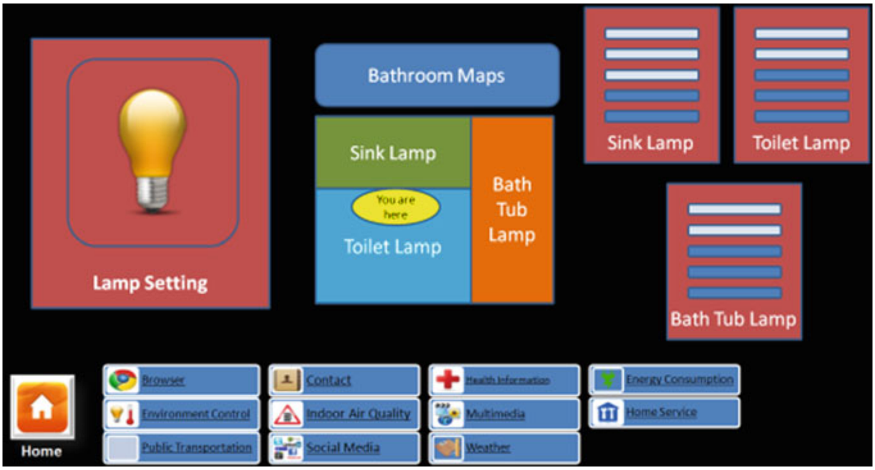


Fig. 3 Persuasive user interface design—as a tool

Fig. 4 Persuasive user interface design—as a social actor

5 Conclusions

This paper presents a case study in which the user interface display could persuade people in saving energy action. Questionnaire design and analysis were conducted to gather which information display should be provided in user interface display. Preliminary study results 35 different information displays and icon displays which were applied in designing user interface design. This research will then test user interface design by evaluating the usability and user preference.

References

Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation. J Environ Psychol 25:273–291

Doukas H, Patlitzianas KD, Iatropoulos K, Psarras J (2007) Intelligent building energy management system using rule sets. Build Environ 42:3562–3569

Ehrhardt-Martinez K, Donnelly KA, John A (2010) Advanced metering initiatives and residential feedback programs: a meta-review for household electricity-saving opportunities. Am Counc Energ Efficient Econ

Engel JF, Blackwell RD, Miniard PW (1995) Consumer behavior. International edition, 8th edn. The Dryden Press, Orlando

Fogg BJ (2003) Persuasive technology: using computers to change what we think and do. Morgan Kaufmann Publishers, United States of America

Fogg BJ (2009) A behavior model for persuasive design. Persuasive Technology Lab, Stanford University

Yao R, Zheng J (2010) A model of intelligent building energy management for the indoor environment. Intell Buildings Int 2:72–80

Investigating the Relationship Between Electronic Image of Online Business on Smartphone and Users' Purchase Intention

Chorng-Guang Wu and Yu-Han Kao

Abstract The extensive popularity of smartphones has been recently providing online business practitioners with an alternative useful channel to communicate product information with potential and existing customers. Previous research on Internet shopping suggests that electronic image, the quality of product information within the shopping website, plays a critical role in influencing online shoppers' purchase decisions substantially. Therefore, by leveraging prior studies on website quality and web customer behavior, this study aims to identify the influential factors that contribute to the electronic image of shopping websites on smartphones, and investigates the effect of smartphone users' perception of the electronic image upon their intended purchases. The arguments proposed for this study were empirically validated by using the data from a web survey of 321 smartphone users in the context of two online bookstores. The findings suggest that users' perception of the electronic image on a smartphone related to the usefulness and scope of product information influences their purchase intention.

Keywords Smartphone · Electronic image · Website quality · Purchase intention

1 Introduction

Over the past few years, smartphones, more than just a cellphone, have been developed as mobile gadgets for connecting to the Internet. Not only can they work as media players, GPS, and cameras but also they are tools for surfing the

C.-G. Wu (✉) · Y.-H. Kao
College of Management, Yuan Ze University, 135 Yuan-Tung Road, Chung-Li, 32003 Taoyuan, Taiwan, Republic of China
e-mail: chuckwu@saturn.yzu.edu.tw

Y.-H. Kao
e-mail: S1007117@mail.yzu.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_173,

Web, managing emails and even checking social media. Although desktop and laptop computers are so far the major devices used to get online, it is worth noting that more and more people are accessing the Web from their smartphones. Therefore, various online businesses gradually deploy their smartphone-based websites for phone holders to easily access their online services in terms of obtaining potential business opportunities. For this, providing appropriate information necessary to satisfy smartphone users is one of the critical issues facing online business practitioners.

According to the e-commerce literature, electronic image (e-image), consisting of website appearance and information content, is considered as one of the most important influential factors of purchase intention related to online business websites (Gregg and Walczak 2008). However, previous research largely focused on examining online purchasers' perception of e-image in the context of computers rather than smartphones. And, e-image in this study that refers to the quality of product information within a shopping website has not been fully defined for the smartphone setting. Thus, based on prior studies on website quality and online shopper attitudes, we attempted to identify several factors that formed the e-image of shopping websites within a smartphone and study the relationship between the factors and smartphone users' online purchase intention.

2 Literature

2.1 Electronic Image and Online Shopping

As an information signal delivered by online businesses to their customers, electronic image (e-image) within the web settings affects online shoppers' overall perception of the value offered by an online store (Lohse and Spiller 1998), and has been considered to be a critical factor that influences the success of e-business (Gregg and Walczak 2008). Unlike online image which presents the photographs or graphics of products online, e-image is viewed as a personality of website that refers to the presentation and quality of product information and an online firm's policies information (Gregg and Walczak 2008). It helps an online business shape its unique online identity as the business can develop a suitable e-image (Hesketh and Selwyn 1999; Sand 2007).

Literature suggests that an online business's e-image is significantly influenced by the quality of information content related to its website which in turn will have a direct and considerable impact on online shoppers' purchase intention (Gregg and Walczak 2008). Online shoppers usually cannot have physical contact with the products demonstrated on the website while purchasing online; under the circumstances, they largely rely on the website information to establish their shopping experience (McKinney et al. 2002). As a result, the enhancement of information quality can foster their intention to purchase online (Gregg and Walczak 2008).

Similarly, prior studies on e-commerce indicate that website quality including design, scope of information, security and privacy, serves as a very useful metric to evaluate online shoppers' purchase intention (Ranganathan and Ganapathy 2002; Park et al. 2004).

2.2 Attributes of Electronic Image on Smartphone

Online purchase refers to the process of searching and transferring product information and making purchases in the online shopping environment (Pavlou 2003). Previous research has been identifying a variety of factors that influence consumers' intention to purchase online. In the context of smartphone, we deliberately chose three of them—usefulness, navigation, scope—to form the e-image of website on smartphone and applies these variables to analyze the user's intention to purchase online via the website displayed in smartphone.

Usefulness refers to the degree to which a person believes that a particular information system would enhance his/her job performance (Davis 1989). In the setting of online shopping, it represents what a consumer can benefit from getting access to shopping website to make a purchase (Abadi et al. 2011), and serves as an important determinant of a consumer's attitude toward purchasing online (Chen et al. 2002). Numerous empirical studies have been investigating the relationship of usefulness and consumers' intention to online purchase; their findings demonstrate that usefulness is positively related to online purchase intention (Kourfaris 2002; van der Heijden and Verhagen 2004; Wen et al. 2011).

Navigation has been used to evaluate the links to required information stored in a website (Alba et al. 1997; Wilkinson et al. 1997). It is concerned with whether a user can easily go back and forth to find a target website in a very short period with no disorientation (Ghalib Al-Masoudi and Chandrashekara 2010). The navigation function of a website has been drawn lots of attentions in the e-commerce sector since making users convenient and time-saving is the key to the success of online shopping (Deck 1997; Huizingh 2000; Ranganathan and Ganapathy 2002).

Scope in this study is related to the level of detail and range of the information provided by the website. The scope of information within an e-commerce website may include firm, brand, product variety, price, quality, service, and so on. Aaker (1991) suggested that the quantities of product or brand information associated with a store would affect consumers' confidence in their purchase decisions. Hymers (1996) also pointed out that consumers prefer surfing the website that is informative for making purchase decisions.

3 Methods

A web-based and cross-sectional survey was conducted to evaluate the research arguments developed for investigating the relationship between the e-image's attributes of a smartphone's website and users' purchase intention. In this section, instrument construction, sampling method, construct measurement, analytical methods and test results are described as follows.

3.1 Instrument Development and Data Collection

Our survey items was developed from previous validated measures in online store image and website quality studies, and reworded to refer particularly to the context of smartphone use. In this study, there are three e-image constructs measured using scales adapted from McKinney et al. (2002), van der Heijden and Verhagen (2004). Purchase intention was assessed using items extended from van der Heijden and Verhagen's (2004) intention to purchase online. All scale items used five-point Likert scales anchored between "strongly agree" and "strongly disagree." The instrument was pre-tested with 30 graduate students to examine the psychometric properties of the scale items. A test of factor analysis and standard reliability indicated that the piloted instrument was reliable with no major bias.

The online questionnaire for this study was composed of two parts in which two online bookstores showing different e-images were illustrated. The first part solicited survey participants to provide their responses for an online bookstore with limited information about its products while the other part asked respondents the same questions as those in the first part for their ideas concerning the online bookstore with detailed information related to its products. The sample consisted of students at several universities in northern Taiwan. Following a single round of data collection with a response rate of 65 %, 321 usable responses were collected.

3.2 Construct Reliability

In this study, the Cronbach's alpha was used to measure the internal consistency of responses. The Cronbach' alpha greater than 0.70 is considered acceptable in confirmatory research and the value should exceed 0.60 for exploratory research (Gefen et al. 2000). Table 1 demonstrates the descriptive statistics and the Cronbach's alpha for each construct of the two different types of e-image. All constructs revealed a reasonable distribution across the ranges, and the alpha value of each construct greatly exceeded 0.70, suggesting adequate reliability.

Table 1 Descriptive statistics and reliability measurements for constructs

E-image type	Construct	Mean	Standard deviation	Cronbach's alpha
Limited	Usefulness	3.40	0.93	0.84
	Navigation	3.76	0.88	0.86
	Scope	3.32	0.92	0.89
	Purchase intention	2.96	0.77	0.86
Detailed	Usefulness	3.86	0.88	0.92
	Navigation	3.85	0.86	0.91
	Scope	3.96	0.83	0.94
	Purchase intention	3.38	0.91	0.91

3.3 Data Analysis and Results

In assessing the proposed research model, construct validity and hypothesis testing were measured using LISREL, a structural equation modeling (SEM) technique. Based upon recommendations by Gerbing and Anderson (1988), data analysis for this study was performed to first test the convergent and discriminant validity of each individual measurement model for the two different types of e-image before making any attempt to evaluate their structural models. Basically, if a measurement model is operating adequately, one can then have more confidence in findings related to the assessment of the hypothesized structural model (Byrne 2001).

To evaluate convergent validity for the measurement models, selected goodness-of-fit statistics related to confirmatory factor analysis (CFA) and standardized indicator factor loadings were examined. The analysis gave a Chi square of 259.61 with 113° of freedom ($\chi^2/d.f. = 2.297$; $p < 0.001$) for the limited type of e-image and a Chi square of 287.81 with 113° of freedom ($\chi^2/d.f. = 2.547$; $p < 0.001$) for the detailed type, both of which were well within the recommended ratio of 3:1. For model fit of the limited type, the goodness of fit index (GFI) was 0.91, adjusted goodness of fit index (AGFI) was 0.88, comparative fit index (CFI) was 0.99, incremental index of fit (IFI) was 0.99, normed fit index (NFI) was 0.98, root mean square residual (RMR) was 0.039, and root mean square error of approximation (RMSEA) was 0.064; those values were within the commonly acceptable benchmarks. As for the detailed type, GFI at 0.90, AGFI at 0.87, CFI at 0.99, IFI at 0.99, NFI at 0.98, RMR at 0.028, and RMSEA at 0.070, suggested adequate model fit as well. Further, the factor loadings of each individual construct's indicator load higher on the construct of interest than on any other variable for both types of e-image. Therefore, convergent validity for the measurement models is met by adequate model fit and high factor loadings.

The assessment of discriminant validity was performed by comparing the average variance extracted (AVE) against the correlation of constructs. To meet discriminant validity, AVE of each construct exceeding the variance due to measurement error is required, i.e., greater than the squared correlation between that and any other construct (Fornell and Larcker 1981). Table 2 shows the AVE and the correlation of constructs for the two types of e-image. The square root of

Table 2 AVE and correlation of constructs

E-Image Type	Construct	Correlation Matrix			
		1	2	3	4
Limited	Usefulness	**0.73**			
	Navigation	0.48	**0.77**		
	Scope	0.68	0.64	**0.86**	
	Purchase intention	0.59	0.63	0.55	**0.80**
Detailed	Usefulness	**0.84**			
	Navigation	0.71	**0.85**		
	Scope	0.81	0.66	**0.91**	
	Purchase intention	0.66	0.53	0.67	**0.86**

[1] Diagonal elements (in bold) are the square root of the average variance extracted
[2] All correlations are significant at 0.01 level

the AVE for each construct is greater than the correlation of the construct to others; thus, discriminant validity is met.

To test the hypotheses, the structural models that specified the hypothesized relationships were evaluated based upon the measurement models. Structural path estimates were measured by examining the statistical significance of all structural parameter estimates. Statistically significant values at $p < 0.05$ were considered to be acceptable in this study. Figures 1 and 2 show the standardized path coefficients, the overall fit indexes and levels of significance for both types of e-image respectively. These metrics provided evidence of adequate fit between the hypothesized model and the observed data.

Based on the analyses, the R^2 value for purchase intention in the model of the limited type of e-image is 0.68, indicating strong predictive power. Likewise, the R^2 value for the model of the detailed type of e-image, 0.56, demonstrates equivalent predictive power. This suggests that the research model is adequate to estimating

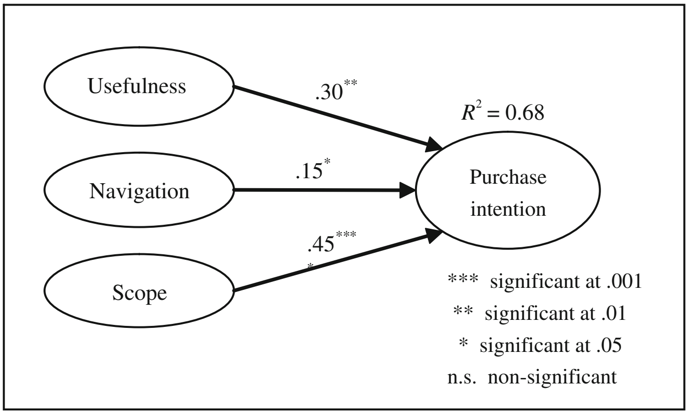


Fig. 1 LISREL estimations of the structural model for the limited type of e-image

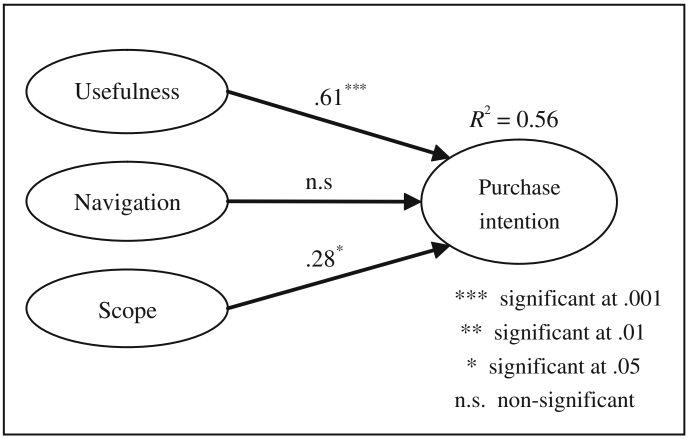


Fig. 2 LISREL estimations of the structural model for the detailed type of e-image

users' intention to make purchases via shopping websites on smartphone. For the limited version, users' purchase intention is well predicted by scope ($\beta = 0.45$, $p < 0.001$), then followed by usefulness ($\beta = 0.30$, $p < 0.01$) and navigation ($\beta = 0.15$, $p < 0.05$). With respect to the detailed version, usefulness ($\beta = 0.61$, $p < 0.001$) and scope ($\beta = 0.28$, $p < 0.05$) show direct and statistically significant effects on purchase intention while navigation has no relationship with intention.

4 Conclusions

The purpose of our study was to identify e-image attributes of a smartphone's shopping website and test the relationship between those attributes and smartphone users' online purchase intention. The findings show that smartphone users are affected by the usefulness and scope attributes regardless of a website's e-image, which provides online business practitioners with the idea regarding how to demonstrate their product information appropriately in the context of smartphones.

References

Aaker DA (1991) Managing brand equity. Free Press, New York

Abadi D, Rezaee H, Hafshejani A, Nasim S, Kermani F (2011) Considering factors that affect users online purchase intentions with using structural equation modeling. Interdisc J Contemp Res Bus 3:463–471

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 Market 39:38–53

Byrne BM (2001) Structural equation modeling with AMOS: basic concepts, applications, and programming. Lawrence Erlbaum Associates, Mahwah, New Jersey

Chen LD, Gillenson ML, Sherrell DL (2002) Enticing online consumers: an expected technology acceptance perspective. Inform Manage 39:705–719

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 13:319–339

Deck S (1997) Ease of navigation key to successful emails. Computerworld 31:4

Fornell C, Larcker DF (1981) Evaluating structural equations with unobservable variables and measurement error. J Market Res. doi:10.2307/3151312

Gefen D, Straub DW, Boudreau MC (2000) Structural equation modeling and regression: guidelines for research practice. Commun Assoc 4:2–77

Gerbing DW, Anderson JC (1988) An updated paradigm for scale development incorporating unidimensionality and its assessment. J Market Res. doi:10.2307/3172650

Ghalib Al-Masoudi MA, Chandrashekara M (2010) Usability satisfaction of open source eLearning courseware websites. J Inf Sci Technol 7:21–35

Gregg DG, Walczak S (2008) Dressing your online auction business for success: an experiment comparing two EBay business. MIS Q 32:653–670

Hesketh AJ, Selwyn N (1999) Surfing to school: the electronic reconstruction of institutional identities. Oxf Rev Educ 25:501–520

Huizingh EKRE (2000) The content and design of web sites: an empirical study. Inf Manage 37:123–134

Hymers J (1996) Integrating the internet into marketing strategy. J Target Measure Anal Market 4:363–371

Koufaris M (2002) Applying the technology acceptance model and flow theory to online consumer behavior. Inf Syst Res 13:205–223

Lohse GL, Spiller P (1998) Electronic shopping. Commun ACM 41:81–87

McKinney V, Yoon K, Zahedi F (2002) The measurement of web-customer satisfaction: an expectation and disconfirmation approach. Inf Syst Res 13:296–315

Park J, Lee Y, Widdows R (2004) Empirical investigation on reputation and product information for trust formation in consumer to consumer market. J Acad Bus Econ 3:231–239

Pavlou PA (2003) Consumer acceptance of electronic commerce: integrating trust and risk with the technology acceptance model. Int J Eletron Commer 7:197–226

Ranganathan C, Ganapathy S (2002) Key dimensions of business-to-consumer web sites. Inf Manag 39:457–465

Sand S (2007) Future considerations: interactive identities and the interactive self. Psychoanal Rev 94:83–97

Van der Heijden H, Verhagen T (2004) Online store image: conceptual foundations and empirical measurement. Inf Manag 41:609–617

Wen C, Prybutok VR, Xu C (2011) An integrated model for customer online repurchase intention. J Comput Inf Syst 52:14–23

Wilkinson GL, Bennett LT, Oliver KM (1997) Evaluation criteria and indicators of quality for internet resources. Educ Technol 37:52–59

Forecast of Development Trends in Big Data Industry

Wei-Hsiu Weng and Wei-Tai Weng

Abstract Big Data technology is used to store, convert, transmit and analyze large quantities of dynamic, diversified data, which may be structured or unstructured data, for the purpose of commercial or social benefit. Big data technology applications need to be able to undertake real-time, high-complexity analysis of vast amounts of data, to help business enterprises perform decision-making within the shortest possible timeframe. With the rapid pace of development in cloud computing applications, both public cloud and private cloud data centers are continuing to accumulate enormous volumes of data. As a result, big data technology applications are becoming ever more important. This paper will analyze recent development trends in the field of big data industry for the reference of interested parties.

Keywords Big data · Industry development · Forecasting · Innovation · SWOT

1 Introduction

Big Data is an emerging terminology to represent the fast growing data size encountered in organizations and societies (Bollier 2010; Brown et al. 2011). Big Data Analytics (BDA) refers to a technology and framework for quickly storing, converting, transferring and analyzing massive amounts of constantly updated,

W.-H. Weng (✉)
Department of Management Information Systems, National Chengchi University, Taipei, Taiwan
e-mail: wh.weng@msa.hinet.net

W.-T. Weng
Department of Industrial Engineering and Management, Ming Chi University of Technology, Taishan, Taiwan
e-mail: wtweng@mail.mcut.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_174,

huge, varied, structured and unstructured data for commercial gain (Russom 2011). BDA has now evolved from large database storage systems to cloud technology in order to analyze and process data in a way that is more economical, more effective and easier for the customer to manipulate (Baer 2011). The key global vendors today include IBM, SPS, Oracle, Teradata and EMC. Solutions currently offered by these BDA vendors include Data Warehouse, Data Mining, Analytics, Data Organization, Data Management, Decision Support and Automation Interface, and so on. Innovative technologies and solutions in this field are currently under rapid development (Mukherjee 2012).

Currently, major IT firms worldwide are exploring possible business opportunity in the Big Data generated market. The Taiwanese IT vendors are strong players worldwide in the manufacturing and integration of IT devices and services. To assist the Taiwanese IT vendors moving forward towards the emerging Big Data market, this research aims to address the question of deriving future trends for the Taiwanese IT industry.

2 Research Method

Qualitative analysis is employed instead of quantitative analysis, by way of expert panel, vendor interviews and focus groups.

2.1 Expert Panel

The expert panel from industry experts is to assist the convergence process of data analysis. To this objective, industrial experts panel of eleven people were selected. The panel consists of CEO, CIO and line of business managers from various domains of Taiwanese IT industry. All of them are from publicly listed firms. Their business domains include System Integration (SI), Independent Software Vendor (ISV), Internet Service Provider (ISV), device manufacturer, and data center operator. These are the major participants in the Big Data industry. The main function of the Expert Panel is to help determining the research framework and deriving strategy. In particular, the following questions are discussed.

1. What are the innovative Big Data technologies potentially important to the Taiwanese IT industry?
2. Who are the major vendors worldwide that could be the benchmark for the Taiwanese Big Data industry?
3. What are the business environments in terms of internal strengths and weaknesses, as well as external opportunities and threats of the IT firms?

4. Recognizing the internal and external business environments, what are the possible production value that could be estimated for the Taiwanese Big Data industry?

2.2 Vendor Interviews and Focus Groups

Representative IT firms from Taiwan are selected as the objects of this study. The selection process is based on the rank of the revenue of the firms as well as their reputation in terms of technology innovation and market visibility. IT vendors of Taiwan enjoy high market share worldwide in the sectors such as computer, communication and consumer electronics manufacturing. Currently the Taiwanese vendors participate in Big Data market include IT device manufacturers, IT service providers, and Internet datacenter operators. We collect and analyze business proposal data of 62 Taiwanese IT vendors. The selection criteria are as follows.

1. Revenue of the firm is among the top five in its industry domain.
2. The firm has announced in public its vision, strategy, products or service toward Big Data market.

Based on these criteria, representatives from 33 IT firms are selected for vendor interviews and focus groups. These firms are summarized in the following Table 1.

3 Development of Big Data Industry

3.1 Development of Innovative Big Data Technology

Big Data technology can be divided into two broad categories: Advanced SQL technology, which is oriented towards the use of relational databases, and NoSQL technology, the emphasis in which is on non-relational databases (Baer et al. 2011). Advanced SQL is specifically designed to provide real-time analysis results with large quantities of structured data. However, as the scale of data collection

Table 1 Selected cases for vendor interviews and focus groups

Business domain	Number of firms
Independent software vendor (ISV)	7
System integration provider (SI)	9
Telecom operator	3
Server and storage device manufacture	6
Networking device manufacture	3
Mobile device manufacture	5
Total	33

grows ever larger, and as the different categories of data that need to be processed become ever more complex, non-structured data is presenting business enterprises with new challenges in terms of data storage and analysis (Borkar et al. 2012). NoSQL non-relational database systems (Adrian 2012) offer enhanced performance and extensibility, making them ideally suited to processing large amounts of non-structured, highly variable data. There are four main types of NoSQL database: key-value databases, in-memory databases, graphics databases, and document databases. The Advanced SQL database platform segment is currently going through a period of market consolidation, indicating that this segment is entering the mature phase in its evolution, characterized by slow but steady growth. By contrast, NoSQL market is still very much in the growth stage, and be expected to play an increasingly important role in big data technology in the future.

Hadoop is a big data technology that is attracting growing interest from enterprises; more specifically, it is a form of key-value database technology (Baer 2011). Leading U.S. retailer Wal-Mart is using Hadoop to analyze sales data and identify new business opportunities; online auction site eBay has been using Hadoop to process unstructured data and reduce the burden of database storage requirements. Hadoop is a software platform that enables users to rapidly write and process large quantities of data. Designed by Doug Cutting, Hadoop was originally an Apache research project, but has since been adopted for commercial applications involving Petabyte-scale big data.

The Hadoop platform architecture comprises three main elements: the Hadoop Distributed File System (HDFS), the Hadoop MapReduce model, and the HBase database system (Kobielus et al. 2011). The operational model of the Hadoop computing framework basically involves coordinating the use of MapReduce distributed computing algorithms with the HDFS distributed file system, which makes it possible to transform ordinary commercial servers into distributed computing and storage groups, creating the capability to store and process huge volumes of data. Supporting this capability is HBase, which is a distributed database system capable of coping with Petabyte-scale data volumes.

Big Data technology are classified and summarized in the following Table 2.

3.2 Development of Global Big Data Industry Leaders

Recognizing the potential business opportunities presented by big data, leading international corporations such as IBM, Oracle, Microsoft, SAP/Sybase, Teradata and EMC have all been moving aggressively into this new field, working to provide enterprises with practical commercial applications for the effective storage and analysis of large volumes of data (IDC 2012). IBM, which has for some years now been focusing heavily on the business intelligence market, recently acquired data warehousing firm Netezza, and will be incorporating Netezza's technology into its Business Analytics Optimization (BAO) solutions as a means of enhancing

Table 2 A taxonomy of big data technology

Category	Technology
Data warehouse	Central enterprise data warehouse
	Data warehouse appliance
	Data marts for analytics
	Analytics processed within the EDW
	Extract, transform, load (ETL)
NoSQL BDA	MapReduce
	Hadoop
	NoSQL or non-indexed DBM
	Column oriented storage engine
	Text mining
Advanced SQL BDA	Complex SQL
	Distributed SQL
	OLAP
	Advanced SQL appliance
	SQL accelerator
Cloud analytics	Public cloud analytics
	Private cloud analytics
	Social analytics
	Software as a service (SaaS)
	Internet of things (IoT)
Embedded analytics	Predictive analytics
	Complex event processing (CEP)
	In-memory database
	In-database analytics
	In-line analytics
Big data visualization	Advanced data visualization
	Real-time reports
	Dashboards
	Visual discovery
	Infographics

their competitiveness. Similarly, Teradata has acquired Aster Data, and EMC has purchased Greenplum (Cohen et al. 2009). This wave of M&A activity reflects leading IT companies' determination to develop the big data market.

BDA vendors have accelerated their expansion and acquisitions. HP for example acquired 3PAR in September, 2010. In November 2010, EMC acquired Isilon. In December 2010, Dell acquired Compellent. In March 2011, Teradata acquired Asterdata. In June 2011, Oracle acquired PillarData. In September 2011, HDS acquired Blue Arc. In April 2012, EMC acquired Pivotal as well.

The wave of acquisitions can be divided into two types. One is system manufacturer's acquisition of a storage system manufacture to provide customers with a one-stop solution. Oracle's acquisition of PillarData and IBM's acquisition of XIV were both of this type. The consolidation enabled large vendors to acquire complementary technologies that make their own system more complete. The other type is buy-outs between storage system manufacturers. If a storage system manufacturer was big enough and was not acquired by a system manufacturer, it began acquiring other smaller storage manufacturers with innovative technologies in order to flesh out their own product lines and technology. EMC's acquisition of Isilon and HDS' acquisition of Blue Arc were both of this type. Whether it was a system manufacturer acquiring a storage system manufacturer or storage manufacturers acquiring each other, in both cases, vendors used their acquisition strategy to acquire key technologies. Continued innovations in information technology means that, large vendors will continue to make new acquisitions in order to make their products more complete and competitive.

4 Analysis on Forecasting Results

4.1 SWOT Analysis of Taiwan's Big Data Industry

The SWOT analysis is an established method for assisting the formulation of strategy. SWOT analysis aims to identify the strengths and weaknesses of an organization and the opportunities and threats in the environment (Pickton and Wright 1998). The strengths and weaknesses are identified by an internal appraisal of the organization and the opportunities and threats by an external appraisal (Dyson 2004). Having identified these factors strategies are developed which may build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats (Weihrich 1982).

By applying the analysis method of Weihrich (1982), the SWOT matrix of Taiwan's Big Data industry is derived as follows Table 3.

4.2 Forecast of Taiwan's Big Data Production Value

Big data mainly comes from enterprise operational data warehouses, cloud computing data centers, shared information on social network websites and intelligent sensor networks. Taiwan is currently in a cloud computing data center expansion phase. Big data access and analysis is the critical technology application for cloud computing data centers and drives the development of Taiwan's server and storage equipment market. One of the driving forces behind the current wave of growth in big data applications is the Taiwanese government's strong support for the cloud computing industry. Cloud computing can be considered one of the emerging smart industries that the Taiwanese government is actively promoting. Many government units have begun deploying cloud services and related applications as a result through the rebuilding of basic infrastructure such as the disaster prevention system, the Ministry of Finance's electronic receipt system and household

Table 3 Competitiveness analysis of Taiwan's big data industry

Strengths	Weaknesses
A. Possesses both hardware and software solutions and provides professional consultancy services experience	A. Limited in the big data related business experience
B. Cooperated with the global leading companies for many years, and prices are flexible	B. Weak research and development of key software technologies such as NoSQL and big data analytics
C. Possesses in-depth vertical domain knowledge, and localized Know-How as well	
D. As an important OEM center of server and storage equipment, Taiwan has the capability of autonomous manufacturing and cheap supply of hardware equipment	
Opportunities	Threats
A. Large-scale cloud data center continues to expand in scale, placing orders directly to the server and storage equipment OEM industry	A. Global leading companies lead technologies and standards
B. Develop the SaaS model of software to attract new customers	B. Part of the business is replaced by emerging cloud computing solutions
C. Enterprise data continue to grow and support the needs of storage devices	C. Industries rise in the emerging markets such as Mainland China, India, and so on
D. Enterprise mobile application software and services with big data needs are growing	

registration system. The adoption of cloud technology by government IT systems will facilitate the introduction of big data development tools in the future.

With these effects, the production value of Taiwanese Big Data industry is expected to achieve steady growth through 2018, as shown in Table 4.

Table 4 Production value of Taiwan's big data industry (USD Million)

Big Data product/service	2013	2014	2015	2016	2017	2018
Server	512	654	773	912	1,028	1,137
Storage equipment	421	511	613	705	803	902
IT service	131	137	142	148	154	161
Software	141	152	160	168	175	182
Total production value	1,205	1,454	1,688	1,933	2,160	2,382
YoY growth (%)	–	20.7 %	16.1 %	14.5 %	11.7 %	10.3 %

5 Conclusions

The development trends in Big Data industry is investigated with innovated technology and global leading vendors. The internal strength and weakness, the external opportunity and threat, as well as the production value forecast for Taiwanese Big Data industry are analyzed and presented.

Vendors interested in exploring the market opportunities of Big Data can use this analysis process and outcome of this research as a reference for their strategic planning, and avoid many unnecessary trial and error efforts. In particular, with a clear picture of the Big Data opportunities and threats, vendors can position themselves more precisely for a market sector of their competitive advantage.

Acknowledgments The authors gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

Adrian M (2012) Who's who in NoSQL DBMSs. Gartner report G00228114
Baer T (2011) 2012 Trends to watch: big data. Ovum report, OI00140-041
Baer T, Sheina M, Mukherjee S (2011) What is big data? The big architecture. Ovum report, OI00140-033
Bollier D (2010) The promise and peril of big data. The Aspen Institute
Borkar V, Carey M, Li C (2012) Inside "big data management": ogres, onions, or parfaits? In: Proceedings of ACM EDBT/ICDT joint conference, Berlin, Germany
Brown B, Chui M, Manyika J (2011) Are you ready for the era of "big data"? McKinsey Q 4:24–35 (McKinsey & Company)
Cohen J, Dolan B, Dunlap M, Hellerstein J, Welton C (2009) MAD skills: new analysis practices for big data. In: Proceedings of ACM VLDB conference, Lyon, France, 24–28 Aug 2009
Dyson RG (2004) Strategic development and SWOT analysis at the University of Warwick. Eur J Oper Res 152:631–640
IDC (2012) Worldwide big data technology and services 2012–2015 forecast. IDC #233485, Volume: 1, Tab: Markets
Kobielus K, Moore C, Hopkins B, Coyne S (2011) Enterprise hadoop: the emerging core of big data. Forrester Res
Mukherjee S (2012) Deploying big data systems. Ovum report, OI00140-035
Pickton DW, Wright S (1998) What's SWOT in strategic analysis? Strateg Change 7(2):101–109
Russom P (2011) Big data analytics. TDWI research, 4th Quarter, 2011
Weihrich H (1982) The TOWS matrix: a tool for situational analysis. Long Range Plan 15(2):54–66

Reliability Analysis of Smartphones Based on the Field Return Data

Fu-Kwun Wang, Chen-I Huang and Tao-Peng Chu

Abstract In recent years, smartphones have become indispensable tools and media for obtaining information. Consequently, investigation and data analysis studies exploring smartphone reliability and failure rates have become increasingly important for mobile phone retailers and manufacturers. The design capabilities and manufacturing technologies for smartphones are continuously upgraded, and customer requirement for reliability increase correspondingly. Therefore, this study investigated after-sales repair and maintenance data obtained from a Taiwanese mobile phone maintenance provider for three brands of smartphones (A, B, and C). We assumed that the quality of the different models of the three brands is consistent. Statistical analysis techniques and software were used to calculate the parameter values of four failure probability distribution functions (i.e., exponential, log-normal, log-logistic, and Weibull). The maximum likelihood estimation (MLE) method was also employed to assess the log-likelihood value and determine the most appropriate failure probability distribution for each smartphone. Finally, we calculated the predicted market failure rate for the three smartphone brands. The results and conclusions obtained in this study can benefit important market players, such as consumers, mobile phone retailers, and manufacturers, regarding smartphone quality, sales strategies, after-sales warranty service packages, and manufacturing process improvements.

F.-K. Wang (✉)
Department of Industrial Management, National Taiwan University of Science and Technology, No.43 Keelung Rd., Sec.4, Taipei 106, Taiwan Republic of China
e-mail: fukwun@mail.ntust.edu.tw

C.-I. Huang · T.-P. Chu
Graduate Institute of Management, National Taiwan University of Science and Technology, No.43 Keelung Rd., Sec.4, Taipei 106, Taiwan Republic of China
e-mail: D9816909@mail.ntust.edu.tw

T.-P. Chu
e-mail: D9816907@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_175,

Keywords Smartphones · Field return data · Interval censored data · Maximum likelihood estimation

1 Introduction

Wireless communication technology has advanced continuously in recent years. The widespread use of smart mobile devices in the communications market has ushered in an era of ubiquitous mobile networks. Cisco Visual Networking Index (Cisco 2012) predicted that more than 10 billion mobile network devices would exist worldwide by 2016, exceeding the current world population of 7.3 billion. With their rapid popularization and the maturity of mobile Internet and networking, smartphones have become an important medium closely connected to the everyday lives of users. In addition to providing sales growth for brand companies and manufacturers, consumers have also become increasingly reliant on smartphones. This indicates that the market opportunities for mobile application services are unlimited. However, hardware brand companies and mobile application service developers must continuously address new changes and challenges in usage behavior.

Smartphones have become indispensable tool for obtaining information, the standard usage and quality stability factors of smartphones significantly influence consumers, mobile phone retailers, and manufacturers on varying levels. Therefore, calculating smartphone life is essential. The purpose of this paper is to calculate the failure rate and MTBF of a smartphone based on the filed return date. The study investigated the after-sales repair data of a Taiwanese mobile phone maintenance provider for three brands of smartphones. Using statistical analysis techniques, the failure probability distribution function for the three smartphone brands was calculated and the predicted failure rate was also investigated.

2 Literature Review

Generally, a traditional reliability prediction method is adopted for electricity production. For example, British Telecom (BT) employed HRD5 (1994) for a number of years, but with limited value because that prediction method addresses only electrical and electronic components, which provided the lowest contribution to field returns. This increased the need to develop a method for estimating the field failure rate of a product prior to its launch in the field. An estimate of a product's field failure rate is a key requirement for product development.

Although laboratory reliability testing is commonly employed for product design decisions, real reliability data is obtained from the field, typically in the form of warranty returns and field tracking studies. Field data generally shows greater variability in component and product failure times compared to data from laboratory testing. Hong and Meeker (2010) asserted that the differences between carefully controlled laboratory ALT experiments and field reliability test results are caused by the uncontrolled field variation (unit-to-unit and temporal) of variables, such as the use rate, load, vibration, temperature, and humidity. Oh and Bai (2001) and Suzuki (1995) noted that field data provide more reliable information regarding life distribution compared to laboratory.

Wu and Meeker (2002) examined the use of field returns to detect potentially serious in-warranty problems. Appropriate model assumptions and robust model estimations are crucial for accurately predicting product field returns. The parametric distribution models traditionally employed for product reliability analyses do not effectively describe product field survival. Zhang et al. (2010) used the Bertalanffy-Richards biological growth model for modeling hard disk drive (HDD) field survival within the warranty period to avoid insufficient field returns observations. The discrepancy in time-to-event measurements further increased the difference between the HDD field survival process and the reliability process. Therefore, Pan (2009) developed models that appropriately describe laboratory reliability data; however, they may be unsuitable for field survival data. Marcos et al. (2005) stated that a product that has been in the field for only a short time compared to the entire warranty period cannot provide sufficient direct information to guarantee good model estimation.

3 Methodology

The methodology regarding the life or lifespan analysis of smartphone market failure statistics conducted is explained. The section explains the analysis process for the smartphone field failure return.

Step 1. Data Collection

Before the data analysis, the smartphone field failure return data was first processed and filtered. Because the information recorded in the maintenance database was complex, only the defect units categorized as warranty data was extracted.

Step 2. Interval-Censored Data Processing

After collecting and processing the data, the number of monthly shipments for each of the three smartphone brands and the number of failures and repairs within the same month were obtained. The data we collected for this study was interval-censored data shown in Fig. 1.

Step 3. Distribution fitting—MLE

The MLE statistical values from each distribution were subsequently used to identify which distribution possessed the greatest observed log-likelihood value for the brands and to determine the optimal failure probability distributions.

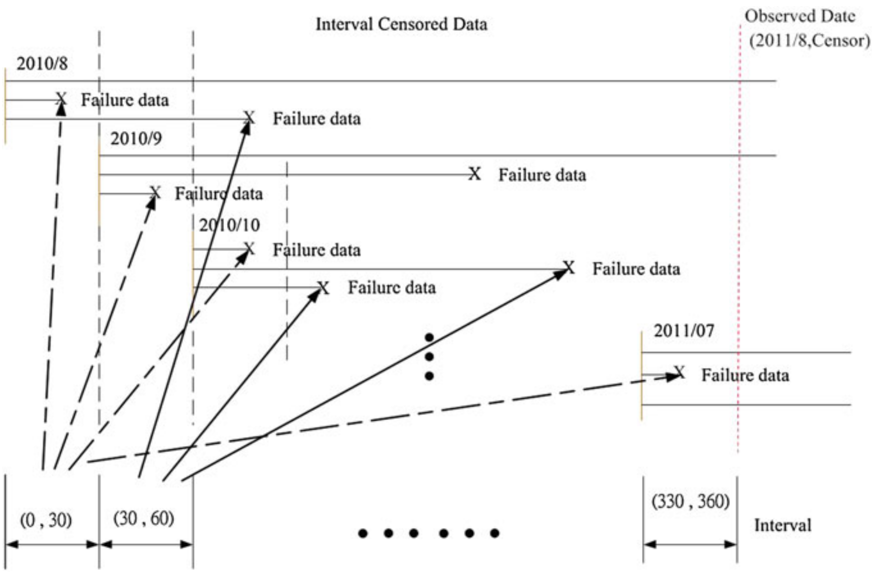


Fig. 1 The interval censoring data of smartphone

Step 4. Identifying the optimal failure probability distribution

MLE was also used to obtain the estimated parameter values employed in the optimal failure probability distributions of the three brands.

Step 5. Predicting and evaluating the field return rate

The estimated parameter values obtained in Step 4 were used to illustrate the actual and predicted failure rates for the three smartphones. MAPE was then applied to calculate the prediction or forecasting efficacy for the three smartphone brands.

4 Data Analysis

This study analyzed cumulative data for the three brands of smartphones from the beginning of shipping in August 2010 to July 2011. A total of 567,860 smartphones were shipped, and the maintenance provider received 6,958 of these smartphones for repair during this period. Table 1 shows the number of shipments and failures each month. The number of failures represents the number of smartphones shipped that month that required repair.

August 2011 was set as the time-censored cutoff point for failure data, with a unit interval comprising 30 days. Table 2 shows the censored failure statistics.

Table 1 The number of shipments and failures each month

Time	Brand A		Brand B		Brand C	
	Shipped units	Failure units	Shipped units	Failure units	Shipped units	Failure units
Aug-10	4,138	236	12,802	503	18,046	504
Sep-10	15,363	245	14,111	348	17,657	394
Oct-10	13,365	238	14,350	333	11,643	416
Nov-10	15,813	167	14,963	231	9,394	388
Dec-10	16,737	177	16,701	231	10,006	250
Jan-11	22,770	125	14,954	202	16,494	241
Feb-11	21,023	150	15,551	160	16,534	214
Mar-11	16,591	86	14,295	103	21,935	142
Apr-11	14,751	82	14,136	117	17,006	120
May-11	21,733	100	12,069	91	15,988	97
Jun-11	19,265	78	11,970	46	23,074	26
Jul-11	15,506	36	13,047	14	24,079	67
Total	197,055	1,720	168,949	2,379	201,856	2,859

This study employed MLE for smartphone failure data from three brands of smartphones to determine the cumulative failure probabilities for four types of distributions, including the exponential, log-normal, log-logistic, and Weibull.

Table 3 shows that when Brand A, B, and C are all log-normal, their log-likelihood values are highest. Therefore, the three observed smartphone brands have identical optimal failure probability distribution.

The statistical analysis results indicate that log-normal is most appropriate to the failure probability distribution function of the three brands.

This study determined the most appropriate failure distributions for the three brands of smart phones using the mentioned experimental steps, and produced Fig. 2 to show the actual and predicted failure rates of the three smartphones.

MAPE was further employed for prediction or forecasting efficacy assessments. The formula for this method is as follows:

$$MAPE = \frac{\sum_{t=1}^{n} \left| Y_t - Y_t' \right| / Y_t}{t} \times 100\ \% \tag{1}$$

In this formula, t is the number of periods for prediction, Y_t is the actual value, and Y_t' is the predicted value.

The calculation results indicate that the MAPE values for Brand A, B and C are 15.89, 8.7, and 16.23 % separately. The typical MAPE values for model evaluation developed by (Lewis 1982). Evidently, Brand B is a high accuracy forecasting model, and Brands A and C are good forecasting models. This indicates that the forecasting efficacy assessment conducted for the developed models in this study provided good forecasting capabilities or better.

Table 2 The censored failure statistics

Time (day)	Brand A		Brand B		Brand C	
	Censored units	Failure units	Censored units	Failure units	Censored units	Failure units
(0,30)	15,470	235	13,033	247	24,012	362
(30,60)	19,187	294	11,924	335	23,048	418
(60,90)	21,633	202	11,978	221	15,891	313
(90,120)	14,669	190	14,019	248	16,886	335
(120,150)	16,505	129	14,192	112	21,793	308
(150,180)	20,873	184	15,391	226	16,320	307
(180,210)	22,645	151	14,752	146	16,253	231
(210,240)	16,560	126	16,470	205	9,756	198
(240,270)	15,646	74	14,732	243	9,006	107
(270,300)	13,127	64	14,017	216	11,227	177
(300,330)	15,118	51	13,763	123	17,263	71
(330,360)	3,902	20	12,299	57	17,542	32

Table 3 The log-likelihood values for each distribution of the three brands

	Brand A	Brand B	Brand C
Exponential	−19,091.17	−25,039.73	−30,360.24
Log-logistic	−19,016.29	−25,005.83	−30,335.86
Log-normal	**−19,001.19**	**−24,954.31**	**−30,260.19**
Weibull	−19,016.29	−25,007.17	−30,338.12

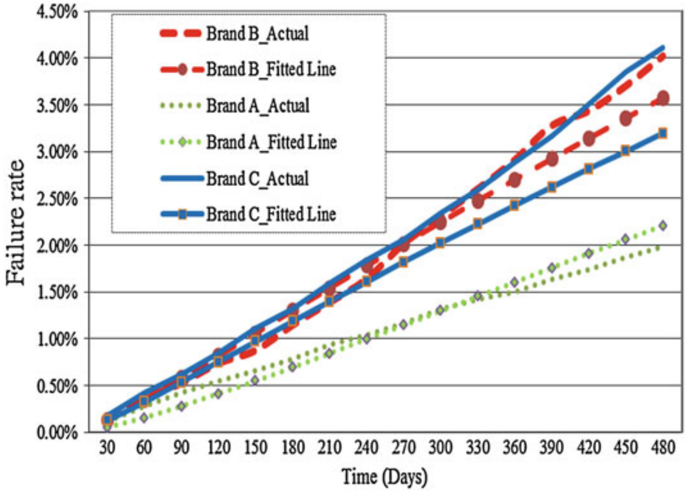


Fig. 2 The interval censoring data of smartphone

Table 4 Predicted failure of Brand A, B, C with log-normal distribution

Years	days	Predicted failure rates (%)		
		Brand A	Brand B	Brand C
1	360	1.61	2.70	2.43
2	720	3.38	5.18	4.61
3	1,080	5.02	7.32	6.49

Figure 2 demonstrates the relationship between the cumulative failure rates and time for the three smartphone brands based on analysis of the field return data. The figure indicates that the failure rate of Brand B for the first year was 2.7 %, the highest among the brands. Brand C was next with a first-year failure rate of 2.43 %. Brand A had the optimum first-year failure rate at 1.61 %. Table 4, shows the three-year predicted failure rates for the three brands.

5 Conclusions

This study used smartphone field return data to investigate the reliability of three brands of smartphones. Relevant analysis results indicated the following:

The goodness-of-fit test performed on the field return data showed that log-normal distribution was the most optimal for the failure probability distributions of all three brands. This differs from the common assumption that the majority of electronic products demonstrate a Weibull distribution. The result also indicates that the structural designs of the three smartphones may be similar. Thus, their optimal failure probability distributions are identical. Consequently, if the smartphone failure rate estimation in this study was performed directly using a Weibull distribution, the results would have demonstrated error compared to the failure rate estimations obtained using log-normal distribution. This would have led to erroneous cost estimations for future smartphone sales, repairs, and warranties for spare parts.

MLE was also employed to identify and demonstrate the relationships between the cumulative failure probabilities and time based on the parameters of the cumulative failure probability density function for the log-normal distributions of the three brands, as shown in Fig. 2. The results indicate that Brand A possessed the optimal product reliability, followed by Brand C and finally Brand B. Therefore, the three brands of smartphones possessed differing levels of reliability. This result is identical to that reported by the maintenance and repair sector from which the data for this study were obtained. And mobile phone maintenance providers can use the product failure analysis data from this study to forecast or predict the material procurement and preparation requirements for spare parts.

References

Cisco Visual Networking Index (2012) Global mobile data traffic forecast update, 2011–2016. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html. Accessed 10 Dec 2012

HRD 5 (1994) Handbook of reliability data for components used in telecommunications systems. http://infostore.saiglobal.com. Accessed 23 Oct 2012

Hong Y, Meeker WQ (2010) Field-failure and warranty prediction based on auxiliary use-rate information. Technometrics 52:148–159

Lewis C (1982) International and business forecasting methods. Butterworth-Heinemann, London

Marcos E, Philip G, Kosuke I (2005) A framework for warranty prediction during product development. In: Proceedings of 2005 ASEA international mechanical engineering congress and exposition, Orlando Florida USA, 5–11 Nov 2005

Oh YS, Bai DS (2001) Field data analysis with additional after-warranty failure data. Reliab Eng Syst Saf 72:12–25

Pan R (2009) A Bayes approach to reliability prediction using data from accelerated life tests and field failure observations. Qual Reliab Eng Int 25:229–240

Suzuki K (1995) Role of field performance data and its analysis. CRC Press, New York

Wu H, Meeker W (2002) Early detection of reliability problems using information from warranty databases. Technometrics 44:120–133

Zhang S, Sun F, Gough R (2010) Application of an empirical growth model and multiple imputation in hard disk drive field return prediction. Int J Reliab Qual Saf Eng 17:565–577

The Impact of Commercial Banking Performance on Economic Growth

Xiaofeng Hui and Suvita Jha

Abstract The financial sector and economic growth spark hot debates. This paper addresses the question of whether commercial banking performance in Nepal reasons to economic growth. In order to answer this question, the present study focuses on analyzing the relationship between deposit, loan and advances and assets as proxy for performance of commercial banks while gross domestic product proxies economic growth over the period of 1975–2010. Using Augmented Dickey Fuller and Ordinary Least Square, the regression results indicated that deposits and assets have significant impact on the economic growth of Nepal while loan and advances has insignificant impact on the economic development. Furthermore, the Granger-Causality test suggests that there was no causality with deposit, loan and advances and assets with the economic acceleration. It can be concluded that not only commercial banking performance but also other variables political stability and technology play the important role in the economic advances in Nepal.

Keywords Banking performance · Nepalese commercial banks · Economic growth · Gross domestic product

---

X. Hui (✉) · S. Jha
School of Management, Harbin Institute of Technology, Harbin 150001, People's Republic of China
e-mail: xfhui@hit.edu.cn

S. Jha
e-mail: sovi1977@yahoo.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_176,

1 Introduction

Linking financial sector with economic growth in an economy is a major concern among economists, financial analysts, researchers and policymakers. An extensive number of literatures suggest that financial institutions are to be the best indicator of a country's real development potential and significantly influence the economic development (Talliman et al. 1998; Goldsmith 1969). Banking industry has much benefit over non-banking markets sector in the developing economies as like of Nepal with weak legal and accounting structures. In this environment, banks can be able to formulate firms disclose information and pay back their debts thereby facilitating spreading out and long-run development (Rajan and Luigi 1999).

Those countries with a better financial system have a trend to increase its economic growth faster. The bank-based financial system emphasizes that assets has the positive role in the economic progress as banks can mobilize resources and reduce risk (Beck and Levine 2004). The study of Hsu and Lin (2000) for Taiwan, and Anwar and Nguyen (2011) for Vietnam reported that both banking and stock market development are positively related to short-run and long-term economic growth. Nepal has established up comprehensive financial infrastructures such as commercial banks, development banks, finance companies, cooperatives, non-governmental organizations. Among the financial institutions, the common resource of supplies funds and the main source of financing to support the national economic performance are commercial banks (Poudel 2005). Commercial banks play an important role in financial sector and occupy 76.7 % of total assets (Nepal Rastra Bank 2011). However, some studies have investigated the impact of financial sector with economic growth of Nepal (Poudel 2005; Kharel and Pokhrel 2012), there are no any reports that focused on the subject of commercial banks performance and their impact on Nepalese economic development. The objective of this paper is to investigate the relationship of commercial banking performances with the economic growth, considering the impact of deposit, loan and advances and assets on the Nepalese economic growth.

2 Data and Methodology

2.1 Data and Variables

Yearly time-series data for the period of 1975–2010 were used in this study. Deposit, loan and advances, and assets were used as commercial banking performance while real GDP per capita at constant prices (RGDP) was used as economic growth. Data of the commercial banks performance were collected from the Nepal Rastra Bank Quarterly Economic Bulletin (published by the Central Bank of Nepal) while RGDP was noted from various issues of Economic Survey of Ministry of Finance whereas population was taken from the Statistical Pocket

Book of CBS. Monetary management turned out to be a key concern for the banking sector in Nepal only since 1975 (Acharya 2003) and that is the reason of to consider data from 1975.

2.2 Details of the Model

2.2.1 Testing for Stationary

In order to check the variables are stationary or non stationary, this study used the Augmented Dickey Fuller (ADF) tests of stationary. In this test null hypothesis means non-stationary in the data and alternative hypothesis means stationary.

2.2.2 Ordinary Least Square Method

In formulating model, it assumes that the RGDP is a function of deposit (DEP), loan and advances (ADV) and commercial banks assets. All the variables were measured in log (LN) value. Given the above theoretical considerations, the behavioral equation of the model was formulated as RGDP = f(DEP, ADV, ASSET) and consequently equation could be written in the following form:

$$\ln(\mathrm{RGDP}) = \beta_0 + \beta_1 \ln(\mathrm{DEP}) + \beta_2 \ln(\mathrm{ADV}) + \beta_3 \ln(\mathrm{ASSET}) \quad (1)$$

All the independent variables were expected to have a positive impact on economic growth. This research was based on the following hypotheses that clearly define the research criteria.

H1. There is a significant relationship between commercial banks deposit and economic growth.
H2. There is a significant relationship between commercial banks loan and advances and economic growth.
H3. There is a significant relationship between commercial banks assets and economic growth.

2.2.3 Testing for Causality

This study used Granger-Causality test proposed by Granger (1969) for testing whether a causal relationship existed among the Real GDP per capita and the deposit, loan and advances, and assets. The test involved estimating the regressions for each variable on the other variable past observations. An F- test was then applied on the residuals of the regressions, and the value was compared to tabulated F- values. If the computed F- value exceeded the critical F- value of the chosen level of significance, the null hypothesis was rejected and concluded that a causality relation existed.

All the estimations for Ordinary Least Square, Unit Root test and Granger Causality test have been performed in the E-Views7 program whereas the ordinary calculations were done in Excel.

3 Results and Discussion

3.1 Descriptive Statistics of the GDP and Commercial Banking Variables

A growth in the real GDP per capita from 1975 to 2010 (Table 1) indicates an improvement in the financial sector due to increasing inflow of remittance as well as the country's macroeconomic policy initiatives. The overall mean value of the RGDP was 8.079 with the standard deviation (SD) of 0.212. Regarding the banking performance variables, deposit was in increasing trend due to structural changes of Nepalese economy and effort of financial sector reform program. Increase in RGDP leads to an increase of money supply that helps the banking sector to have more deposits and consequently lead to higher lending. In addition, that results in more investments and hence leads to fast economic growth. The overall mean value of the deposit was 10.38 with SD of 1.87. Growing loan and advances indicated that the role of loan was expanding fast as a source of funding for economic activities in the country. The mean value of the loan and advances was 10.11 with SD of 1.90. Similarly, increasing assets would provide stronger, resilient to shocks and capable of funding the real sector and, therefore, enhancing economic growth. The mean value of assets was 10.69 with SD of 1.88.

3.2 Augmented Dickey Fuller Test

The results of the ADF test are reported in Table 2. The Schwartz Bayesian Criterion (SBC) is used to determine the optimal number of lags included in the test. The ADF test results suggest that at the 1 and 5 % significance level could not

Table 1 Descriptive statistics of the employed variables

Variable	N	Minimum	Maximum	Mean	SD
RGDP	36	6.95	7.60	7.26	0.23
DEPOSIT	36	7.07	13.33	10.40	1.86
LOAN and ADV	36	7.08	13.13	10.11	1.90
ASSET	36	7.51	13.58	10.69	1.88

Table 2 Augmented dickey fuller unit root tests for level and 1st difference variables

Level			1st difference		
Variable	Intercept	Trend and intercept	Variable	Intercept	Trend and intercept
RGDP	−0.292 (0.916)	−1.917 (0.624)	RGDP	−6.124(0.0000)	−5.957(0.0001)*
Deposit	−2.193(0.212)	−1.645(0.753)	Deposit	−4.195(0.0024)	−4.31 (0.0087)*
Loan	−0.086 (0.943)	−1.92 (0.620)	Loan	−4.947(0.0003)	−4.88 (0.0021)*
Assets	−1.376 (0.582)	−0.80 (0.955)	Assets	−2.470(0.1315)	−2.57 (0.2946)

*Indicate that the variable is significant at 1, 5 and 10 % respectively

reject the null hypothesis for any variables, which meant that the unit root problem existed and the series were non-stationary. Almost all the variables including deposit, loan and advances, and assets have non-stationary both when include intercept and when include intercept and trend at level while all the variables were stationary at first difference except assets. This result gives support to the use of ordinary least square to determine the relationships of banking performance and economic growth.

3.3 *Ordinary Least Square Results*

The Unit Root test resulted in the time series data were non-stationary. Thus, the analysis was performed using the regression analysis and the model was estimated by ordinary least square. The value of R-Square, the coefficient of determination, represented the correlation between the observed values with the predicted values of the dependent variable and provided the adequacy of the model. Here the value of the R-Square was 0.963 that meant the independent variable in the model could predict 96.3 % of the variance in the dependent variable (Table 3). The *p* value was given by 0.000 that was less than 0.05, resulting in the significance of the model. The regression models assume that the error deviations are uncorrelated. The constant parameter was 6.908.

Deposit and economic growth were negatively but significantly related with the economic growth. Deposit coefficient with a value of −0.268 implied that if

Table 3 Regressions between commercial banking performance and real GDP

Variable	Coefficient	t-statistic	Probability
C	6.908	90.427	0.000
Deposit	−0.268**	−2.248	0.0316
Loan	0.120	1.617	0.1157
Assets	0.256***	1.763	0.0874
R-squared	0.96		
F-statistic (probability)	282.52 (0.000000)		

**, ***Indicate that the variable is significant at 1, 5 and 10 % respectively deposit was increased by a unit, economic growth was threatened as it made RGDP to decline by 0.268. Deposit is expected to positively impact on economic growth as suggested by Mckinnon (1973) and Shaw (1973). This can be attributed to the fact that commercial banking in Nepal has not strategically positioned banks to adequately mobilize enough deposit that would positively affect the economy. Apart from that, one major cause for this is the Nepalese banking system is dominated by the public sector banks in terms of shares of deposits and their mobilization (Jha and Hui 2012). Joint venture and domestic private banks have very few branch networks and are concentrated in urban centers. This showed little capacity to absorb small urban or rural savings and serve the credit needs of the small borrowers, rural or urban. The commercial banks limited their operations to large amounts- both in acceptance of deposits and lending. The minimum balance requirements in some Kathmandu Valley banks make them unapproachable even to the middle class families in the Valley. Bulk investors also have ability to negotiate on interest rates, which small investors lack. More evidences are available that average households in rural areas can save smaller amounts. But the commercial banks have shown little interest in this kind of savings. Given the oligopolistic cartel ling, they are over liquid and have no need to innovate for deposit mobilization. The negative but significant result also indicates that the commercial banks deposit in a country is crucial to the economic development.

A positive but insignificant relationship is established between loan and advances and economic growth. This result is inconsistent with the finding of Aurangzeb (2012) for the Pakistan banking sector. The loan and advances coefficient was 0.120, implying that a unit increase in loan and advances leads to an increase in RGDP by 0.120 units. The implication of this is that commercial banks were unable to find an appropriate client for ending their excess liquidity in the market and the funds directed to them by banks have not been optimally utilized to increase their productivity which inevitably improves economic growth. Besides, this might be due to the commercial banks are concentrated in urban areas. The excess of credit programs has made very little dent in the rural credit market. More than 80 % of the borrowing households have still to depend on non-formal sources for their credit needs. Majority of the credit programs have been unable to directly cater to the needs of the bottom 20 % households because the poor lack other resources and knowledge to benefit from the deposit-credit programs. Also, the negligence of commercial banks in the credit administration process increases the chances for non-performing loans and other classified assets and this has adverse effect on bank capital and the economy at large. This effect reduces the ability of commercial banks to further extend credit and may cause bank distress or failure since the profitability of a bank is directly related to the credit it grants. The lending rate charged on credit by banks is on the high side which deters investors from borrowing to embark on productive activities and give room for moral hazard. This runs contrary to the findings of Aurangzeb (2012) for the Pakistan banking sector. Although the relationship of loan and advances and RGDP found weak they did not mean that loan did not matter for the economy. Much to the contrary, they reinforce the argument that credit has a crucial role on overall productivity via a correct allocation of financial resources, a conclusion that has already found convincing empirical backing (Bebczuk and Garegnani 2007). The assets of the commercial banks plays significant and equal role in economic growth as signified by the positive and statistically significant coefficient, which meant that the assets of the Nepalese commercial banks relative to domestic economy did add value to its economy. Therefore, commercial banking sector is necessary to represent an added value for local economy. This result contradicts the finding of Awdeh (2012) which shows that the assets are insignificant with economic growth for the Lebanon banking sector. The asset coefficient was 0.256, implying that a unit increase in asset leads to an increase in RGDP by 0.256 units respectively. According to the Ordinary Least Square model, the result showed that, deposit, and assets were significant effect on the economic growth. For that reason, hypotheses 1 and 3 have been accepted and have a significant impact on economic growth of Nepal while loan and advances was not significant with economic growth. And hypothesis 2 has been rejected.

3.4 Tests for Causality

Table 4 shows that Granger Causality test between the commercial banking performance in terms of deposit, loan and advance and asset and economic growth in Nepal. The F-statistics and its corresponding values of the probability suggest that none of the commercial banking performance measures seemed to Granger cause the economic growth in Nepal. This suggests that neither the deposit, nor loan and advances, nor commercial banks assets Granger caused the economic growth in Nepal. Therefore, this study was accepting the null hypothesis. On the other hand, the results of Granger Causality models reveal that growth in the economic activities in Nepal (represented by RGDP) did not seem to Granger cause the deposit, loan and advances and assets. It might be either the size of market is too small. Most of the banks are highly concentrated in urban areas, particularly in Kathmandu valley and even more, particularly in city centers and commercial banks might not be efficiently transforming deposit into loan and that most of the loan they grant might not be for productive purposes.

Table 4 Granger causality test for commercial banking performance with economic growth in Nepal

Null hypothesis	F-Statistic	Probability
DEP does not Granger cause GDP	2.36771	0.1116
GDP does not Granger cause DEP	0.46194	0.6346
LOAN and ADV does not Granger cause GDP	1.59730	0.2197
GDP does not Granger cause ADV	0.15989	0.8530
ASSETS does not Granger cause GDP	2.23719	0.1249
GDP does not Granger cause ASSETS	0.39836	0.6750

4 Conclusions

Unit root test confirmed the non-stationary of all the variables at level whereas stationary at the first difference. Regression results indicate that deposits and assets have significant impact on the economic growth of Nepal while loan and advances was not significant impact on the economic growth. Although the commercial banks assets in the economy has increased but none of the expectations of liberalization, such as extension of the organized credit market to more rural areas, increasing access for smaller borrower or more efficient and productive use of financial resources seem to have been achieved. The loan and advances did not improve economic activities in Nepal. The Granger-Causality test confirmed the commercial banks performance did not Granger causes the economic progress. As a result it is required to grant an appropriate operating situation for the banking industry to execute its services in Nepal and should be encouraged to lend more to the productive sector.

Acknowledgments The authors would like to thank the National Science Foundation of China (71173060, 70773028 and 71031003) for their supports.

References

Acharya M (2003) Development of the financial system and its impact on poverty. Econ Rev 15, Nepal Rastra Bank

Anwar S, Nguyen LP (2011) Financial development and economic growth in vietnam. J Econ Financ 35:348–360

Aurangzeb KA (2012) Contributions of banking sector in economic growth: a case of Pakistan. Econ Financ Rev 1(2):45–54

Awdeh A (2012) Banking sector development and economic growth in Lebanon. Int Res J Financ Econ 100:53–62

Bebczuk R, Garegnani L (2007) Autofinanciamiento empresario y crecimiento económico. Ensayos Económicos 47, Central Bank of Argentina

Beck T, Levine R (2004) Stock markets, banks and growth: panel evidence. J Banking Financ 28:423–442

Goldsmith RW (1969) Financial structure and development. Yale University Press, New Haven, CT

Granger CWJ (1969) Investigating causal relations by econometric models and cross-spectral methods. Econometric 37:424–438

Hsu CM, Lin SM (2000) Financial development and endogenous growth model. Ind Free China 9:21–47

Jha S, Hui X (2012) A comparison of financial performance of commercial banks: a case study of Nepal. Afr J Bus Manage 27:7601–7611

Kharel RS, Pokhrel DR (2012) Does Nepal's financial structure matter for economic growth? Working paper serial number NRB/WP/10

McKinnon RI (1973) Money and capital in economic development. Brookings Institution, Washington, DC

Nepal Rastra Bank (2011) Banking supervision report 2010. Bank Supervision Department, Nepal Rastra Bank, Nepal. http://www.nrb.org.np/bsd/reports/Annual_Reports–Annual_Bank_Supervision_Report_2010.pdf

Poudel NP (2005) Financial system and economic development. Nepal Rastra Bank in 50 years. Nepal Rastra Bank, Kathmandu

Rajan R, Luigi Z (1999) Financial systems, industrial structure and growth. University of Chicago, Mimeo

Shaw ES (1973) Financial deepening in economic development. Oxford University Press, New York

Talliman Ellis, Moen (1998) Commercial banking, organization and decision theory. Federal Reserve Bank of Atlanta, U ms, pp 381–404

Data and Information Fusion for Bio-Medical Design and Bio-Manufacturing Systems

Yuan-Shin Lee, Xiaofeng Qin, Peter Prim and Yi Cai

Abstract This paper presents methods of data analysis and information fusion in bio-medical design and bio-manufacturing system performance improvement. Technical methods of data and information fusion and the new industrial engineering role in bio-medical design and bio-manufacturing systems development are discussed in this paper. A case study in regenerative medicine is presented to validate the product development lead time estimation, and to demonstrate that the total processing time can be significantly reduced through integrated approach. In overview, this research develops a method for transforming uncontrolled biological procedures into reproducible, controlled manufacturing processes.

Keywords Bio-manufacturing · Information fusion · Design and manufacturing · Bio-medical application

1 Introduction

Biomedical engineering is the application of the combination of engineering principles and design concepts with medicine and biology technologies for healthcare purposes. Bio-manufacturing was originally referred as the use of living organism to manufacture a product, which is considered as a higher discipline of biomedical engineering. Bio-manufacturing is referred to the emerging research areas that compass manufacturing methods that use a biological organism, or parts of a biological organism, in an unnatural manner to produce a product, as well as products designed to detect, modify, maintain and study biological organisms for use as new manufacturing agents (Couto et al. 2012).

Y.-S. Lee · X. Qin (✉) · P. Prim · Y. Cai
Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, USA
e-mail: yslee@ncsu.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_177,

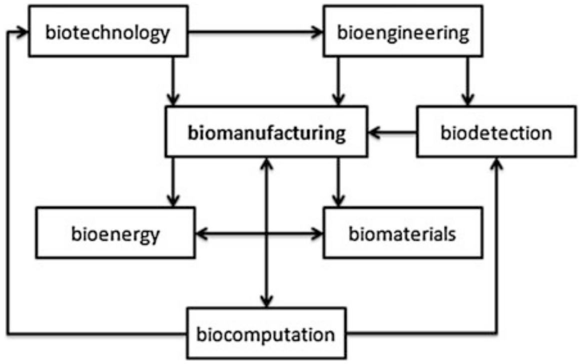


Fig. 1 Bio-manufacturing and its related areas

Figure 1 shows the new emerging biomanufacturing and regenerative medicine and its related areas. The new emerging research includes efforts from biotechonoloy, bioengineering, biodetection, biomaterials, biocomputation, and bioengery. Within the region of bioengineering, Regenerative Medicine Manufacturing (RMM) has been thriving during the past two decades and gradually becoming one of the most value-added, competitive industries in the nation, or even over the world.

Regenerative medicine is always referred as the technologies creating living functional cells, tissues or organs to repair and replace damaged ones due to age, disease, damage or other defects. It is considered as an evolutional treatment offering the potential of lifetime cures for unmet medical needs by stimulating previously damaged organs to heal themselves or creating tissues and organs for implantation. In the last few years, we have been collaborating with Wake Forest University Institute of Regenerative Medicine (WFIRM) to work on regenerative medicine and bio-manufacturing systems development, which refers to viewing regenerative medicine from a systems engineering perspective by modeling, parameterizing, optimizing and controlling the process to achieve better results. In this paper, we will address the new industrial engineering role in the bio-manufacturing and biomedical engineering areas. A case study of regenerative medicine will be discussed.

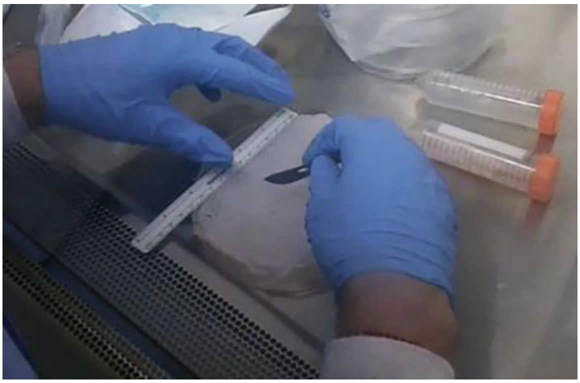
2 Bio-Manufacturing and Regenerative Medicine

In regenerative medicine, a significant effort to increase tissue area and volume has been explored using mechanical strain methods. The major intent is to plastically deform the biological material so that the surface area increases. In some cases, the strain has also produced rapid cell and tissue growth but the results being reported seem inconsistent and effort to find effective methods to expedite the regeneration of tissue continues. Although a variety of tissue has been studied in the literature, our activity has focused primarily on skin tissue. The primary drive force is the high fatality of severe burned patients with large area of thermally or chemically burned skin tissues. To treat patients with severe burns, small skin grafts can be harvested from healthy places on the body, quickly expanded to much larger area compared to the original area outside of the body, and then transplanted back to a burned area of the body.

With the rapid growth of regenerative medicine research, a new set of products—and processes to create those products—are emerging. For the Industrial Engineer who will work with the commercial production of these products, it will be necessary to use engineering specifications to define both the products and the related processes. These terms include quantifying measurable attributes in the biological domain such as functionality, viability, and metabolic activity, as well as traditional attributes such as time, count, and size. To regenerate healthy skin for treating the severe burned patients, a small area of skin harvest from the patient needs to be stretched and grown into a larger area of healthy skin. After a successful clinical study, researchers began investigating the biaxial expansion of skin by testing human and pig skin from the back and upper legs. We are currently in the first phase of this study, and are attempting to establish an upper limit to the amount of force that can be applied to skin graft specimens without tearing them. A more effective and efficient skin expansion bioreactor design still remains a major challenge in regenerative medicine. In this paper, we present our efforts in exploring the promise of skin regeneration by investigating the skin growth factors and developing mechanical methods to expedite the regeneration of skin in the laboratory for safe implantation.

Figure 2 shows the preparation process of skin expansion. The objective of this research effort is to describe the expansion as a manufacturing process with sufficient specifications, such that the process is reproducible within given tolerances. The primary structural element in most mammalian soft tissue is collagen, which forms a mesh-like network to carry and deflect tensile and compressive stresses, which in turn act to deform this network. Induced stresses, which are large enough and/or occur over large enough periods of time, create permanent tissue deformation. Of particular interest, cells within these deforming tissues often respond with tissue growth, not only by increasing the collagen network strength, but also

Fig. 2 Procedure of skin expansion for regenerative medicine



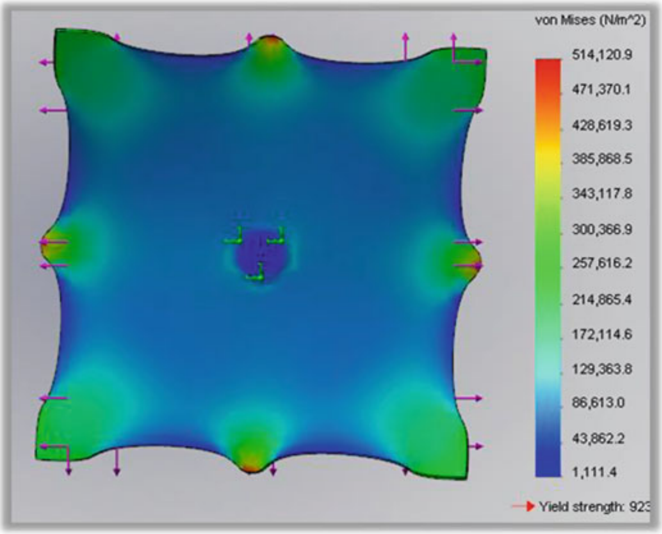


Fig. 3 Analytical modeling of soft tissue expansion for regenerative medicine

by proliferating, which increases the tissues' functional capacity. As such, tissue expansion can achieve different goals, each with a specific set of process parameters that seek to optimize those goals. Figure 3 shows how collagen-based, soft tissue responds to mechanical deformation and the effects of different process parameters based on the analytical modeling.

Many of the current skin stretching practices cause skin tissue failures during skin expansion. It is critical to understand and identify the causes of the failure in skin expansion and to develop a bioreactor that can effectively deliver the healthy regenerated skin tissues. In this paper, we have explored and examined how collagen-based, soft tissue responds to mechanical expansion and the effects of different skin expansion parameters. Figure 3 shows an example of skin stretching by biaxial skin stretching in both X- and Y-directions. Several clamping points were loaded with force to clamp the skin tissue during the skin expansion process.

3 Information Fusion in Bio-Manufacturing Systems

Information fusion (IF) is the concept of a group of data driven methods, which refers to a series of processes that integrate and synergize the information acquired from multiple sources to result in more accurate and reliable description of the situation, or even reveal hidden aspects of the situation (Dasarathy 2001). Such sources can be various types of sensors, databases, and other information gathered by human. The goal of IF is to help people make decisions that are better than those only based on individual source without synergy. Information fusion can be simply considered as the combination of sensor fusion and data fusion. Sensor fusion, as is easily understood, is to establish multi-dimensional sensor array to ensure a sufficient sampling information over individual source. Data fusion always includes data processing with various mathematical methods. Conventional data fusion methods include: Kalman Filter, Bayesian Decision Theory, Dempster-Shafer Evidential Reasoning, Neural Network, Expert System, Blackboard Architecture, Fussy logics, etc. In this paper, we look into the possible tools to be used in information fusion for bio-manufacturing systems development.

Information fusion plays an important role in the context of production and manufacturing process as discussed in our earlier work in (Lee et al. 2013). Figure 4 shows the information flow of conventional manufacturing system based on the part geometry, dimension and quality control data and information.

The creation of novel manufacturing technologies and engineering skills may support long-term presence that secure the entire value system. Based on that, we believe it is reasonable to introduce the concept of information fusion and apply the corresponding methods in the regenerative medicine manufacturing. Figure 5 shows the sequential steps involved in producing cells, which can be modeled based on a multi stage manufacturing process as presented in our earlier work in (Lee et al. 2013).

When information fusion is applied in conventional manufacturing, one of the most essential decisions to make is to determine which process is the best choice. Common constraints in process selection often include material attributes, geometry complexity, and properties requirement of the part, etc. Various criteria, including reduction of the total processing time, minimized total cost, and optimal product quality are always applied (Jin and Shi 2012). From the perspective of information fusion, such constraints and criteria, as well as the information acquired from multiple sensors, measured by all kinds of facilities are collected to serve as data flow to support the decision making.

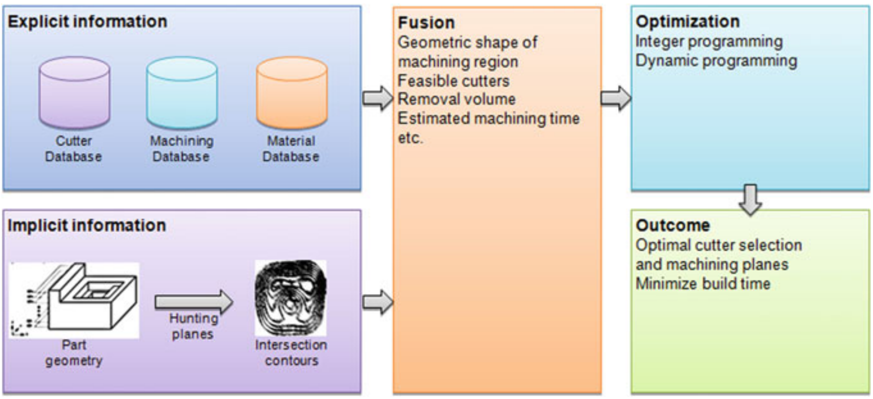


Fig. 4 Data flow and information fusion for process planning and milling operations

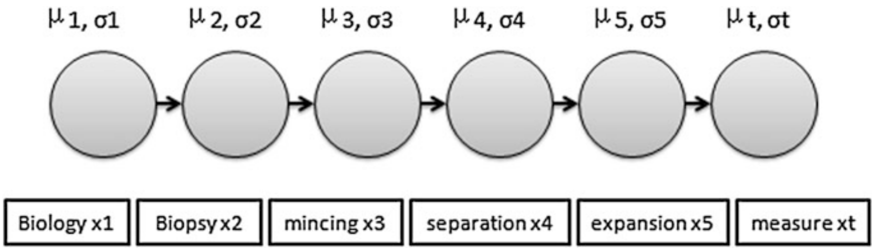


Fig. 5 Procedure of steps in bio-manufacturing processes

Table 1 Information flow for bio-manufacturing and regenerative medicine manufacturing

	Conventional manufacturing	Regenerative medicine manufacturing
Input	Discrete and continuous, can be loaded from each stage of the process	Discrete and continuous, can be loaded from each stage of the process
Constraints	Processing time, cost, quality, etc.	Cell survival rate, cost, function, etc.
Output	Optimal process selection	Optimal process selection
Noise	System error, white noise, etc.	System error, white noise, etc.
	Accumulative, propagating along with data flow	Accumulative, propagating along with data flow
Flow direction	Forward with time flow direction, parallel or serial	Forward with time flow direction, parallel or serial

The following Table 1 presents the common points shared and differences between a conventional manufacturing process and the regenerative medicine manufacturing (RMM) process from the process structure point of view. In Table 1, it can be seen that differences exist between elements from the regenerative medicine manufacturing and the conventional manufacturing process. Concerning all the issues shown in Table 1, in this paper, a hybrid information fusion method is suggested to support the decision making process.

Figure 6 shows the data flow and information fusion in RMM process. Concerning the high randomness and the accumulation and propagation of the variances from the starting point to downstream steps, a data cleaning and classification process is needed before the fusion. Instead of directly inputting raw data into the model, raw data is cleaned and classified into qualitative data and quantitative data. Quantitative data is directly passed to the fusion step of the modeling; however, qualitative data need to be preprocessed in advance. After a series of preprocessing procedures, such as data mapping, noise removal, key factor identification, the remaining data is discretized and passed into the fusion step.

As shown in Table 1 as well as Figs. 4 and 6, there are many differences between the regenerative medicine manufacturing and the conventional manufacturing processes. This is due to the following reasons found in this research: First of all, the material varies from individual to individual, since the cells are

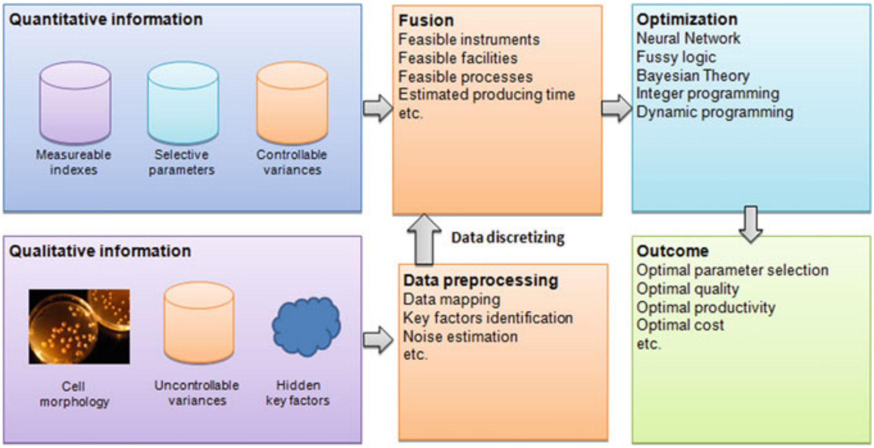


Fig. 6 Information fusion of regenerative medicine manufacturing systems

sampled from patients through biopsy process. As mentioned earlier, individual difference may severely impact the outcome of the entire process dependent on different age, gender, disease state etc. Secondly, manual operation introduces non-neglectable variances, which indicates inconsistency of the process. These variances vary from patches to patches, which yields lot-to-lot difference in ultimate outcome of the RMM process. Thirdly, unlike the conventional manufacturing, the discretizing of the data through the entire process is almost impossible. Thus, the traditional simple optimizing algorithms may not be directly applied. Furthermore, some of the RMM processes are still in state of being developed. The process itself is not completely well defined yet and some of the key factors remain unidentified.

Due to the high diversity of data, optimization algorithms may include soft computing methods, machine learning methods and other conventional statistical methods, the preference of which depends on the specific situation of the data. Optimal outcomes are designed to be generated throughout the model. However, optimization highly depends on each step of the data processing including the preprocessing, since the high randomness and huge amount of noises severely increase the risk of failing to identify the key factors. Nevertheless, the method is supposed to provide an acceptable optimal solution within a certain tolerance space, which is much better than the trial and error methods.

4 Conclusions

In this paper, an information fusion modeling technique is presented for modeling the bio-manufacturing systems for regenerative medicine manufacturing. The challenges related to bio-manufacturing with living cell therapies were presented.

Possible solution approaches to these challenges were investigated through both processing perspective and business perspective. This paper presents the possible future industrial engineering role in solving the challenges of the emerging new area of regenerative medicine manufacturing associated with information fusion and modeling.

Acknowledgments This work was partially supported by the National Science Foundation (NSF) Grants (CMMI-0800811, CMMI-1125872) to North Carolina State University. Their support is greatly appreciated. The authors also gratefully acknowledge the helpful comments and suggestions of Dr. Richard Wysk, Dr. Paul Cohen of North Carolina State University and Dr. Sang Jin Lee, Dr. James Yoo, Dr. Anthony Atala of Wake Forest University Institute of Regenerative Medicine, which have significantly improved this paper.

References

Couto DS, Perez-Breva L, Cooney CL (2012) Regenerative medicine: learning from past examples. Tissue Eng Part A 18(21–22):2386–2393. (120725085622009, Mary Ann Liebert, Inc. publishers)

Dasarathy BV (2001) Information fusion–what, where, why, when, and how? Inf Fusion 2(2):75–76

Jin R, Shi J (2012) Reconfigured piecewise linear regression tree for multistage manufacturing process control. IIE Trans 44(4):249–261

Lee YS, Qin X, Cai Y (2013) Data and information fusion for multi-stage manufacturing systems. In: Proceedings of 2013 industrial and systems engineering research conference (ISERC), San Juan, Puerto Rico, 18–22 May 2013, (CD) Paper Number: ISERC2013-1415

Evaluating the Profit Efficiency of Commercial Banks: Empirical Evidence from Nepal

Suvita Jha, Xiaofeng Hui and Baiqing Sun

Abstract This study offered an application of a non-parametric analytic technique, namely data envelopment analysis for measuring the performance of the Nepalese commercial banking sector. It explored the efficiency of the Nepalese commercial banks with the use of interest expenses and loan loss provision as inputs and net interest income, commission income and other operating income as outputs for the period of 2005–2010. It was also observed the effects of scale and of the mode of ownership (public sector, joint venture and domestic private sector) on bank behavior and therefore, on bank performance in the Nepalese banking industry. The public sector banks most recently in the analyzed period were observed to perform relatively more efficient than joint venture banks and domestic private banks with respect to their profit efficiency due to the large scale of branch networks.

Keywords Nepalese commercial banks · Data envelopment analysis · Profit efficiency · Ownership

1 Introduction

The banking sector is one of the most tightly regulated industries, especially in the developing countries. Although regulation varies in intensity from country to country, bank performance in emerging economies is often criticized due to lack of

S. Jha (✉) · X. Hui · B. Sun
School of Management, Harbin Institute of Technology, 150001 Harbin, People's Republic of China
e-mail: sovi1977@yahoo.com1

X. Hui
e-mail: xfhui@hit.edu.cn2

B. Sun
e-mail: wiseseaman@163.com3

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_178,

competition and management skills. How the increased competitive pressure will affect banks depends partially on how efficiently they are running. Bank efficiency depends on the quality and associated risk on loans, and if they are not controlled, then the scores calculated may lead to erroneous conclusion (Mester 1996). A majority of studies focused on cost efficiency while research on the revenue and profit efficiency has been much scarcer (Ariff and Can 2008) despite the fact that analyzing profit efficiency constitutes a more important source of information for bank management than the partial assessment offered by the cost efficiency analyses. In fact, a profit-based approach is better in capturing the diversity of strategy responses by financial firms in the face of dynamic changes in competitive and environmental conditions. The profitability approach, which is a relatively newer approach, Drake et al. (2006) proposed the use of a profit-oriented approach in data evaluation analysis (DEA) context that is in line with the approach of Berger and Mester (2003). With reference to Nepal, Gajurel (2010) has used DEA to evaluate the cost efficiency of Nepalese banking sector whereas Jha et al. (2013) has reported technical efficiency of commercial banks under intermediation approach using deposits and interest expenses as inputs and loan and advances and interest income as outputs. There has been no any report about profit efficiency of the Nepalese commercial banks.

Due to the small amount of reliable work done on Nepalese commercial banking sector despite the unprecedented growth, Nepal witnessed several bank crashes one after another causing severe panic in the general population. This necessitated restructuring of the banking sector to increase its financial efficiency. This study is more relevant in the banking field as it includes loan loss provision as an input in computation of profit efficiency to verify the impact of credit risk on the efficiency score. The task of this paper is to examine profit efficiency of the Nepalese commercial banks during the period 2005–2010 using DEA approach.

2 Data and Methodology

2.1 Data and Variables

In this analysis included 18 commercial banks, which have been established before 2005 in Nepal. Many literatures suggest the use of homogeneity conditions for decision-making units in a model (Yeh 1996) and encourage the use of DEA for firms with similar resources and operations providing similar products and services (Oral and Yololan 1992). Therefore, commercial banks that started its operations after 2005 are not included in this investigation. In the present study, we adopted the profit-oriented approach to find out the profit efficiency using interest expenses and loan loss provision as inputs and three outputs—net interest income, commission income and other operating income. The required data for the input and output variables were mainly obtained from the Nepal Rastra Bank Bulletin published by the Central Bank of Nepal (Nepal Rastra Bank 2011), annual audited financial statements of the commercial banks published by the respective banks. Efficiency scores were estimated with MATLABR2010 a program whereas the ordinary calculations were done in Excel.

2.2 Details of the Model

We used DEA to estimate technical, pure technical and scale efficiencies of the Nepalese commercial banks for the period of 2005–2010. One of the well-known advantages of DEA, which is relevant to this study, is that it works particularly well with small samples. The research applied the DEA technique based on constant return on scale (CRS) and variable return on scale (VRS) assumptions. The detail of the model is explained in our previous work (Jha et al. 2013). The relative profit efficiency under CRS (PECRS) and profit efficiency under VRS (PEVRS) were measured as described by Jha et al. (2013). The scale efficiency was found by PECRS/PEVRS. The efficiencies among not only individual selected banks but also three types of the Nepalese commercial banks based on ownership—public sector banks (PSB), joint venture banks (JVB) and domestic private banks (DPB) were compared in this study.

3 Results and Discussion

3.1 Efficiency Estimates-Individual Commercial Banks

Table 1 shows the profit efficiency scores under CRS of individual banks. Among the public sector banks, Nepal Bank Limited (NBL) was fully efficient in year 2007, 2009 and 2010 while Rastriya Banijya Bank Ltd (RBBL) and Agricultural Development Bank Ltd (ADBL) were only fully efficient in year 2009 and 2010 because the share of non-performing loan (NPL) is very high from 2005 to 2008. Poor evaluation, insufficient follow up and supervision of loan distribution ultimately resulted in massive booking of poor quality assets, the level of which remains high. Hence, more provisions had to be made. In 2009 and 2010, this situation slightly improved and the growth in NPL was reduced. Among the joint venture banks, Nabil Bank Ltd (NABIL) bank was fully efficient from 2005 to 2009 and Standard Chartered Bank Ltd (SCBL) showed the consistency at its efficiency scores for all the years. Both NABIL and SCBL, which are holding highest share of deposits, have shown relatively better performance than rest while Nepal Bangladesh Bank Ltd (NBBL) from 2008 to 2009 and Everest Bank Ltd (EBL) in 2010 showed fully efficient. No any domestic private banks had 100 % efficiency from 2005 to 2010. Nepal Credit and Commerce Bank Ltd (NCCBL)

Table 1 Individual commercial banks technical efficiency under CRS

	Bank	Profit efficiency under CRS						Avg
		2005	2006	2007	2008	2009	2010	
PSB	NBL	0.487	0.780	1.000	0.981	1.000	1.000	0.875
	RBBL	0.410	0.689	0.811	0.843	1.000	1.000	0.792
	ADBL	0.698	0.620	0.743	0.882	1.000	1.000	0.824
	Avg	0.532	0.696	0.851	0.902	1.000	1.000	0.830
JVB	NABIL	1.000	1.000	1.000	1.000	1.000	0.978	0.996
	SCBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	HBL	0.464	0.536	0.492	0.689	0.693	0.759	0.606
	NSBI	0.369	0.382	0.421	0.489	0.462	0.690	0.469
	NBBL	0.233	0.406	0.901	1.000	1.000	0.792	0.722
	EBL	0.456	0.622	0.788	0.993	0.770	1.000	0.771
	Avg	0.587	0.658	0.767	0.862	0.821	0.870	0.761
DPB	NIBL	0.716	0.595	0.617	0.634	0.563	0.996	0.687
	BOK	0.476	0.622	0.577	0.656	0.743	0.927	0.667
	NCCBL	0.213	0.290	0.397	1.000	1.000	1.000	0.650
	LBL	0.291	0.291	0.783	0.624	1.000	0.891	0.647
	NIC	0.457	0.357	0.471	1.000	0.618	0.869	0.629
	MPBL	0.998	1.000	0.867	0.572	0.527	0.442	0.734
	KBL	0.620	0.600	0.571	0.486	0.493	0.740	0.585
	LXBL	0.546	0.634	0.725	0.605	1.000	1.000	0.752
	SBL	0.587	0.665	0.763	0.709	0.692	0.678	0.682
	Avg	0.545	0.562	0.641	0.699	0.737	0.838	0.670
Avg		0.557	0.616	0.718	0.787	0.809	0.876	0.727

from 2008 to 2010, Lumbini Bank Ltd (LBL) in 2009, Nepal Industrial and Commercial Bank Ltd (NICBL) in 2008 and Laxmi Bank Limited (LXBL) from 2009 to 2010 were fully efficient. DPB have also shown a good efficiency trend. This shows that less slack was produced by these banks. Thus, the fully efficient banks armed with modern banking technology and business performance. It is remarkable here that the method of resource use in the efficient banks is functioning well, and featuring no misuse of resources. In the strength of DEA terminology, these commercial banks can be termed as internationally efficient banks. Other banks were deviating a lot from the optimal input–output mix. It shows that some large banks were efficient. Hence, it is using economies of scale to take advantage and able to maximize profits. However, a few other large banks are unable to achieve profit efficiency in the same way as their counterparts have taken. This is due to internal factors relating to non-interest income and to external factors like loan loss provisions.

Table 2 shows the profit efficiency scores under VRS of individual banks. RBBL and ADBL were found operating efficiently with the efficiency score of 1. Similarly, NABIL and SCBL were fully efficient from 2005 to 2010 while NBL from 2006 to 2010, NBBL from 2008 to 2010 and EBL in 2010 showed 100 %

Table 2 Individual selected commercial banks pure technical efficiency under VRS

	Bank	Profit efficiency under VRS						Avg
		2005	2006	2007	2008	2009	2010	
PSB	NBL	0.912	1.000	1.000	1.000	1.000	1.000	0.985
	RBBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	ADBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Avg	0.971	1.000	1.000	1.000	1.000	1.000	0.995
JVB	NABIL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	SCBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	HBL	0.521	0.570	0.522	0.690	1.000	0.786	0.681
	NSBI	0.530	0.594	0.738	0.798	0.545	0.723	0.655
	NBBL	0.309	0.505	0.985	1.000	1.000	1.000	0.800
	EBL	0.544	0.677	0.876	0.938	0.870	1.000	0.817
	Avg	0.651	0.724	0.854	0.904	0.903	0.918	0.826
DPB	NIBL	0.716	0.604	0.636	0.886	1.000	1.000	0.807
	BOK	0.627	0.675	0.953	0.999	0.833	0.944	0.838
	NCCBL	0.379	0.589	0.953	1.000	1.000	1.000	0.820
	LBL	0.568	0.775	1.000	1.000	1.000	1.000	0.891
	NIC	0.566	0.538	0.701	1.000	0.840	0.952	0.766
	MPBL	1.000	1.000	0.981	0.966	0.624	0.476	0.841
	KBL	0.684	0.692	0.867	0.840	0.859	0.922	0.811
	LXBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	SBL	1.000	1.000	1.000	1.000	0.880	0.779	0.943
	Avg	0.727	0.764	0.899	0.966	0.893	0.897	0.858
Avg		0.742	0.790	0.901	0.951	0.914	0.921	0.870

efficient among JVBs. Among DPBs, LXBL was fully efficient while Siddhartha Bank Ltd (SBL) from 2005 to 2008, Nepal Investment Bank Ltd (NIBL) from 2009 and 2010, Nepal Credit and Commerce Bank Ltd (NCCBL) from 2008 to 2010, LBL from 2007 to 2010, NIC in 2008, Machhapuchhre Bank Ltd (MPBL) from 2005 to 2008 showed fully efficient. As per Table 3, when the scale efficiency of the individual bank was examined, all the PBS were fully efficient in 2009 and 2010. Among JVB, NABIL from 2005 to 2009 and SCBL from 2005 to 2010 were determined as competent banks while the scale efficiency score of NBBL from 2008 to 2009 and EBL 2010 showed 100 % efficient. NCCBL from 2008 to 2010, NIC in 2008, MPBL in 2006, LXBL from 2009 to 2010 showed 100 % efficient among DPB.

3.2 *Efficiency Score: Ownership Classification*

Table 4 demonstrates average profit efficiency classified on the basis of ownership. There was an increasing trend in their mean of yearly efficiency measures of the

Table 3 Individual commercial banks scale efficiency

	Bank	Profit efficiency under VRS						Avg
		2005	2006	2007	2008	2009	2010	
PSB	NBL	0.534	0.780	1.000	0.981	1.000	1.000	0.883
	RBBL	0.410	0.689	0.811	0.843	1.000	1.000	0.792
	ADBL	0.698	0.620	0.743	0.882	1.000	1.000	0.824
	Avg	0.547	0.696	0.851	0.902	1.000	1.000	0.833
JVB	NABIL	1.000	1.000	1.000	1.000	1.000	0.978	0.996
	SCBL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	HBL	0.891	0.941	0.941	0.998	0.693	0.965	0.905
	NSBI	0.695	0.643	0.570	0.613	0.848	0.955	0.721
	NBBL	0.752	0.803	0.915	1.000	1.000	0.792	0.877
	EBL	0.838	0.919	0.900	1.059	0.885	1.000	0.933
	Avg	0.863	0.884	0.888	0.945	0.904	0.948	0.905
DPB	NIBL	0.999	0.987	0.970	0.716	0.563	0.996	0.872
	BOK	0.760	0.921	0.605	0.657	0.892	0.982	0.803
	NCCBL	0.563	0.493	0.417	1.000	1.000	1.000	0.746
	LBL	0.513	0.375	0.783	0.624	1.000	0.891	0.698
	NIC	0.807	0.663	0.672	1.000	0.736	0.913	0.798
	MPBL	0.998	1.000	0.884	0.593	0.844	0.929	0.875
	KBL	0.907	0.868	0.658	0.579	0.574	0.803	0.731
	LXBL	0.546	0.634	0.725	0.605	1.000	1.000	0.752
	SBL	0.586	0.664	0.763	0.708	0.786	0.870	0.730
	Avg	0.742	0.734	0.720	0.720	0.822	0.932	0.778
Avg		0.750	0.778	0.798	0.826	0.879	0.949	0.830

commercial banks of Nepal. The average annual score based on CRS for PSB, JVB and DPB from 2005 to 2010 were determined 83, 76 and 67 % respectively. It indicated that PSB exhibited higher average efficiency compared to their counterparts. This result is contrary to Ariff and Can 2008 which showed that the JVB are profit-efficient relative to the PSB for Chinese banks. One major cause for this is the Nepalese banking system is dominated by PSB in terms of deposit mobilization and PSB hold larger share of total deposit of the banking system, thereby resulting in higher profits. It is often argued that larger banks possess more flexibility in financial markets and are better able to expand their credit risks (Cole and Gunther 1995). Due to having relatively very few branch networks with limited assets, JVB and DPB have little capacity to deposit mobilization in small urban or rural savings and make lower profit than PSB.

The level of managerial efficiency as revealed by PTE score under VRS is more in PBS relative to JVB and DPB. In VRS specification, the average score of the efficiency of the commercial banks of Nepal varied from 0.65 to 1. PSB showed the consistency in their performance for each year with the score 1 whereas DPB had higher profit efficiency under VRS (86 %) than that for JVB (82 %). The pure technical inefficiency is generally caused by inappropriate management practices

Table 4 Average efficiency of commercial banks

	Technical efficiency				Pure technical efficiency				Scale efficiency			
Years	PSB	JVB	DPB	Avg	PSB	JVB	DPB	Avg	PSB	JVB	DPB	Avg
2005	0.53	0.59	0.54	0.55	0.97	0.65	0.73	0.78	0.55	0.86	0.74	0.72
2006	0.70	0.66	0.56	0.64	1	0.72	0.76	0.83	0.70	0.88	0.73	0.77
2007	0.85	0.77	0.64	0.75	1	0.85	0.90	0.92	0.85	0.89	0.72	0.82
2008	0.90	0.86	0.70	0.82	1	0.90	0.97	0.96	0.90	0.95	0.72	0.86
2009	1	0.82	0.74	0.85	1	0.90	0.89	0.93	1	0.90	0.82	0.91
2010	1	0.87	0.84	0.90	1	0.92	0.90	0.94	1	0.95	0.93	0.96
Avg	0.83	0.76	0.67	0.75	1.00	0.82	0.86	0.89	0.83	0.91	0.78	0.84

but in case of Nepal, higher meant profit efficiency under VRS for PSB was consistent with the PSB have a large volume of operations and resources in Nepal. They would be able to get in benefits of economies of scale and earn more profit. On the other hand, JVB and DPB have relatively lower profit due to higher costs in their small branch networks. As stated before, scale efficiency score for each bank can be obtained by taking a ratio of technical efficiency score to pure technical efficiency score. The value of scale efficiency equal to 1 means that the bank is working at most dynamic scale size which corresponds to constant returns-to-scale. Furthermore, being scale efficiency less than 1 shows that the bank is not operating at its optimal scale. The scale efficiency of the commercial banks showed the mean efficiency each year by decomposing profit efficiency under CRS into profit efficiency under VRS and scale efficiency to gain insight into the main sources of inefficiencies. The scale efficiency varied in between 0.55 and 1. The average scale efficiency of the commercial banks was 84 %, indicating that the actual scale of production has differed from the most productive scale size by about 16 %. According to Hassan and Sanchez (2007) if scale inefficiency is greater than profit efficiency under VRS, it means wrong mix of inputs and outputs for the reasons beyond their control inefficiency. Here, scale inefficiency was 16 % whereas profit inefficiency under VRS was 11 %, suggesting wrong mix of inputs and outputs.

4 Conclusions

Concerning the ownership, the public sector banks were more efficient than joint venture banks and domestic private banks during the study period of 2005–2010 because public sector banks have higher the size of total assets. The commercial banks that have expanded their operations in large scale appeared to be more profit efficient than those operating only at a small scale. Not only this, increasing loan activity of the public sectors banks made them more efficient than joint venture banks and domestic private banks, which have limited networking and urban concentration. The individual commercial banks yearly analysis showed that the efficiency of majority of the banks in Nepal is still not fully efficient. Thus it is still needed for commercial banks in Nepal to improve their efficiency.

Acknowledgments The authors would like to thank the National Science Foundation of China (71173060, 70773028 and 71031003) for their supports.

References

Ariff M, Can L (2008) Cost and profit efficiency of Chinese banks: a non-parametric analysis. China Econ Rev 19:260–273

Berger AN, Mester LJ (2003) Explaining the dramatic changes in performance of U.S. Banks: technological change, deregulation and dynamic changes in competition. J Financ Intermed 12:57–95

Cole RA, Gunther JW (1995) Separating the likelihood and timing of bank failure. J Bank Financ 19:1073–1089

Drake LM, Hall MJB, Simper R (2006) The impact of macroeconomic and regulatory factors on bank efficiency: a non-parametric analysis of Hong Kong's banking system. J Bank Financ 30:1443–1466

Gajurel DP (2010) Cost efficiency of Nepalese commercial banks. Nepalese Manage Rev

Hassan K, Sanchez B (2007) Efficiency determinants and dynamic efficiency changes in Latin American banking industries. Network financial institute working paper no. 32, Indiana State University, USA

Jha S, Hui X, Sun B (2013) Commercial banking efficiency in Nepal: application of DEA and Tobit model. Inform Tech J 12:306–314

Mester L (1996) A study of bank efficiency taking into account risk-preferences. J Bank Financ 20:1025–1045

Nepal Rastra Bank (2011) Banking supervision report 2010. Bank Supervision Department, Nepal Rastra Bank, Nepal.http://www.nrb.org.np/bsd/reports/Annual_Reports–Annual_Bank_Supervision_Report_2010.pdf

Oral K, Yololan O (1992) An empirical study on analyzing the productivity of bank branches. Iie Trans 46:282–294

Yeh QJ (1996) The application of data envelopment analysis in conjunction with financial ratios for bank performance evaluation. J Oper Res Soc 47:980–988

Explore the Inventory Problem in a System Point of View: A Lot Sizing Policy

Tsung-Shin Hsu and Yu-Lun Su

Abstract This article presents a study on the make-to-order inventory management problem in an anonymous manufacturer which produces precision screw and bolt for European customers. Seeing that this company keeps about 800 active wide varieties of screw and bolt items, of which the manufacturing normally undergoes six processing steps each requires 1–4 h setup before production proceeds, the company is forced to keep inventory-item in their make-to-order production. In this clear and certain inventory problem setting, we can make a study from system point of view to effectively reduce the inventory and meet customers' requirements. Although the operations of business are preceded by the operation mechanism, it is easily found that we still can enhance inventory performance by some control factors such as lot-size policies and parameters. To facilitate the study we develop a system simulator according to the company's SOP as the tool to visualize the inventory problem then achieve effective management.

Keywords Make-to-order · Inventory management · Lot-size policies · WMS management systems · Inventory turnover · ROI

1 Introduction

Businesses have long recognized that good inventory management is valuable; it is especially essential for those the inventory is a large percentage of assets in its balance sheet. Having the necessary items just in time to be sold or be consumed is

T.-S. Hsu (✉) · Y.-L. Su
Department of Industrial Management, National Taiwan University of Science and Technology, Taipei, Taiwan, Republic of China
e-mail: tshsu@mail.ntust.edu.tw

Y.-L. Su
e-mail: D9801010@mail.ntust.edu.tw

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_179,

obviously the best practices in maintaining high inventory turnover and satisfying customers as well. Stockless production and purchasing, lean manufacturing are well known practices for these purposes. However, uncertainty is unavoidable; reducing the lot size is a next choice. Seeing that amounts of inventory are resulted from triggering the needed replenishment orders, large lot sizes may result in excess amounts of inventory items in the stockroom. On the other hand, small lot sizes can lead to lost sales and higher production costs; we can not say it is a smart practice for the manufacturers especially for that setup costs are high.

This article presents a study on the make-to-order inventory problem in an anonymous manufacturer named as XYZ-company. XYZ-company is a precision screw and bolt producer which services European customers more than 30 years. It provides more than 800 product items, of which each piece of product undergoes 6 manufacturing processing steps including heading, thread rolling, drilling, coating and polishing normally. Since the setups before production precede take 1–4 h in every processing steps, and customer orders are mostly repeated and some in small quantities, order by order production is uneconomical. Therefore, XYZ-company is forced to keep inventory-item in their make-to-order production, and making up an inventory high as 58 % of its total asset, slowing down inventory turnover as 3.23 annually.

The devil of inventory seems in the details of the order-sizing. Since Harris (1913) proposed the EOQ, most of the inventory studies focused on determining the least cost inventory. Literature review articles (Chen et al 2012; Yu et al. 2012; Lin and Chung 2012; Duc et al. 2010; Wee et al. 2007; Abad 2008) showed that thousands studies based on the same theory foundations. These studies vastly extended to the assumptions of different demand patterns, covered single and multiple products, multiple warehouses or layers, existence of price discount and delayed payment, perishable products, and so on. Based on EOQ model, many studies focused on the effect of the parameter changing, Porteus (1985) discussed the effects of reducing setup cost, Jordan (2nd Quarter 1987) discussed the cost and profit affected by declining interest rates. Excepting least cost model, Schroeder and Krishnan (1976) viewed inventory as an financial investment and developed the lot size by optimizing the ROI.

2 The Problem

The conflict of management functions always exists in XYZ-company; finance wants to hold down inventory, manufacturing wants to maximize their production performance, while sales people emphasize on meeting customers' requirements. Providing a systematic solution to effectively managing the inventory is sensible. Since inventory related operation of XYZ-company is unchangeable and well known, and it has high inventory percentage of the asset and low inventory turnover, we can take this inventory as a whole and make a systematic study; instead of just obtain piecewise results of the inventory to this issue. Moreover, we can practically study to realize how effective the lot sizing rules XYZ-company's inventory is.

Although XYZ-company's inventory related operations are guided by the implemented standard operation procedures, managers still can take certain actions, such as override lot size decisions, reduce setup costs; eliminate sluggish inventories etc., to enhance inventory performances.

XYZ—company normally keep more than 800 product items in its stockroom, among them we pick AA series which contain 25 active product items, contribute 5 % of sale amount in average. Draw from its ERP database one year ago, we found XYZ-company received 53 incoming customer orders of AA product series in the planning horizon of 4 months. Among these 53 orders, 29 orders can be fulfilled and shipped to customers directly because inventories can cover the requirements; that is only 24 replenishment orders which cover 13 product items are to be produced. From these historical data, we can simulate since all these 53 orders are completed and shipped, measured by dividing sales by average inventory value.

The study design simulate of production and sales. To facilitate the study of the actually operated inventory system in XYZ we develop a system simulator which imitating the company's operation procedures according to the SOP in use. By means of this simulator we can understand and visualize the dynamics of the inventory related operation and then undergo the study.

3 Research Design

Figure 1 depicts a causation that simplifies the study of the inventory of XYZ-company, in which the causes are controllable factors; the effects are performance indicators of inventory; the rectangular box in-between expresses the system simulator that simulating XYZ-company's operation and inventory processes.

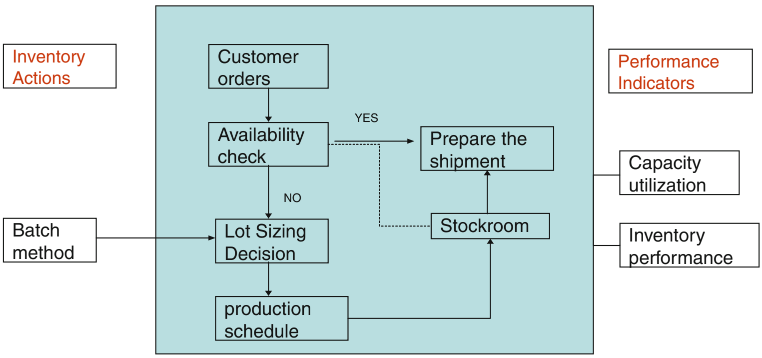


Fig. 1 System simulator

3.1 System Simulator

To facilitate a realistic inventory study such as which of XYZ-company, we develop a system simulator which imitating the company's inventory related SOP in use. By means of this, in coming customer orders can be processed automatically by the developed software; we can manipulate XYZ-company's inventory, visualize how the inventory related operations work, and measure the effects result from the inventory decisions. The simulator is developed according to the procedures and rules as follow:

1. Inventory checking: When receiving a customer order, warehouse people normally will check whether there are enough amounts of inventory for the required items. If the answer is yes shipment orders are issued accordingly, else replenishment orders will be issued instead.
2. Lot size decision: When receiving a replenishment order, operation people have to determine how large the production lot should be and then the order is scheduled to produce. Once this decision has been made, the quantity produced in excess of requirement becomes part of inventory in the stockroom. Lot sizing rules which compromising the costs of setup and inventory is essential.
3. Scheduling and production: Replenishment orders in XYZ-company normally are scheduled according to FCFS rule. The system kernel will use this rule to determine the sequence of replenishment order to be produced.
4. Order completing and reporting.
5. Order picking and preparing for shipment.

3.2 Inventory Actions

Using the system simulator as the kernel, we can test what kind of effects is resulted from the inventory actions we take. Similar to the people operated system guided by the SOP, the incoming customer orders are processed and inventory related operation generated by the software. We will emphasize our study on lot sizing; the comparing rules are traditional EOQ, ROI-based EOQ, and the experience based order lots.

3.3 Performance Indicators

Inventory turnover, in order to reduce costs to the minimum of the company will get more benefits than the expansion of the material reserves, lowest cost Order Quantity does not necessarily mean profitable. The performance of this inventory study covers compromising the performance of production and inventory. From production performance and output value, the amount shipped value/average inventory, average inventory performance. These movements result in the creation of material and financial accounting documents.

4 Analyze the System

In this study, the XYZ–Company order data, a total of 53 orders, 25 kinds of products, input simulator, after simulation, 53 orders only 24 orders need to produce 29 orders inventory ready to ship directly; 13 kinds of products need to produce 12 kinds of products are in stock and ready to ship directly. Production order items the different bulk procurement policy, regardless of the number of orders size, the EOQ procurement batch policy, simulation results Table 1.

Inventory and out of storage shown in Fig. 2.

Average inventory amount of $3,689,626 by the end of the data can be seen, the output value of $4,644,236, the shipments total amount of $4,581,750. Under the same conditions, the use of the ROI procurement volume, the analog data shown in Table 2.

Inventory and out of storage shown in Fig. 3.

Average inventory amount of $3,584,198 by the end of the data can be seen, the output value of $3,153,563, the shipments total amount of $4,581,750.

Large orders in the Order 10,000, ROI order quantity policy, and orders less than 10,000 orders, the EOQ purchasing bulk policy, the analog data shown in Table 3.

Inventory and out of storage shown in Fig. 4.

Table 1 EOQ procurement batch policy simulation results

Working days	7	8	13	14	22	23	38	39	45
Amount of storage	0	368021.9599	0	440926.2	0	301575.3	0	809480.7	0
Amount of inventory	3499906	3867927.96	3690428	4131354	3588354	3889930	3712429.515	4521910	3976910

46	52	53	59	60	68	69	94	95
253170.7236	0	239931.6	0	372237	0	239931.6	0	1618961
4230080.91	4230081	4470013	3379013	3751250	3443249.506	3683181	2793431	4412392

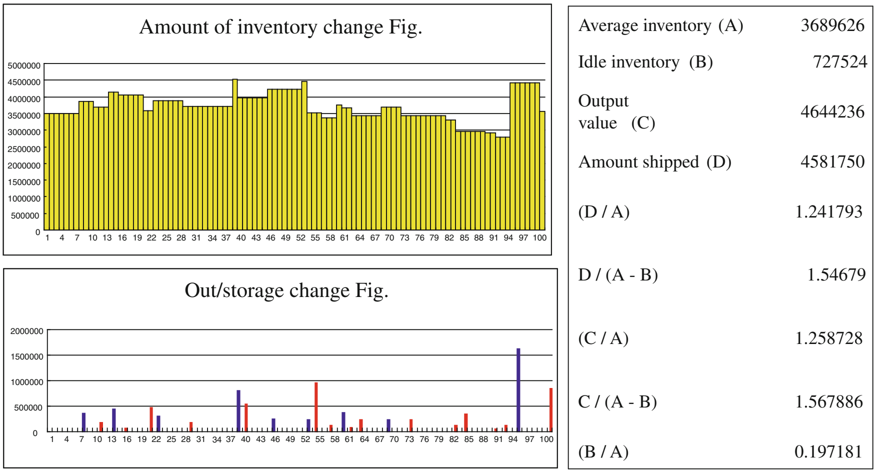


Fig. 2 EOQ inventory and out of storage

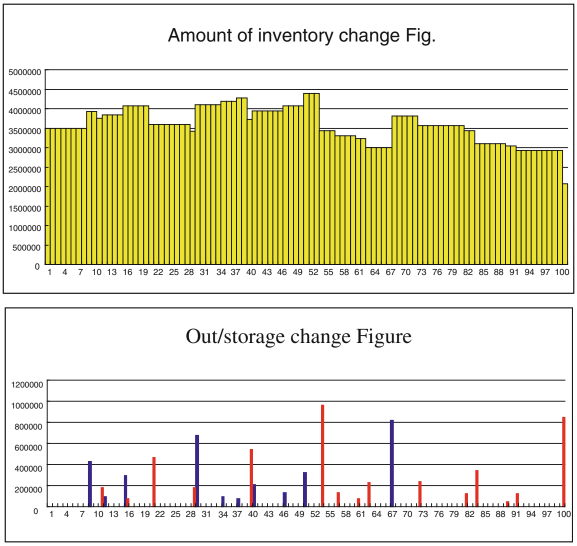
Table 2 ROI procurement batch policy simulation results

Working days	8	9	11	15	16	29	30	34	35	37
Amount of storage	0	425587.5	0	0	293212.5	0	679575	0	91942.5	0
Amount of inventory	3499906	3925494	3747994	3847009	4068221	3419721	4099296	4099296	4191239	4191239

38	40	41	46	47	50	51	67	68
80902.5	0	208312.5	0	135915	0	323610	0	815490
4272141	3727141	3935454	3935454	4071369	4071369	4394979	2995979	3811469

By the end of the data that the average inventory amount of $3,544,073, the output value of $3,104,128, shipped a total amount of $4,581,750.

Compare the three procurement batch policy, in the amount of the average inventory is, EOQ procurement batch >the ROI procurement batch> EOQ & ROI purchasing bulk; in the output value of the total amount is, EOQ procurement batch> the ROI procurement batch> EOQ & ROI procurement batch; while shipments total amount of three bulk Policy are the same, so the three bulk Policy inventory Turnover the EOQ & ROI procurement bulk > ROI procurement bulk > EOQ procurement bulk, comparative data shown in Table 4.



Average inventory (A)	3584198
Idle inventory (B)	727524
Output value (C)	3153563
Amount shipped (D)	4581750
(D / A)	1.278319
D / (A - B)	1.603876
(C / A)	0.879852
C / (A - B)	1.103928
(B / A)	0.202981

Fig. 3 ROI inventory and out of storage

Table 3 EOQ & ROI procurement batch policy simulation results

Working days	7	8	10	11	15	16	29	30	34	35
Amount of storage	0	367861.5	0	99015	0	301504	0	679575	0	91942.5
Amount of inventory	3499906	3867768	3867768	3789283	3789283	4018787	3370287	4049862	4049862	4141804

37	38	40	41	45	46	50	51	67	68
0	80902.5	0	208312.5	0	135915	0	323610	0	815490
4141804	4222707	3677707	3886019	3886019	4021934	4021934	4345544	2946544	3762034

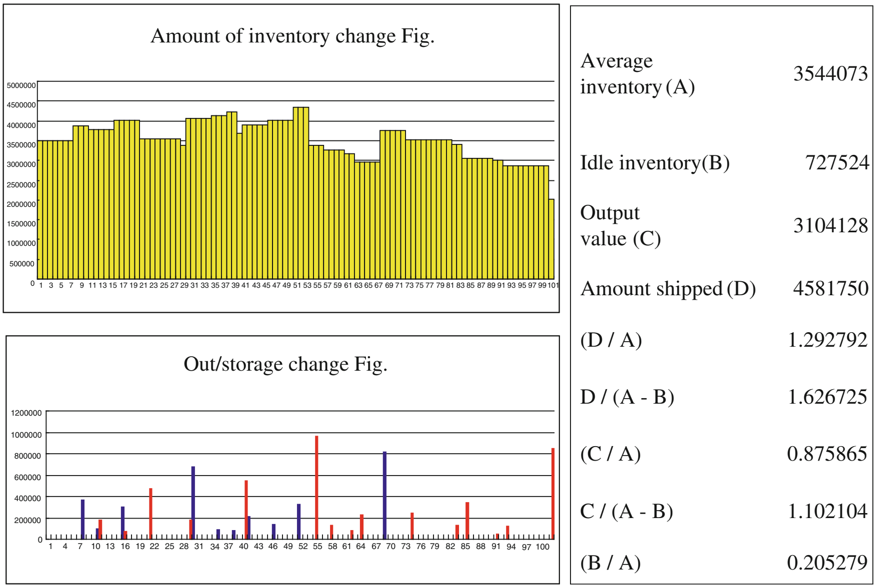


Fig. 4 EOQ & ROI inventory and out of storage

Table 4 Policy comparison

Batch strategy	Average inventory	Out value	Amount shipped	Output value/average inventory
EOQ model	3,689,626	4,677,236	4,581,750	1.241793
ROI model	3,584,198	3,153,563	4,581,750	1.278319
10,000 or above adopt ROI	3,544,073	3,104,128	4,581,750	1.292792

5 Discussion and Conclusion

The results appear from Table 4. EOQ model, the highest average inventory, the highest output value; ROI model, inventory costs are low compared to the EOQ model, the output value is lower than the EOQ model; mining EOQ bulk when demand is less than 10,000 procurement, higher than that the 10,000 mining ROI bulk purchases, both mixed-mode, the lowest cost of inventory, the output value of the lowest. Compare the three procurement batch policy, in the amount of the average inventory is, EOQ procurement batch> the ROI procurement batch> EOQ & ROI purchasing bulk; in the output value of the total amount is, EOQ procurement batch> the ROI procurement batch> EOQ & ROI procurement batch; while shipments total amount of three bulk Policy are the same, so the three bulk Policy inventory Turnover the EOQ & ROI procurement bulk > ROI procurement bulk > EOQ procurement bulk. In different batch Policy, the average inventory costs, output and output value/average inventory change scenarios.

Therefore, it is recommended that a small variety of small orders EOQ model is more suitable for large orders recommended ROI mode, this two mixed strategy inventory costs can be greatly reduced. Emergency inserted single need to increase capacity utilization, and not allowed out of stock recommended EOQ model, because of the EOQ the highest capacity and rush orders will not stock.

References

Abad PL (2008) Optimal price and order size under partial backordering incorporating shortage, backorder and lost sale costs. Int J Prod Econ 114(1):179–186

Chen X, Hao G, Li X, Yiu KFC (2012) The impact of demand variability and transshipment on vendor's distribution policies under vendor managed inventory strategy. Int J Prod Econ 139(1):42

Ton Hien Duc T, Luong HT, Kim YD (2010) Effect of the third-party warehouse on bullwhip effect and inventory cost in supply chains. Int J Prod Econ 124(2):395

Jordan PC (1987) The effects of declining interest rates on order sizing, inventory, and investment. Prod Inventory Manage 28(2):65

Lin SD, Chung KJ (2012) The optimal inventory policies for the economic order quantity (EOQ) model under conditions of two levels of trade credit and two warehouses in a supply chain system. Afr J Bus Manage 6(26):7669

Porteus EL (1985) Investing in reduced setups in the EOQ model. Manage Sci 31(8):998–1010

Schroeder RG, Krishnan R (1976) Return on investment as a criterion for inventory models. Decis Sci 7(4):697

Wee HM, Yu J, Chen MC (2007) Optimal inventory model for items with imperfect quality and shortage backordering. Omega 35(1):7

Yu Y, Wang Z, Liang L (2012) A vendor managed inventory supply chain with deteriorating raw materials and products. Int J Prod Econ 136(2):266

Harris FW (1913) How many parts to make at once, factory. Mag Manage 10(2):135–136

Global Industrial Teamwork Dynamics in China and Southeast Asia: Influence on Production Tact Time and Management Cumulative Effect to Teamwork Awareness-1/2

Masa-Hiro Nowatari

Abstract This research is international comparative survey on the teamwork awareness (TA) of China (four plants/Dalian, Shanghai: two, Guanzhou) and, Malaysia, Thailand and Vietnam in Southeast Asia. TA of the first line workers is compared between plants through country according to same category products. And those seven plants are surveyed from the production tact time (PTT) and the cumulative management effect (CME) from point of view. It clears TA are different by PTT and CME even if same category products. PTT effects on task orientation (TO) positively and CME effects on people orientation (PO) positively in the teamwork appraisal factors (TAF), respectively. And it confirms TA has stronger TO in Chinese workers, but has stronger PO in Southeast Asian workers.

Keywords Production tact time · Management cumulative effect · Teamwork awareness · Teamwork appraisal factors · China · Malaysia · Thailand · Vietnam

1 Introduction

The Industrial teamwork dynamics (ITD) has been developed to clarify relationship between line worker's teamwork awareness and team productivity through Japan domestic case studies in 1990s. From 2000s, it has been stepping up from ITD to global industrial teamwork dynamics (GITD), and studying various influences on TA by religion and national wealth through many overseas cases outside Japan. In this research, comparison study with China and countries in Southeast Asia bloc is carried out by GITD. Seven overseas plants belonging to the same Japanese parent company are surveyed, and workers in the front line are

M.-H. Nowatari (✉)
Department of Management Science, Faculty of Engineering, Tamagawa University, Tamagawa Gakuen, 6-1-1, Machida, Tokyo, 194-8610 Japan
e-mail: nowatari@eng.tamagawa.ac.jp; masahiro.nowatari@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_180,

research subjects. To the Japanese manager who carries out local plant, understanding teamwork of local workers is important to localizing Japanese-style production management. However, TA of local line workers has a tacit level understanding yet, and staying Japanese manager has misunderstood no difference, local worker's TA is same as Japanese. Therefore, large opportunity loss has been revealed. It is important to make teamwork as practical knowledge from tacit knowledge into explicit knowledge. If it sets up it as significant management tool, it will be able to bring up huge effect in labor-intensive assembly line, especially. Also it contributes to mutual understanding between Japanese managers and local manager, workers in every country, each other positively. On the other hand, it needs to meet quickly with changing market demand, and PTT has to match with market speed. PTT is key index on production management. Moreover, construction on localization of Japanese-style production management requires many years, it is introduced MCE as glocalization (global-localization) index.

2 Research Subject

Research subject is first line worker in the plants of China, Malaysia, Thailand and Vietnam on Japanese-owned local electrical plants. TA is tested influences by PTT and MCE, and especially internal structure of TA is tested by same category product.

3 Production Tact Time and Teamwork Awareness

Production tact time (PTT) means production interval as the whole plant and is based by market demand speed. PTT must realize manufacturing system based on invest by evaluating return on investment (ROI) according to production strategy. It consists of 4 viewpoints, where (location), what (production item), how many (production scale) and how to produce. This paper focuses on same product category globally, and confirms relationship between PTT and Teamwork awareness (TA).

4 Survey Method

4.1 Teamwork Appraisal Factors

In order to measure TA, teamwork appraisal factor (TAF) is set up. TAF has two categories, "task orientation (workability): TO" and "people orientation (cohesiveability): PO". And TAF consists of twelve factors (sixty questionnaire items) of six factors on TO (thirty questionnaire items), and six factors on PO (thirty questionnaire items). Moreover, every questionnaire item is appraised on five stages evaluation (1, 2, 3, 4, 5), and more positive figure means favorable and strong awareness to teamwork. TO means capability for carrying out the task (job, work) given as a work team, and PO is capability for maintaining team as a work team (Table 1).

Questionnaire method had been carried out from 2007 until 2011 with factory tour, interview, collecting data and fact finding.

4.2 Surveyed Plants

Seven plants of four plants (Dalian, Shanghai: two, Guanzhou) in China, and three plants (Malaysia, Thailand, Vietnam) classified into Southeast Asia bloc, were surveyed. Number of respondents sum total is 5,668 persons, and questionnaire collect ratio is around eighty percentages. In addition, MCE has specified as operation years which is continuing period of each plant from starting operation to surveyed year. And, unit of PTT is "a second/a piece". On size of employee, plant of greater than two thousands are D and S, and other five plants are from four hundreds to eight hundreds. The product H are produced in plant D and V, the product P is only S, the products Y are in three plants which are R, B and T, and the products M are produced at G and T. Only the plant T produces two products Y and M, and the others plant produces a single product. The operation years of plant B is overwhelmingly thirty-five years long. Plant D, S, R and T are around ten years and G and V as short

Table 1 Teamwork appraisal factors (TAF)

Productivity orientation	Team work appraisal factors (P = 12, p = 60)	Number of questionnaire items
TO: Task orientation (workability) (P = 6, p = 30)	1. Level of work management	5
	2. Training and instruction to subordinates by the leader's superior	5
	3. Training and instruction to subordinates by the leader	5
	4. Care of subordinates by the leader	5
	5. Ability to accomplish work	5
	6. Conformance to job requirement (progress, quality and quantity)	5
PO: People orientation (cohesive ability) (P = 6, p = 30)	7. Cohesiveness	5
	8. Atmosphere of group	5
	9. Human relations	5
	10. Morale	5
	11. Mutual cooperativeness on working	5
	12. Satisfaction	5

as from two to four years. Even plant R, B and T produce same product Y category, PTT is slightly varying from two to four seconds according to product specification and automation level. So PTT can be divided into three levels roughly, ten seconds or less group for product Y and product M derived from product Y (product M's PTT is close to product Y's PTT) in plant T, sixty seconds group for product H and P, and three-hundreds seconds group for product M (Table 2).

4.3 Teamwork Process

Teamwork process in this research is based on Steiner in social psychology. ITD is an interdisciplinary approach by Group Dynamics (GD) and Industrial Engineering (IE), and is an evaluation system which analyzes quantitatively internal structure of a work team's teamwork awareness. The adaptability of resources (man, machine in a team) to given task (job, work into as a team) effects to team productivity, and it is considered as teamwork process which is team members' interaction of TAF (Fig. 1).

4.4 Hypothesis

To keep up PTT, production line is set up and worker assignment is organized, adequately. Work team is grouped together here, their work team's resources are adapted into daily given task, and teamwork process is formed. On the other hand, localization of Japanese-style production management needs many years to make up high productivity same as Japan domestic. So this glocalization needs indispensable many years to go beyond social culture of each country. To confirming it, it introduces MCE as glocalization index. And, following hypothesis will be tested.

Hypothesis Teamwork awareness is influenced by corporate culture even if producing same category product.

5 Result and Consideration

5.1 Social Background of Teamwork Awareness

Shorten PTT leads decreasing workload in a worker, but leads increasing repeat number of work. So it seems shorten PTT leads strengthen TO awareness, because learning effect is early got through decreasing work contents and increasing repetition, and it is brought up simple management, effective instruction and

Table 2 Researched plant

Country	City	Plant	Began operation	Surveyed year	Number of employee	Number of answerer			Collected ratio (%)	Working year All	Age All
						All	Staff	Line	All	Mean/SD	Mean/SD
China	Dalian	D	1993	2007	2,300	2,104	231	1,873	91.5	4.07/4.17	22.96/5.41
	Shanghai (1)	S	2005[a]		2,400	1,550	470	1,080	64.6	3.61/3.48	19.75/5.41
	Shanghai (2)	R	1994		460	423	74	349	92.0	4.07/4.86	26.40/8.24
	Guangzhou	G	2005		470	424	155	269	90.2	1.14/0.80	22.05/4.68
Malaysia	Kuala Lumpur	B	1974	2009	789	419	55	364	53.1	8.08/8.08	29.52/8.42
Thailand	Ayutthaya	T	2001	2010	436	312	81	231	71.6	3.07/1.94	28.49/4.79
Vietnam	Ho Chi Minh	V	2007	2011	451	436	81	355	96.7	1.30/1.01	24.43/4.13

Country	City	Plant	Main religion	Management cumulative effect (MCE) (Year)[b]	Production Tact Time (PTT) (second/unit)[d]	Product	Production line system
China	Dalian	D	Buddhism	14	60	H	U-Line/I-Line
	Shanghai (1)	S		12	60–300	P	U-Line
	Shanghai (2)	R		13	2	Y	Full automatic line
	Guangzhou	G		2	300	M	U-Line/I-Line
Malaysia	Kuala Lumpur	B	Islam	35[c]	4	Y	Semi automatic line
Thailand	Ayutthaya	T	Buddhism	9	4–10	Y & M	U-Line/Semi automatic line
Vietnam	Ho Chi Minh	V	Buddhism	4	60	H	U-Line/I-Line

* Figures in Table 2 are on surveyed year, respectively
a Mergered year from three keiretsu companies into S
b Continuing year from beginning operation to surveyed year
c The first overseas plant from the parent company in Japan
d Average production interval time as whole plant

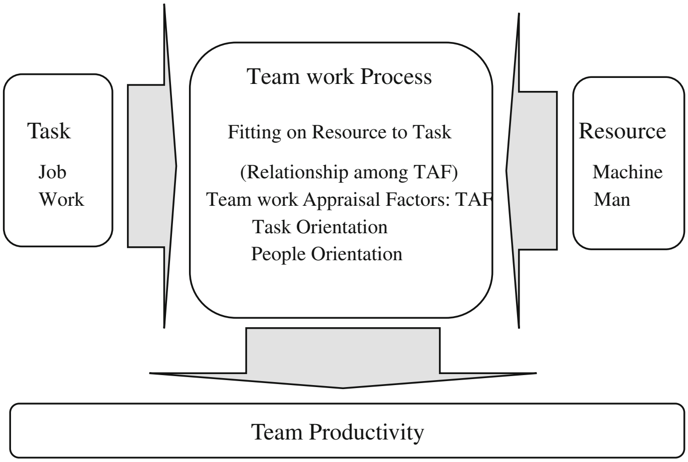


Fig. 1 Industrial teamwork dynamics: ITD

capability improving. More automated work seems TO become downward by less manual work. On the other hand, it seems PO is influenced by MCE. Daily management effort has accumulated knowhow from internal and external management activity, and this effort has made up strong PO. Although employee' continued working year may effect on TA, but local employee of Southeast Asia has shorter working year. Furthermore, it seems increasing number of kinds of product must lead complexity to daily operation and it may effect on TO.

5.1.1 TO Versus PO in China

In China, TO is higher than PO in plant D, R, G except S. In plant S, higher PO bases on reason management policy is "High wages than High efficient", it different from other plant's policy "High efficient than High wages". Therefore, plants of China have tendency stronger TO than PO.

5.1.2 TO Versus PO in Southeast Asia

Plant B in Malaysia, plant T in Thailand and plant V in Vietnam are belonging to the Southeast Asia bloc. Their TA is different from plants in China. PO is strongly recognized than TO (Table 3).

Table 3 Line/comparision between task orientation and people orientation

Country	City	Plant	Number of employee	Mean						SD					
				TAF	T0	P0	T0	Comparision (larger signs •)		TAF	T0	P0	F0	Comparision (larger signs •)	
								T0	P0					T0	P0
China	Dalian	D	1,873	3.99	4.05	3.98	**	•		0.722	0.751	0.689	**	•	
	Shanghai(1)	S	1,080	3.83	3.83	3.84	–		•	0.715	0.761	0.666	**	•	
	Shanghai(2)	R	349	4.29	4.30	4.28	–	•		0.634	0.643	0.625	–	•	
	Guangzhou	G	269	3.91	3.95	3.87	–	•		0.673	0.694	0.650	–	•	
Malaysia	Kuala Lumpur	B	364	3.70	3.63	3.76	*		•	0.818	0.808	0.823	–		•
Thailand	Ayutthaya	T	231	3.35	3.31	3.38	–		•	0.940	0.972	0.907	–	•	
Vietnam	HoChiMinh	V	355	4.55	4.53	4.56	–		•	0.611	0.641	0.581	*	•	

* $p < 0.05$, ** $p < 0.01$

5.1.3 PTT Versus TA in China

Shorten ordering of PTT is set up plant R, D, G and S (G and S are same), and it confirms higher ordering of TAF mean, means of TO and PO are able to also set up plant R, D, G and S as same. Especially, plant R has highest PTT and highest TAF mean. When PTT is shorter, TAF mean has higher. That is remarkable feature in China (Tables 2, 3).

5.1.4 PTT Versus TA in Southeast Asia

Same as Sect. 5.1.3, shorten ordering of PTT is set up plant B in Malaysia, plant T in Thailand and next plant V in Vietnam, but it confirms higher ordering of TAF mean, means of TO and PO are able to set up plant V, plant B and next plant T, not same as PTT ordering. There is no clear relationship between PTT and TAF mean. This reason based on Plant B that has multi-ethnic country workers including terminable temporary worker from Indonesia, China, India, Nepal, Vietnam, Bangladesh and they have different religions, languages and customs (Tables 2, 3).

5.1.5 CME Versus TA in China

Here, MCE is defined as continuing operation years, so it seems if MCE is larger, TAF mean has larger. Operation years of four plants in China are divided into two groups, first group is plant D, S and R which is long group around ten years, and next group is plant G in shorter year. Plant S is unified by one with three plants located in Shanghai area, and after unification has passed only two years. Therefore, plant S remains influence of corporate culture of three plants respectively at the surveying time (Tables 2, 3).

5.1.6 CME Versus TA in Southeast Asia Bloc

Higher ordering of TAF mean is plant V, plant B and next plant T, but longer ordering of MCE is plant B, plant T and next plant V. There is no clear relationship between TAF mean and MCE (Tables 2, 3).

5.2 *Teamwork Awareness Difference Between Plant Produced Same Category Product*

5.2.1 Hypothesis Test

It tests TA differences among plants according to same product category. These comparison are plant D in China and plant V in Vietnam which produce product H, plant R in China and plant B in Malaysia which produce product Y, and plant G in China and plant T in Thailand which produces product M, respectively. Mean and SD of TAF are completely different between plants of China with plants in Vietnam, Malaysia and Thailand. Also TO mean of China is higher than PO, but each plant in Southeast Asia bloc has higher PO mean than TO with significant difference on t0 and F0 (Table 4).

Moreover, it tests differences between line workers by discriminant analysis. All correct ratio are higher more than eighty percentages, and it can be said TA between plants differs greatly even if produce same category product.

The weight of each TAF is reviewed as discriminant coefficients with statistical significance. Plant D and V which are producing same category product H, have statistical significant difference except factor 3 as between China and Vietnam. Plant R and B which are producing the same category product Y, have statistical significant difference except factor 3, 6, and 10 as between China and Malaysia. Furthermore, plant G and T which are producing the same category product M, have statistical significant difference except factor 2, 4, 5 and 10 as between China and Thailand. Also all comparisons are more influenced on PO by religion as social culture in each country. Furthermore, common important factors which discriminant coefficient is more than 1.0 are “7.Cohesiveness”, “9.Human Relations” and “12.Satisfaction” through all analyzing. These three factors belong to PO and it seems strongly influence by MCE (Table 5).

Therefore,

Hypothesis Teamwork awareness is influenced by corporate culture even if producing same category product” is accepted.

5.2.2 Teamwork Unity

Factor loading values (FLV) on first and second principal component on principal component analysis based on mean value, is analyzed and unity as a work team is checked based on convergence of factor loadings values. Furthermore, relationship between these unity and PTT is considered. All FLV on first principal component are positive larger number, and can be understood all as basic teamwork factors. Second principal component can be understood to divide into two clusters, TO and PO. All cumulative contributed ratio (CCR) until second principal component is

Table 4 Line/comparision between countries

	Product	H				Y				M			
	Plant	D(n = 1,873)		V(n = 355)		R(n = 349)		B(n = 364)		G(n = 269)		T(n = 231)	
	Country	China (Dalian)		Vietnam (Ho Chi Minh)		China (Shanghai(2))		Malaysia (kuala Lumper)		China (Guangzhou)		Thailand (Ayutthaya)	
TAF	Statistics	Mean	SD	Mean	SD	Meas	SD	Mean	SD	Mean	SD	Mean	SD
TO	1–6	4.02	0.767	4.51**	0.655**	4.28	0.656	3.65**	0.798**	3.93	0.685	3.28**	0.961**
PO	7–12	3.92	0.695	4.55**	0.598**	4.25	0.631	3.76**	0.824**	3.85	0.635	3.39**	0.895**
All	1–12	3.97	0.734	4.53**	0.628**	4.27	0.644	3.71**	0.813**	3.89	0.662	3.34**	0.930**
PTT (Production tact time) (second/unit)		60		60		2		4		300		4–10	

* $p < 0.05$, ** $p < 0.01$

Table 5 Line/comparision between Country

TAF	Product	H	Y	M
	Plant	D(n = 1,873)	R(n = 349)	G(n = 269)
		V(n = 355)	B(n = 364)	T(n = 231)
	Statistics	DC [a]	DC	DC
		12.476 [b]	−8.156	−6.695
TO	1	0.369**	2,180	1.358**
	2	−0.428**	0.556**	0.045
	3	0.036	−0.194	−0.774**
	4	−0.237**	0.535**	0.164
	5	−1.430**	−0.552**	0.282
	6	−0.592**	−0.194	1.396**
PO	7	−1.049**	−1.327**	−1.356**
	8	−0.282**	1.625**	1.325**
	9	3.895**	1.033**	1.381**
	10	0.612**	0.164	0.128
	11	−2.741**	−0.827**	−0.679**
	12	−1.257**	−1.082**	−1.548**
Correct ratio (%)		83.62	81.77	81.80
Discrimination function		**	**	**

* $p < 0.05$,** $p < 0.01$
a Discriminant coefficient, *b* Constant

over sixty-five percentage, thus two clusters is able to fully explain. Some factors are mixed beyond own belonging cluster, but TAF are divides into two cluster TO and PO, generally.

It shows two-dimensional figure by FLV of first principal component is taken along a horizontal axis, and second principal component is taken along a vertical axis.

Each area set up as multiplied by distance between coordinate points on extreme value as the positivest and the negativest on first and second principal components axis, is defined as a unity sense of teamwork. There is difference in TA between China and Southeast Asia bloc, difference between plant D and V is especially great, plant D area is about four times weaker than plant V in TAF, about three times stronger in TO, and plant V has about around thirty times remarkably stronger than plan D in PO. Therefore, hypothesis is accepted also on this analysis. According to smaller area of TAF in order, it sets up plant T, V, R, B G and D. Plant T, R and B has 10 s or less PTT, they belong to smaller TAF area. Here, it means smaller area has strong sense of unity. According to smaller area on TO, it sets up ordering to plant D, T, R, G, V and B. It is able to confirm plant D, R, G in China has smaller area and sense of unity is stronger. And same as to smaller area on PO, it set up ordering to plant V, B, T, R, G and D. It can be said plant D, R, G in China has larger area, but plant V, B, T belong in the Southeast Asia bloc has stronger sense of unity as cohesive ability.

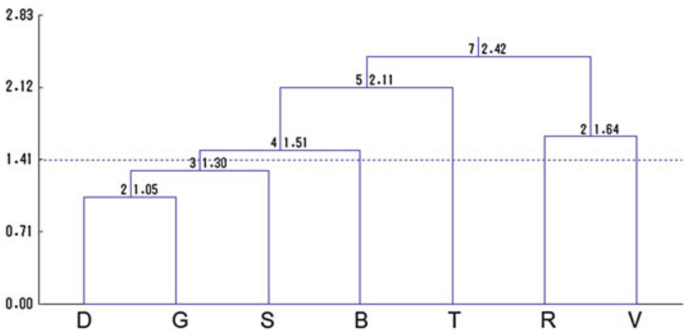


Fig. 2 Line/relationship among plants (r0 = 0.747)

5.2.3 Relationship Among Plants

Interrelationship among each plant is confirms through cluster analysis. Here, group average method (clustering method) and Euclidean distance (valuation scale) are adopted. Plant D, G, and S in China form a cluster as Chinese be made same social cultural sphere, and plant B and T in the Southeast Asia bloc add to this cluster with little later. But a cluster is formed by plant R and V, independently. Plant R is full automatic line and it perfectly different from others, and plant V has small MCE and complex management problems (Fig. 2).

6 Conclusion

This research certifies that Production Tact Time (PTT) and MCE (Management Cumulative Effect) affect into Teamwork Awareness (TA) of line worker's team from point of global. In test of hypothesis, it confirms that PTT shortening affects into Task Orientation (TO) positively.

Acknowledgments This research activity has been supported by OMRON Corporation as overseas social survey during 2007–2011. I appreciate very much for all of the people concerned in Japan and overseas plants, and especially thanks to all local peoples who cooperated directly answering to questionnaire. And graduation research student from 2008 to 2010 of my laboratory is summarizing fundamental investigation of this research. I introduce them and consider it as acknowledgement here.

Global Industrial Teamwork Dynamics in Malaysia—Effects of Social Culture and Corporate Culture to Teamwork Awareness—2/2

Masa-Hiro Nowatari

Abstract Research purpose is to verify how social culture and corporate culture effect into teamwork awareness (TA), respectively. Answerer is native employee on Japanese-owned local electrical plants in multi-racial nation Malaysia. Confirmation on TA difference caused by social culture bases on propagated religion in born country on each employee, and by corporate culture confirms as corporate attributes based on management cumulative effect (MCE). It clears that effect of corporate culture is stronger than social culture, and that corporate culture as social group process has been growing up glocalization (global-localization) while working time. This is second research related to Global Industrial Teamwork Dynamics (GITD) after first Chinese social survey. Propagated religions are Islam has Malaysia, Indonesia, Buddhism has China, Vietnam and Hinduism has India. Here, awareness concerning teamwork in daily production activity is caught as a group process in social psychology, and the internal structure is considered. Finally, the hypothesis is tested through statistical tests and discriminant analysis, principal component analysis.

Keywords Religion · Islam · Buddhism · Hinduism · Race · Malaysian · Chinese · Indian · Indonesian · Management cumulative effect · Teamwork awareness · Teamwork appraisal factors

1 Introduction

Teamwork on making product in the first line worker's team is able to pick up Group Process in Social Psychology, and this global research has been developing since 2000. It takes quarter century since Japanese manufacturing industry started

M.-H. Nowatari (✉)
Department of Management Science, Faculty of Engineering, Tamagawa University, Tamagawa Gakuen 6-1-1, Machida, Tokyo, 194-8610 Japan
e-mail: nowatari@eng.tamagawa.ac.jp; masahiro.nowatari@gmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_181,

overseas development, and this trend will be strongly increasing more and more. On localizing of Japanese-style production management, it needs to unify with local social culture always. So, staying manager from home country must construct and create their plant's original culture by themselves according to glocalization (global-localization) from point of global view, and it must localize their original Japanese-style production system through local propagated religion and social culture. And it should include teamwork management in this process. Heaping up daily management activity makes growing up corporate culture beyond social culture while working hours, and strengthen original glocalized (global-localized) production management. This glocalization is based on management cumulative effect (MCE), and it means continuing year from beginning operation. MCE is able to accumulate management knowhow and wisdom through many trial and error related to daily management problem solving.

2 Research Objective

Research objective is to verify how social culture and corporate culture effect into teamwork awareness (TA) in Malaysia. Consideration on social culture bases on propagated religion in born country on each employee, and corporate culture confirms as corporate attributes, respectively. To certifying it, hypotheses are set and tested. First of all, *t* test (Welch method) and F-test is done as basic statistical test according to all, task orientation (TO) and people orientation (PO) of teamwork appraisal factors (TAF). Next, it considers TAF differences between religions and between plants by correct discriminant ratio on discriminant analysis. It certifies TAF differences between plants are more strongly than between religions. This is fruit of their efforts on daily localizing activity based on Japanese-style production system.

3 Research Plants

3.1 Surveyed Plants

Surveyed plants are in Malaysia on Japanese-owned local electrical plants. Plant A and C have strong MCE based on around forty operating years, and plant B has twenty over years. Mean working year of employee has seven to ten years in each plant, respectively. And mean age is around thirty years old. So, number of staying Japanese manager is very few, and local managers have been managed themselves plant. These plants have clear production management strategy and have acquired various certifications as ISO and so on. This survey was done from 2008 to 2010 and basic analyzing was done by graduation thesis of my senior students.

Their parent company, headquarter is in Japan and is listed company in the Tokyo stock market, and are typical company, having large capital, sales and employee in the world (Table 1).

3.2 Personal Attribute

Each plant has been employed many ethnic races, plant B has many Chinese and Indonesian than Malaysian. And plant C has most ethnic races and two-way employ system, permanent and contract. Working average year of key person has around ten years and average year is thirty years old, respectively (Table 2).

3.3 Propagated Religion

It shows propagated religion and national wealth as gross domestic product for each person, nominal (GDP) on every country. Islam area has been propagated in Malaysia (state religion), Indonesia and Bangladesh, and Hinduism area has India and Nepal. Moreover, Buddhism area has China and Vietnam but propagation rate is unknown. Malaysia has higher GDP, so it is able to employ person from neighbor countries (Table 3).

4 Survey Method

4.1 Teamwork Appraisal Factors

In order to measure TA, teamwork appraisal factor (TAF) is set up. TAF has two categories, "task orientation (workability): TO" and "people orientation (cohesiveability): PO". And TAF consists of twelve factors (sixty questionnaire items) of six factors on TO (thirty questionnaire items), and six factors on PO (thirty questionnaire items). Moreover, every questionnaire item is appraised on five stages evaluation (1, 2, 3, 4, 5), and more positive figure means favorable and strong awareness to teamwork. TO means capability for carrying out the task (job, work) given as a work team, and PO is capability for maintaining team as a work team. Questionnaire method had been carried out with factory tour, interview, collecting data and fact finding (Table 4).

Table 1 Researched plant

Plant	A	B	C
State	Selangor	Penang	Selangor
Surveyed year	2008	2008	2009
Established year	1973	1991	1973
Capital (billion yen)	3	1	0.5
Sales (billion yen)	30	10	3
Product items	Semiconductor, system LSI	Facsimile, MFP device	Electronic relay
Number of employee	1411	574	800
Number of answerer (Line + Staff)	615 (504 + 111)	476 (265 + 211)	419 (364 + 55)
General manager	Japanese	Japanese	Japanese
Department head	Local 100 %	Local 70 %	Local 100 %
Number of japanese staying staff	3	5	4
Production management strategy	First foothold of semiconductor manufacturing in Southeast Asia	100 % export global development	First overseas plant from the parent company in Japan Export main, having worldwide share
Characteristic of production management	a. Full automatic line and labor-intensive handwork in clean-room	a. Cell production system for full synchronized production (UA line, SMT line, U line with cart, U & I line with cart),	a. Continuous production system from making mold, parts making to assembly,
	b. Promotion on manpower rearing of next generation (IT, WTTP), employee participating	b. Added value management strategy,	b. 24 h full operation,
	c. Corporate culture beyond race difference and social culture, Objective achievement by all unison	c. Logistics (VMI, JIT, KANBAN),	c. Full automatic production 65 % and semi automatic production 35 %
	d. Line company, CSR activity,	d. Multi-skill operator	
	e. Japanese speaking ability person is 58 employees.	e. Line by mixed race/ethnic,	
		f. TVMS	

(continued)

Table 1 (continued)

Plant			A	B	C
Certification			ISO 9002, ISO 14001, ISO 9001, OHSAS 18001	ISO 9002, ISO 14001, ISO 9001, OHSAS 18001	ISO 9002, ISO 14001, ISO 9001, TS 16949
Personal attribute	Working year (year)	Mean	9.99	6.76	8.08
		SD	7.964	5.157	8.078
	Age (year)	Mean	31.48	30.44	29.52
		SD	8.774	8.505	8.421
Parent company (headquarter in Japan)[a]	State		Tokyo	Tokyo	Kyoto
	Established year		1875	1950	1933
	Capital (billion yen)[b]		440	40	60
	Sales (billion yen)[b]		6,000	350	620
	Number of employee[b]		210,000	20,000	36,000

[a] Figure is on 2011 financial year, [b] International

Table 2 Personal attribute in plant

Plant (number of answerer)	Nationality (race)	Number of answerer n	Personal attribute		Nationality unknown, n = 68		
			Working year (year)		Age (year)		Pamanent/contract
			Mean	SD	Mean	SD	(Line/staff)
A(n = 562)	Malaysia	393	9.27	7.955	30.29	8.728	Par. (Line/staff)
	China	32	12.43	7.450	35.50	6.564	Par. (Staff)
	India	137	10.33	7.734	32.31	8.255	Par. (Line)
B (n = 476)	Malaysia	90	7.97	4.357	33.66	9.057	Par. (Line/staff)
	China	157	8.06	6.005	33.22	7.894	Par. (Line/staff)
	Indonesia	131	4.05	2.833	23.64	3.040	Par. (Line)
	India	41	10.71	5.217	36.92	9.096	Par. (Line/Staff)
	Nepal	28	2.79	0.357	25.64	4.931	Par. (Line)
	Vietnam	29	2.84	0.375	27.47	5.048	Par. (Line)
C = (404)	Malaysia	249	10.57	8.216	31.97	8.426	Par. (Line/staff)
	China	12	14.70	10.646	35.08	10.379	Par. (Line/staff)
	Indonesia	98	2.16	1.087	22.84	3.396	Con.(Line)
	India	15	14.20	10.051	34.53	7.936	Par. (Line)
	Nepal	3	3.00	1.732	23.00	2.828	Con.(Line)
	Vietnam	4	2.00	0	22.00	2.160	Con.(Line)
	Bangladesh	23	2.13	2.801	26.69	5.498	Con.(Line)

Table 3 Propagation and national wealth

Religion	Islam			
Country	Malaysia	Indonesia	Bangladesh	
Propagation rate (%)[a]	State religion	88.8	89.7	
GDP (US \$)[b]	6,999	2,590	621	
Religion		Buddhism	Hinduism	
Country	China	Vietnam	India	Nepal
Propagation rate (%)[a]	–	–	80.5	80.6
G D P (US \$)[b]	3,678	1,060	1,031	642[c]

[a] The ministry of foreign affairs (http://www.mofa.go.jp/mofaj), 2009 surveyed
[b] GDP/Gross domestic product for each person, nominal JETRO (http://www.jetro.go.jp/world/), 2009 surveyed
[c] The ministry of foreign affairs (http://www.mofago.jp/mofaj), 2010 surveyed

4.2 Hypotheses

At localizing process on Japanese-style production management, it is important understanding local employee's TA that different from Japanese, and certifying TA differences among religion from point of global view. In recent years, Japan

Table 4 Teamwork appraisal factors (TAF)

Productivity orientation	Team work appraisal factors (P = 12, p = 60)	Number of questionnaire items
TO : task orientation (workability) (P = 6, p = 30)	1. Level of work management	5
	2. Training and instruction to subordinates by the leader's superior	5
	3. Training and instruction to subordinates by the leader	5
	4. C are of subordinates by the leader	5
	5. Ability to accomplish work	5
	6. Conformance to job requirement (progress, quality and quantity)	5
PO : people orientation (cohesiveability) (P = 6, p = 30)	7. Cohesiveness	5
	8. Atmosphere of group	5
	9. Human relations	5
	10. Morale	5
	11. Mutual cooperativeness on working	5
	12. Satisfaction	5

parent companies have been deploying positively to make global standard into too diversity of Japanese-style production management in every local plant from point of a bird's-eye view. Global department called "Monozukuri-Innovation Head Office" supports this activity. And it begins proposing new management concept called "glocalization (global-localization)" as utilizing local-management based on global standard. This is second age after first manufacturing only age on localization. So first of all, it confirms TA difference among religions as social culture, and secondly it certifies difference among plants from corporate culture for employee according to same religion. Following hypotheses are set up and tested.

Hypothesis 1 Teamwork awareness is affected by religion as social culture.

After answerers on each plant are reclassified into their religion based on hometown country from Table 2, basic statistical method and discriminant analysis are used and tested.

Hypothesis 2 Teamwork awareness is different among plants even if same race.

After confirming their corporate culture on each plant, it certifies each plant has been particular cumulative wisdom on production management through repeated trial and error on daily management activity since established, and this wisdom is completely different each other even if they have same propagated religion and same race belonging to same mother country. This MCE means corporate culture, it seems stronger MCE brings up more unique TA. If it is true, it will be certified high correct discriminant ratio on discriminant analysis and many statistical significant on basic statistics among plants.

Table 5 Religion/reliability

Religion	Islam	(Number of factor : 12) Buddhism	Hinduism
Number of answerer n	984	234	224
Krombacher's α	0.966	0.964	0.915

Hypothesis 3 Teamwork awareness is stronger affected by corporate culture than social culture.

Here, it confirms how affect magnitude to corporate culture and social culture to TA according to results of Hypothesis 1 and 2. Each plant has been positively deployment by OJT, KAIZEN, 5S, QC Circle in localizing process of Japanese-style production system, and they have been made original corporate culture as unique MCE. It seems there is two cultures that corporate culture as employee activity during working time, and social culture as resident activity outside working time.

5 Result and Consideration

5.1 Social Culture and Teamwork Awareness

It considers religion as social culture how affect to TA according to Islam area including Malaysia, Indonesia and Bangladesh, and Buddhism area including China and Vietnam, and Hinduism including India and Nepal. Those three religions believer are extracted from each plant through Tables 2 and 3. Before hypothesis test, it confirms Krombacher's α reliability coefficient for certifying internal consistency of TAF measure. All Krombacher's α composed TAF have 0.9 over, it is no problem (Table 5).

On testing of Islam criterion, it is able to confirm high statistical significance with Buddhism mean, but there is no significance with variance. On the contrary, there is no significance with mean with Hinduism, but variances of TO and TAF are able to confirm statistical significance. Moreover, on testing of Buddhism criterion, it is able to confirm high statistical significance with Hinduism mean, and variances of TO and TAF are able to confirm statistical significance. In this way, it can confirm statistical significance on mean than variance among religions. TA is different among Islam and Buddhism, moreover Buddhism and Hinduism too, but there is no difference between Islam and Hinduism.

Confirmation on internal consistency of TAF based on principal component analysis, cumulative contributed ratio until second principal component is good as seventy percentages over. "5.Ability to Accomplish Work" and "6.Conformance to Job Requirement" on TO belong with PO in Islam and Buddhism, and

Table 6 Religion/TAF comparison (discriminant analysis)

TAF	Criterion	Islam (n = 984)		Buddhism (n = 234)
	Comparison	Buddhism n = 234 DC[a]	Hinduism n = 224 DC	Hinduism n = 224 DC
	Constant	−1.102	0.956	−2.792
TO	1	0.278**	−0.208**	0.717**
	2			
	3			
	4	−0.451**		−0.573**
	5	0.288**	0.638**	−0.298**
	6		−0.399**	0.445**
PO	7	0.722**	0.505**	
	8	−0.570**	−0.546**	
	9	−0.273**	−0.492**	0.386**
	10	0.268**		0.427**
	11		0.191*	−0.395**
	12			
C D R (%)[b]		64.53	59.77	65.07
Discriminant function		*	*	*
		Average CDR: 63.12 (%)		

* $p < 0.05$, ** $p < 0.01$
[a] Discriminant coefficient, [b] Correct discriminant ratio

Table 7 Plant/reliability

	(Number of factor: 12)			
Plant	A			
Race	Malaysian	Chinese	Indian	
Number of answerer n	393	32	137	
Krombacher's α	0.932	0.974	0.952	
Plant	B			
Race	Malaysian	Chinese	Indonesian	Indian
Number of answerer n	90	157	131	41
Krombacher's α	0.934	0.969	0.968	0.944
Plant	C			
Race	Malaysian	Indonesian		
Number of answerer n	249	98		
Krombacher's α	0.952	0.929		

"12.Satisfaction" belongs into TO and "6.Conformance to Job Requirement" is into PO in Hinduism.

Moreover, TA difference among religions is analyzed by discriminant analysis, and discriminant function is got statistical significance, respectively. But average correct discriminant ratio is lower as around sixty percentage. Common confirmed factors are "1.Level of Work Management" and "5.Ability to Accomplish Work" of TO, and "9.Human Relations" of PO, those factors affects to TA difference among religions (Table 6).

Therefore, (Hypothesis 1) "Teamwork awareness is affected by religion as social culture" is accepted on between Islam and Buddhism, and Buddhism and Hinduism, but between Islam and Hinduism is rejected. So it seems Islam and Hinduism has similarity teamwork awareness, each other.

5.2 Corporate Culture and Teamwork Awareness

Through same procedure as above Sect. 5.1, all answerer are divided into each race in each plant except small answerer race from Table 2. Similarity of questionnaire content of TAF are confirmed, and all Krombacher's α have 0.9 over on race at each plant, it is no problem, too (Table 7).

On basic statistic test, Malaysian belongs to Islam area has statistical significance on differences of Mean and SD at TO, PO and TAF between plant A (criterion) and plant B, and between plant A and C, and between plant B and C, respectively. This tendency is same in between plant B and C on Indonesian. Again, it confirms Chinese belongs to Buddhism and Indian belongs to Hinduism have statistical significance on Mean at TO, PO and TAF between plant A (criterion) and plant B and SD has same tendency except TO. So statistical significance between means is able to confirm through all TO, PO and TAF, TA is completely different among plants even if they are same race.

Therefore, (Hypothesis 2) "Teamwork awareness is different among plants even if same race" is accepted on mean, but on SD is rejected by no statistical significance on TO in Malaysian and Chinese.

On principal component analysis on each plant, cumulative contributed ratio until second principal component has around seventy percentage over, it is good. Plant A has phenomenon "6.Conformance to Job Requirement" on TO is taken into PO. And plant B has "6.Conformance to Job Requirement" on TO is taken into PO and, "12.Satisfaction" belongs into PO is taken into TO. Moreover plant C has "5.Ability to Accomplish Work" and "6.Conformance to Job Requirement" on TO are taken into PO.

And TA difference between plants based on same race confirms according to discriminant analysis. Average correct discriminant ratio is seventy-three percentages though only Chinese has no statistical significance on discriminant function. This ratio has larger than religion value sixty-three percentages. Every plats have unique corporate culture as MCE, and it is large different from others.

Table 8 Plant/TAF comperison (discriminent analysis)

TAF	(Race)		Malaysian		Chinese	Indian	Indonesian
	Criterion	A (n = 393)		B (n = 90)	A (n = 32)	A (n = 137)	B (n = 131)
	Comparison	B	C	C	B	B	C
		n = 90	n = 249	n = 249	n = 157	n = 41	n = 98
		D C[a]	DC	DC	DC	DC	DC
	Constant	−6.129	−3.302	2.324	−2.127	−7.395	7.210
TO	1	1.045**		−0.639**	−0.855**		0.471**
	2	−0.583**	0.813**	0.493**	−0.826**	1.223**	
	3					−0.946**	−1.148**
	4	0.457**	−0.280**	−0.763**	0.659**		−0.640**
	5					−0.752**	−0.411@
	6						1.488**
PO	7			−0.443**			−0.996**
	8						
	9		−0.437**				
	10	0.860**	0.638**	−0.403**	0.869**	0.785**	
	11	-0.439**		0.628**	−0.962**		
	12	0.366@	0.241**			1.091**	−0.454*
CDR (%)[b]		75.36	63.24	70.21	68.78	79.78	83.41
Discriminant Function		**	*	@	–	*	**
						Average CDR: 73.46(%)	

@ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

[a] Discriminant coefficient, [b] Correct discriminant ratio

Corporate culture affects more strong to TA than social culture as religion. Each plant has been particular cumulative wisdom through repeated trial and error on daily management activity since established plant, and this wisdom content is completely different from others even if same propagated religion, same race belonging to same mother country. Common confirmed factors are "1.Level of Work Management", "2.Training and Instruction to Subordinates by The Leader's Superior" and "4.Care of Subordinates by The Leader" of TO, and "10.Morale", "11.Mutual Cooperativeness on Working" and "12.Satisfaction" of PO. Those factors are large difference of TA among plants (Table 8).

5.3 Corporate Culture and Social Culture

As above mentioned, it confirms corporate culture affects more strong to TA than social culture according to statistical significant test on basic statistic and discriminant analysis.

Therefore, (Hypothesis 3) "Teamwork awareness is stronger affected by corporate culture than social culture" is accepted.

6 Conclusion

In multi-racial nation Malaysia, it confirms particular corporate culture as management cumulative effect make affect into teamwork awareness than social culture as propagated religion on each race in their mother country. On (Hypothesis 1) "Teamwork awareness is affected by religion as social culture", and (Hypothesis 2) "Teamwork awareness is different among plants even if same race", it certifies interesting knowledge. Both hypotheses are accepted partially not all, so continued research activity is needed. (Hypothesis 3) "Teamwork awareness is stronger affected by corporate culture than social culture" is accepted and interesting for future management localizing, and it seems Japanese style production management will make firm glocalization (global-localization) system through management cumulative effect based on daily production activity.

Acknowledgments This research activity has been supported by OMRON, TOSHIBA and TOSHIBA TEC corporations as overseas social survey during 2008–2009. I appreciate for all of the people concerned in Japan and overseas Malaysia plants, and especially thank to all local peoples who cooperated directly answering to questionnaire. And I have no words to express my gratitude on kindness supporting of staying Japanese staff, local Malaysian and Chinese staff within very busy during two years, respectively. And graduation research student from 2008 to 2009 of my laboratory is summarizing fundamental investigation of this research. I introduce and give an acknowledgement to them in here.

Relaxed Flexible Bay Structure in the Unequal Area Facility Layout Problem

Sadan Kulturel-Konak

Abstract In this paper, relaxed flexible bay structure (RFBS) is introduced to represent the facility layout problem (FLP) with unequal area departments, which is a very hard problem to be optimally solved. The flexible bay structure (FBS), which is a very common layout in many manufacturing and retail facilities, makes the problem restrictive as departments have to be placed in parallel bays with no empty spaces allowed. The RFBS, however, relaxes the FBS representation by allowing empty spaces in bays, and therefore, it results in more flexibility while assigning departments in bays. In addition, departments are allowed to be located more freely within the bays, and they can have different side lengths as long as they are within the bay boundaries and do not overlap. The effectiveness of the new representation is shown using it in a hybrid probabilistic tabu search-linear programming (PTS-LP) approach. The comparative results show that improvements have been achieved by allowing partially filled bays using the RFBS.

Keywords Facilities planning and design · Unequal area facility layout · Relaxed flexible bay structure · Probabilistic tabu search

1 Introduction

The Facility Layout Problem (FLP) in the continuous plane is generally defined as to partition of a planar area into a number of departments with known area and interdepartmental material flow requirements. The goal is minimizing the total material handling cost which, in general, is a function of the distance and the amount of material flow between departments. The constraints of the problem

S. Kulturel-Konak (✉)
Penn State Berks, Management Information Systems, Tulpehocken Road, 7009 Reading, PA 19610, USA
e-mail: sadan@psu.edu

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_182,

include satisfying the area requirements of the departments, the boundaries of the layout and restrictions on the departments' shapes, such as maximum aspect ratio and minimum side length. The output of the FLP is called block layout, which specifies relative location and shape of each department in the area. Therefore, a block layout should be easily transferable to the actual facility design.

Excellent review papers (Kusiak and Heragu 1987; Meller and Gau 1996; Singh and Sharma 2006; Drira et al. 2007) present an overview of research on block layout design. There are exact algorithms developed for different versions of the FLP in the continuous plane, such as Montreuil (1990), Meller et al. (1998), Sherali et al. (2003), Castillo et al. (2005), and Konak et al. (2006). The exact approaches to the FLP have a major limitation of being restrictive with the size of the problem that can be optimally solved due to computational intractability of the problem. Therefore, the majority of work on the FLP has focused on heuristic approaches promising to find good solutions in relatively short amounts of time. Meta-heuristic approaches such as Simulated Annealing (SA) (Meller and Bozer 1996), Genetic Algorithms (GA) (Banerjee et al. 1997; Gau and Meller 1999) and Tabu Search (TS) (Kulturel-Konak et al. 2007; Kulturel-Konak et al. 2004; Scholz et al. 2009), Ant Colony Optimization (ACO) (Komarudin and Wong 2010; Wong and Komarudin 2010), have been previously applied to the problem.

The FBS, which was first proposed by Tong as a continuous layout representation, is a very common layout in many manufacturing and retail facilities. In the FBS, departments are located only in parallel-bays with varying widths, and bays are bounded by straight lines on both sides. Departments are restricted to be located only in one bay, and they are not allowed to expand over multiple bays. In the original description of the FBS, the total area of the departments in a bay defines the width of the bay because bays are expected to be completely filled by departments, and all departments in a bay have the same width. Therefore, each bay must include a feasible combination of departments with respect to the shape constraints, which could be difficult to satisfy if departments have different size and shape constraints. These restrictions significantly limit the number of feasible layout configurations in the FBS as reported in Konak et al. (2006). As a result, the FBS may not yield block layouts with low material handling costs in highly constrained problems. Another drawback of the FBS arises if the facility area is bigger than the total area of the departments. Any extra space in the facility is handled in various ways in the literature, including using dummy departments, allocating empty space at one side of the facility (Konak et al. 2006), or allowing empty space within the bays and adjusting departments accordingly as in (Wong and Komarudin 2010; Kulturel-Konak and Konak 2011). One of the drawbacks of using dummy departments is the increased computational efforts to solve the problem.

Despite the disadvantages summarized above, the FBS also has some desirable features that make it a practical layout representation scheme. Therefore, the main motivation of this paper is to improve the FBS, particularly in the cases where the facility has an empty space, so that it would be more practical. First, the RFBS, allowing departments to be located more freely within the bays, was proposed by Kulturel-Konak and Konak (2011). Then, Kulturel-Konak (2012) improved the representation also allowing departments in a same bay having different side-lengths as long as they are within the bay boundaries and do not overlap. In this paper, the PTS-LP approach previously developed by Kulturel-Konak (2012) is presented as the solution approach. Then, results from two approaches incorporating slightly different RFBS approaches are compared using a set of test problems from the literature.

2 Methodology

2.1 Solution Representation

In a regular TS, the objective function under consideration should be evaluated for each and every element of the neighborhood of the current solution, which can be very costly from the computational standpoint. Therefore, PTS considers only evaluating a random sample of the neighborhood in creating solution candidates while solving complex problems to reduce computational effort. The PTS-LP uses a permutation encoding where a solution π is represented as an array of 2 N elements such that numbers from 1 to N represent corresponding departments, and zeros represent bay breaks. The solution array encodes the order in which the departments are lined up in the facility and the positions of the bay breaks in this department order. The actual FBS layout is constructed by assigning department s to bays from the top to the bottom based on the order given in the encoding and starting a new bay at each bay break position. For example, the layout given in Fig. 1 is represented as array (4, 0, 5, 3, 0, 1, 2, 0, 0, 0) which is decoded as follows. Department 4 is the first department to be assigned to the facility, and “0” succeeding department 4 indicates a bay break. The last two “0”s in the array indicate empty bays. Because the maximum possible number of bays is equal to the number of departments, the encoding array has 2 N elements (N zeros for bay breaks and N department indexes). To prevent a degenerate encoding, empty bays are always stored at the end of the array.

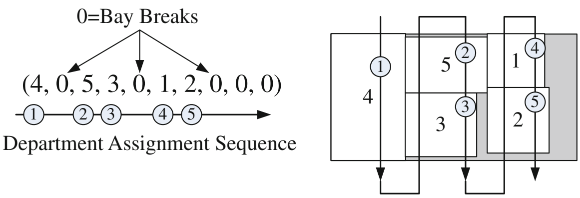


Fig. 1 The encoding scheme of the PTS-LP and RFBS representation

2.2 Local Move Operators

The PTS-LP uses two move operators, namely Insert(i, j) and Swap(i, j), to generate neighborhood solutions from the current solution. Operator Insert(i, j) removes the element in the ith position of the solution array and insert it to the jth position. Operator Insert(i, j) is a versatile move as it is possible to add or remove a bay, or to change the number of departments within bays. Operator Swap(i, j) swaps the elements at the ith and jth positions of the solution array. Swap(i, j) is performed only if both elements at the ith and jth positions are departments. Swap move does not change either the relative locations of the bay breaks in the current layout or the number of the departments in bays.

2.3 PTS-LP Approach

Given a candidate solution π, the actual locations of the departments are determined using an LP formulation, called Problem $RFBSLP(\pi)$ (Kulturel-Konak 2012). Problem $RFBSLP(\pi)$ uses the tangential support approximation for non-linear department area constraints from Sherali et al. (2003). The notation and variables used in Problem $RFBSLP(\pi)$ and the PTS-LP approach are as follows:

N, NB	Number of departments and bays, respectively
$NB(\boldsymbol{\pi})$	Number of bays in π
$b(i)$	Index of the bay where department i is located
$k(i)$	Position of department i (from the bottom) in bay $b(i)$
$\pi(b, k)$	Kth department (from the bottom) located in bay b
N_b	Number of departments in bay b
(x_i, y_i)	Coordinates of the centroid of department i
d_{ij}^x, d_{ij}^y	Distances between the centroids of departments i and j in the x and y axes directions
l_i^x, l_i^y	Side lengths of department i in the x and y axes directions
ub_i^x, ub_i^y	Maximum side lengths of department i in the x and y axes directions
lb_i^x, lb_i^y	Minimum side lengths of department i in the x and y axes directions
X_b	Location of bay break b in the direction of the x axis
h_i	The facility boundary violation of department i in the y axis direction
w_i	The facility boundary violation of department i in the x axis direction
f_{ij}	Amount of material flow between departments i and j
Δ	Number of tangential support points
π^*	The best solution in $N(\pi)$
π^{**}	The best-feasible-solution-so-far
t_{NI}	Number of iterations in which π^{**} has not been updated
P	Department pairs with positive flows, $P = \{(i, j):i < j, f_{ij} > 0\}$
C	Penalty term due to infeasible departments, $C = \sum_{(i,j)\in P} f_{ij}(W + H)$.

Problem $RFBSLP(\pi)$.

$$\min z = \sum_{(i,j) \in P} f_{ij}(d_{ij}^x + d_{ij}^y) + C(\sum_i h_i + \sum_i w_i)$$

Subject

$$\begin{array}{ll}
d_{ij}^x \geq |x_i - x_j| & \forall (i,j) \in P \\
d_{ij}^y \geq |y_i - y_j| & \forall (i,j) \in P \\
lb_i^x \leq l_i^x i^x & \forall i \\
lb_i^y \leq l_i^y i^y & \forall i \\
X_{b(i)-1} \leq x_i - 0.5 l_i^x & \forall i : b(i) > 1 \\
X_{b(i)} i + 0.5 l_i^x & \forall i \\
x_i + 0.5 l_i^x - w_i \leq W & \forall i : b(i) = NB(\boldsymbol{\pi}) \\
y_i + 0.5 l_i^y - h_i \leq H & \forall i : k(i) = N_{b(i)} \\
x_i - 0.5 l_i^x \geq 0 & \forall i : b(i) = 1 \\
y_i - 0.5 l_i^y \geq 0 & \forall i : k(i) = 1 \\
y_j - 0.5 l_j^y \geq y_i + 0.5 l_i^y & \forall i,j : b(i) = b(j) \text{ and } k(j) = k(i) + 1 \\
a_i l_i^x + 4 \bar{x}_{ip}^2 l_i^y \geq 4 a_i \bar{x}_{ip} \quad , p & \\
w_i, h_i, x_i, y_i, l_i^x, l_i^y \geq 0 & \forall i \\
X_b \geq 0 & \forall b \\
d_{ij}^x, d_{ij}^y \geq 0 & \forall (i,j) \in P
\end{array}$$

Problem $RFBSLP(\pi)$ determines the shape and locations of the departments within the bays while it ensures that departments don't overlap and department area constraints are satisfied. Problem $RFBSLP(\pi)$ can also be solved effectively because the FBS provides a tight LP lower bound.

Procedure PTS-LP

Step 1. Set $t = 1$. Randomly generate an initial solution.

Step 2. Apply Insert(i, j) on current solution $\pi\pi$ with probability λ_t for $i = 1,\ldots,$ $N + NB$, $j = 1,\ldots,N + NB$ to create new solutions. Add new solutions to $N(\pi)$.

Step 3. Apply Swap(i, j) on current solution s with probability λ_t for $i = 1,\ldots,$ $N + NB-1$, $j = i+2,\ldots,N + NB-1$ to create new solutions. Add new solutions to $N(\pi)$.

Step 4. Evaluate non-tabu solutions in $N(\pi)$ by solving Problem $FBSLP(\pi)$ of Kulturel-Konak (2012) optimally. Determine the best solution in $N(\pi)$, π^*, and add π^* to the tabu list. Set $\pi = \pi^*$

Step 5. Set $t = t+1$ and $t_{NI} = t_{NI} + 1$. If π^* improves upon π^{**}, set $\pi^{**} = \pi^*$ and $t_{NI} = 0$.
Step 6. Set $\lambda_t = 1 - t_{NI}(1 - \lambda_{min})/100$, and if $t < t_{\max}$ go to Step 2.
Step 7. Increase Δ and evaluate π^{**} one more time.

3 Comparative Results

One of the main motivations of this paper is to remedy drawbacks of the FBS when the facility has empty space as in the case of problems F10, BA12, BA13, BA14, Tam20, Tam30, SC30, and SC35. In Table 1, the previous best-known FBS solutions of these problems are given. In Table 2, the best results found by the PSO-LS (Kulturel-Konak and Konak 2011) and the PTS-LP (Kulturel-Konak 2012) are compared. In this paper, the PTS-LP parameters are: $\lambda_{\min} = 0.1$, $t_{\max} = 2{,}000$, $\Delta = 20$ during search, $\Delta = 50$ for the best-feasible solution). Both approaches using RFBS improved their previous best-known FBS solutions. The PTS-LP was able to further improve the solution quality in each problem and the improvement is up to 5.61 %. However, the PSO-LS is much faster than the PTS-LP in finding the solutions.

Table 1 The best-known FBS solutions of the test problems with empty spaces

Problem	Best-known FBS	Reference
F10	9,020.75	
BA12	8,299.50	Wong and Komarudin (2010)
BA14	4,904.67	
Tam20	9,003.82	
Tam30	19,667.45	
SC30	3,679.85	Wong and Komarudin (2010)
SC35	3962.72	Wong and Komarudin (2010)

Table 2 Comparative results of approaches using RFBS

Problem	PSO-LS (Kulturel-Konak and Konak 2011)	CPU sec PSO-LS	PTS-LP (Kulturel-Konak 2012)	CPU sec PTS-LP	%Improve over PSO-LS
F10	9,020.75	2	8,583.53	689	4.85
BA12	8,129.00	10	8,021.00	1,988	1.33
BA14	4,780.91	19	4,696.37	3,725	1.77
Tam20	8,753.57	104	8,454.38	13,321	3.42
Tam30	19,462.41	924	19,322.98	43,167	0.72
SC30	3,443.34	873	3,362.17	14,120	2.36
SC35	3,700.75	1,842	3,493.18	18,847	5.61

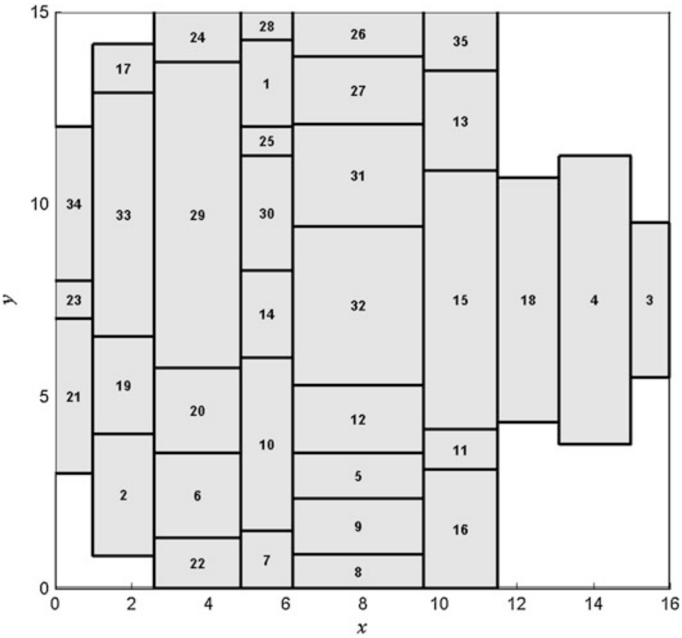
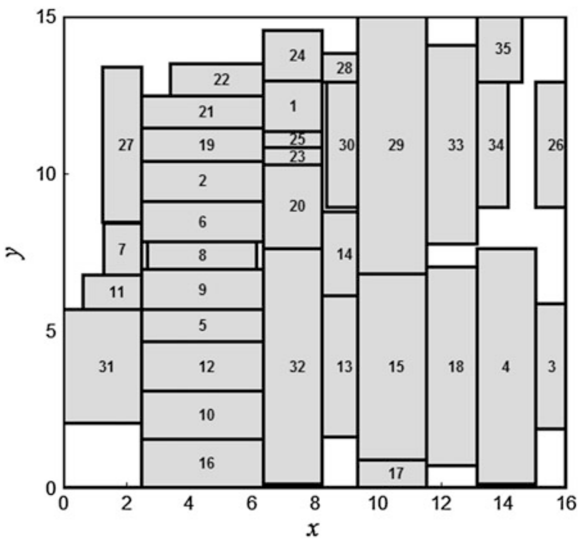


Fig. 2 The best RFBS solutions found for problem SC35 by the PSO-LS

Fig. 3 The best RFBS solutions found for problem SC35 by the PTS-LP



The detailed layouts of the new best-solutions found for SC35 using both approaches are given in Figs. 2 and 3. As seen from best layouts found, the PTS-LP can use the empty space in the facility much more efficiently than the PSO-LS; therefore, it is able to fine tune the layout.

4 Conclusions

This new approach, called RFBS, provides significant reduction in material handling cost since a larger number of department combinations can be considered in bays without violating department shape constraints. However, the results have shown that not only lower costs, but also more practical layouts can be obtained by the new relaxed FBS approach. It should be noted that the RFBS representation is still more restrictive compared to the general representation used in many exact formulations.

References

Banerjee P, Zhou Y, Montreuil B (1997) Genetically assisted optimization of cell layout and material flow path skeleton. IIE Trans 29:277–291

Castillo I, Westerlund T (2005) An e-accurate model for optimal unequal-area block layout design. Comp and Oper Res 32:429–447

Drira A, Pierreval H, Hajri-Gabouj S (2007) Facility layout problems: a survey. Annu Rev Control 31:255–267

Gau KY, Meller RD (1999) An iterative facility layout algorithm. Int J Prod Res 37:3739–3758

Komarudin, Wong KY (2010). Applying ant system for solving unequal area facility layout problems. Eur J Oper Res 202 (3):730–746

Konak A, Kulturel-Konak S, Norman BA, Smith AE (2006) A new mixed integer programming formulation for facility layout design using flexible bays. Oper Res Lett 34:660–672

Kulturel-Konak S (2012) A linear programming embedded probabilistic tabu search for the unequal-area facility layout problem with flexible bays. Eur J Oper Res 223:614–625

Kulturel-Konak S, Konak A (2011) A new relaxed flexible bay structure representation and particle swarm optimization for the unequal area facility layout problem. Eng Optimiz 43(12):1263–1287

Kulturel-Konak S, Norman BA, Coit DW, Smith AE (2004) Exploiting tabu search memory in constrained problems. INFORMS J Comput 16:241–254

Kulturel-Konak S, Smith AE, Norman BA (2007) Bi-objective facility expansion and relayout considering monuments. IIE Trans 39:747–761

Kusiak A, Heragu SS (1987) The facility layout problem. Eur J Oper Res 29:229–251

Meller RD, Bozer YA (1996) A new simulated annealing algorithm for the facility layout problem. Int J Prod Res 34:1675–1692

Meller RD, Gau KY (1996) Facility layout objective functions and robust layouts. Int J Prod Res 34:2727–2742

Meller RD, Narayanan V, Vance PH (1998) Optimal facility layout design. Oper Res Lett 23:117–127

Montreuil B (1990) A modeling framework for integrating layout design and flow network design. In: Proceedings of the 8th international material handling research colloquium, 19–21 June, Hebron, KY. Charlotte, NC, 43–58

Scholz D, Petrick A, Domschke W (2009) STaTS: a slicing tree and tabu search based heuristic for the unequal area facility layout problem. Eur J Oper Res 197:166–178

Sherali HD, Fraticelli BMP, Meller RD (2003) Enhanced model formulations for optimal facility layout. Oper Res 51:629–644

Singh S, Sharma R (2006) A review of different approaches to the facility layout problems. Int J Adv Manuf Technol 30:425–433

Wong KY, Komarudin (2010) Solving facility layout problems using flexible bay structure representation and ant system algorithm. Expert Syst Appl 37:5523–5527

Comparisons of Different Mutation and Recombination Processes of the DEA for SALB-1

Rapeepan Pitakaso, Panupan Parawech and Ganokgarn Jirasirierd

Abstract This paper aims to propose comparisons of mutation and recombination processes of differential evolutionary algorithm (DEA) to solve a simple assembly line balancing problem in which the cycle time is given, in order to minimize a number of workstations (SALBP-1). Firstly, we apply general DEA to solve SALBP-1 which has following steps: (1) generating an initial set of solutions, (2) applying mutation, (3) recombination, and (4) selection process. To extend our general DEA, we present 5 different types of mutations and 3 recombination processes to enhance the search capability of DEA. From the computational results we can conclude that the proposed heuristics can find 100 % optimal solution out of 64 test instances which is better than the algorithm proposed in the literature.

Keywords Simple assembly line balancing · Differential evolution algorithm · Binomial recombination · Exponential recombination

1 Introduction

An assembly line balancing problem (ALBP) is a problem that tries to assign a certain number of tasks to some workstations that lay along the conveyor belt or other logistic tools that perform similar functions. The assignment process is done

R. Pitakaso (✉) · P. Parawech · G. Jirasirierd
Department of Industrial Engineering, Ubonratchathani University, Ubonratchathani, Thailand
e-mail: enrapepi@ubu.ac.th

P. Parawech
e-mail: dekkop@hotmail.com

G. Jirasirierd
e-mail: ganokgarn@hotmail.com

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_183,

when we want to keep some conditions such as predecessor constraints, cycle time constraints etc., in order to provide the best pre-defined objective functions such as a minimal number of workstations, minimal cycle time, maximal assembly line efficiency etc. These objectives can be considered individually or simultaneously (Scholl 1999; Baybars 1986).

Assembly line balancing problems (ALBPs) are normally solved and considered as precedent graphs. The graph consists of some numbers of nodes that correspond to a number of tasks. Each node in the graph represents a specific task, while an edge connecting two nodes represents the precedent relation between the corresponding tasks. Figure 1 illustrates an example of a precedent graph for an 8-tasks ALBP having processing times between 3 and 9 time units. The precedent constraints for example, task 6 must proceed after the completion of task 4, task 1, and task 2.

The simple assembly line balancing problem (SALBP) has been being distinguished into 2 types which are (1) SALBP-1 to minimize the number of stations for a given fixed cycle time, and (2) SALBP-2 to minimize the cycle time for a given number of stations. SALBP-1 is normally used when to set the new assembly line, while the SALBP-2 is used when to change the production process in the existing assembly line. In this paper, we focus only on SALBP-1 because it is one of the most used in textile industry which is now the blossoming industry in Thailand. SALBP-1 has a huge number of exact and heuristic techniques that are available in the literature. Exact algorithms are mostly based on the branch and bound method (Johnson 1988; Hoffmann 1992; Scholl and Klein 1997). Recently, some researchers turn their directions toward meta-heuristics techniques such as genetic algorithm, particle swam optimization and differential evolution algorithm (Kim et al. 1996; Andreas and Nearchou 2005; Andreas 2007). DEA presented in this paper, uses 5 different mutations and 3 recombination processes and compare their performance based on computational time used to find best solution with the solutions presented in the literature. This paper is organized as followed: Sect. 2 presents the proposed heuristic (DEA), Sect. 3 presents the computational results of the test instances, and Sect. 4 is the conclusion of the whole paper.

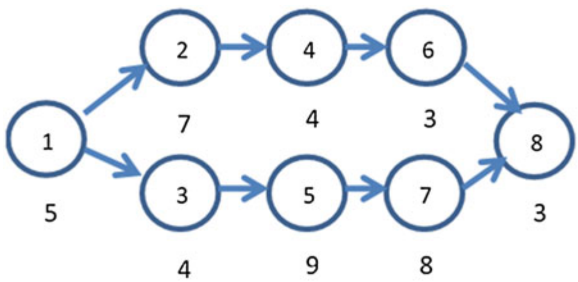


Fig. 1 Example of precedent diagram of ALBPs

2 Proposed Heuristic

In this paper, we present the differential evolution algorithm (DEA) to solve SALBP-1. We will now discuss about the general procedure for DEA which consists of several steps which are (1) construct a set of initial solution, (2) perform the mutation, (3) obtain new generation of solutions by recombination and selection process. The general procedure of DEA is shown in Fig. 2.

Figure 2 represents the general DE algorithm to solve general problems. The notations used in Fig. 2 are as followed: *NP* is predefined number of population. Ω is a vector representing the solution of the problem. Detail of applying DEA to solve SALBP-1 is to explain in the following sections.

2.1 Randomly Generated Vector Ω (Target Vector)

First step of the proposed algorithm is to generate a set of vector Ω, a number of vector Ω that will be randomly generated equals to NP (number of population which is the predefined parameter). Each vector composes of D components while D equals to number of tasks that will be assigned to a certain number of work stations. For example, in Fig. 1, the number of tasks shown is 8 thus each vector Ω will has dimension of 8 as shown in Fig. 3. If we set *NP* to 3 thus three vectors which has dimensions of 8 components will be generated as shown in Fig. 3.

The numbers shown in Fig. 3 represent values of target vector $X_{i,j,G}$, while i is population label. j is a component label which corresponds to vector dimension (D). In this case, vector dimension is 8 or D = 8 and j is running from 1 to 8 which has value of 0.92, 0.08,…,0.44 consecutively. The values of each component in a vector are randomly picked between predefined minimum value and maximum value. In our algorithm, we set minimum value as 0 and maximum value as 1.

Procedure of Differential Evolution algorithm (DEA)

```
Begin randomly generate a set of target vectors •;
        (Number of vectors that are generated equals to NP)
        while termination condition not satisfied do
                for j=1 to NP do
                Perform mutation process using formula (6)-(10)
                Perform crossover process using formula (11),(13)
                Perform selection process using formula (14)
                end for
        end while
End Begin
```

Fig. 2 The general procedure of DE algorithm

popu-lation	1	2	3	4	5	6	7	8
1	0.92	0.08	0.65	0.05	0.99	0.02	0.68	0.44
2	0.75	0.88	0.45	0.52	0.12	0.98	0.54	0.34
3	0.79	0.01	0.56	0.39	0.76	0.82	0.94	0.03

Fig. 3 A chromosome represented SALBP-1

The vector that is shown in Fig. 3, is the vector that is used in DEA, obtaining the result for assembly line balancing, we need to transform the target vector to illustrate the SALBP-1 solution. The transforming procedure shows in Fig. 4.

If the cycle time of a production line in Fig. 1 is set to 12 time units. The first assignment is done by assigning task 1 to workstation 1. Currently, workstation 1 has $U = 0$ or remaining processing time is 12 units (full cycle time). Then, task 1 is assigned to workstation 1. After the first assignment, i is set to 2. Now, we have to find the candidate tasks to enter workstation 1. After task 1 is assigned to station 1, task 2 and task 3 can now enter station 1 thus list $\theta = \{2, 3\}$ and they have component values in list $\theta = \{0.08, 0.65\}$. Then task 2 will be assigned to station 1 because it has the least value of the component in the vector. Currently, station 1 now has $U = 5$ thus the remaining processing time in station 1 equals to $12 - 5 = 7$. Processing time of task 2 equals to 7 thus task 2 can be assigned to station 1. Due to station 1 has no remaining time to put a single task in then work station 2 will be opened and re-done all processes mentioned above until all ask is assigned to a work station then the transforming process is terminated. The result of the transforming procedure is shown in Fig. 5.

```
Start a procedure of vector transforming
Begin with Set K=1 and i=1; U=0;
        While i<= N do
              Find a candidate list that can be assigned to work station K
                  considered precedent graph and name it as list •
              Select the task that correspond to the component in a vector that has
                  the least value of a vector component in •and name it as task •
              Check processing time of •  (P • ) and set U=U+P •
          if U<=cycle time do  Assign • to station K and set i=i+1;
              else do   K=K+1; U=0;
          end-if
        end-while
```

Fig. 4 A general procedure of the vector transforming

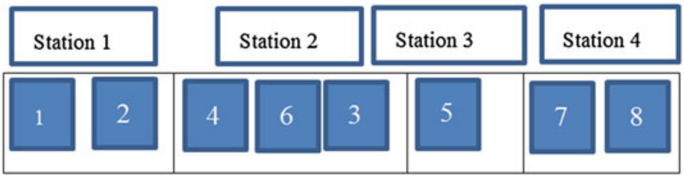


Fig. 5 A result of transforming process

2.2 Perform Mutation Process of Vector Ω

In the mutation process the mutant vector ($V_{i,j,G+1}$) will be generated from the target vector ($X_{i,j,G}$) by process mentioned in Sect. 2.1. Traditionally, the mutation process of DEA is performed using formula (6) in our algorithms we apply 5 mutation formulas drawn from Qin et al. (2009) which shown in formulas (6)–(10).

Denote r1, r2, r3, r4, r5 is the random vector which randomly select from a set of vector Ω. $X_{best,G}$ represents best vector found so far in the algorithm. F is predefined integer parameter, in the proposed heuristics is set equals to 2. i is vector number which run from 1 to NP and j is component number which run from 1 to D.

2.3 Perform Recombination Process on Mutant Vector $V_{i,j,G+1}$

The result of mutation process is a set of mutant vectors $V_{i,j,G+1}$ which will apply the recombination process and get the trial vector ($U_{i,j,G+1}$) as the product of the recombination process. In the traditional DEA the binomial recombination formula (11) is applied additionally. In our algorithm, we use 1 exponential recombination formula (12) which drawn from Qin et al. (2009) and develop 1 more exponential recombination formula (13)

$$U_{i,j,G+1} = \begin{cases} V_{i,j,G+1} & if\ \ rand_{i,j} \leq CR\, or\, j = Irand \\ X_{i,j,G} & if\ \ rand_{i,j} > CR\, or\, j \neq Irand \end{cases} \tag{11}$$

$$U_{i,j,G+1} = \begin{cases} V_{i,j,G+1}\ when\ randb_{i,j} & \\ X_{i,j,G}\ if\ randb_{i,j} & > j \end{cases} \tag{12}$$

$$U_{i,j,G+1} = \begin{cases} V_{i,j,G+1} & when\, j \leq rand\, b_{i,j,1}\, and\, j \geq rand\, b_{i,j,2} \\ X_{i,j,G} & when\, rand\, b_{i,j} < j < rand\, b_{i,j,2} \end{cases} \tag{13}$$

Let $rand_{i,j}$ be a random number run from 0 to 1 and CR is the recombination probability which is the predefined parameter in the proposed heuristics which is set to 0.8. $Irand$ is random integer number. Denote $randb_{i,j}$, $randb_{i,j,1}$ and $randb_{i,j,2}$

as random integer number which used to represent the component position of the mutant vector and they can run from 1 to D. Formula (12) shows that component 1 to component $randb_{i,j}$ in trial vector will equal to mutant vector ($V_{i,j,G+1}$) the remaining components will equal to target vector ($X_{i,j,G}$). Formula (13), the trail vector will equal to mutant vector only the component that has j less than or equals to $randb_{i,j,1}$ and is greater than or equals to $randb_{i,j,2}$. The remaining components will copy value from the target vector.

2.4 Perform Selection Process on the Trial Vector $V_{i,j,G+1}$ and the Target Vector $X_{i,j,G}$

The result of selection process will be the target vector in the next generation which will be used as the starting point of mutation process of the next iteration. The selection process is applied using formula (14)

$$X_{i,j,G+1} = \begin{cases} U_{i,j,G+1} & if\ f\left(U_{i,j,G+1}\right) \le f\left(X_{i,j,G}\right) \\ X_{i,j,G} & otherwise \end{cases} \tag{14}$$

Let $f\left(U_{i,j,G+1}\right)$ and $f\left(X_{i,j,G}\right)$ be the objective function of the trial vector ($U_{i,j,G+1}$) and the target vector ($X_{i,j,G}$). The objective function of the trial and target vector can be transformed using the procedure that is mentioned in Sect. 3.1.

Table 1 Computation result of the proposed heuristics

Instance No–N-CT	Op.	An.	DE														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1-7-6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2-7-7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3-8-20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
4-11-48	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5-11-62	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6-9-6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
7-9-7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8-11-10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
9-21-14	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
10-28-342	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
11-30-25	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
12-30-30	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
13-70-176	21	22	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
14-70-364	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
15-83-8412	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
16-111-5755	27	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
17-111-8847	18	19	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
18-111-10027	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Table 2 Summary of the computational result

	DE															An.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
N-opt	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	61
AvC	0.65	0.54	0.51	0.65	0.55	0.54	0.49	0.45	0.35	0.68	0.54	0.54	0.72	0.71	0.71	2.0

3 Computational Framework and Result

We test our proposed heuristics with 64 test instances drawn from website: http://alb.mansci.de/index.php?content=search&content2=search&content3=classify-add2&content4=classify-add&searchstring=data%20set&sdl=true and compare our algorithm with Andreas and Nearchou (2005). In Table 1 we show computational result only for 18 out of 64 test instances but we will conclude the computational result of all test instances in Table 2. Our proposed algorithms compose of 15 sub-algorithms which are the combinations of 5 different mutation process and 3 recombination processes (DE-1 uses mutation formula (6) and recombination formula (11) while DE-2 uses mutation formula (6) and recombination formula (12) etc.). We test our algorithms on a computer that is run by Intel CPU core i5-2476 M at 1.6 GHz. We run our algorithm 5 times and each time we run 100 iterations. Let we define following abbreviations used in both table as following : ***No*** is a number of test instances, ***N*** is number of tasks a test instances, ***CT*** is the given cycle time of a test instances, ***Op*** is the optimal solution found in the literature, ***An*** is the best result published by Andreas and Nearchou (2005), ***Nopt*** is number of optimal solution found by an algorithm and ***AvC*** is an average computational time used by the algorithm.

From the computational results, the proposed heuristics, DE-1 to DE-15, can find 100 % optimal solution out of 64 test instances which are better than Andreas and Nearchou (2005) which can find optimal solution 61 cases. Andreas and Nearchou (2005) use average computational time 2.00 s while our algorithm use 0.35–0.72 s to execute our algorithm.

4 Conclusion

In this paper, we present the differential evolution algorithm (DEA) to solve SALBP-1. We present 15 DEA algorithms which use different mutations and recombination formulas. From the computational results, we find that our algorithms can find 100 % optimal solution while the best algorithm published so far can find 91.05 % optimal solution. We also use 64–84 % less computational time than that of Andreas and Nearchou (2005). Moreover, we reveal that the best combination of mutation and recombination process judged from the least computational time is using mutation formula (9) and recombination formula (13) which use 84 % computational time less than that of Andreas and Nearchou (2005).

References

Andreas CN (2007) Balancing large assembly lines by a new heuristic based on differential evolution method. Int J Adv Manuf Technol 34:1016–1029

Andreas CN, Nearchou (2005) A differential evolution algorithm for simple assembly line balancing. Paper present in the 16th International federation of autimatic control (IFAC) world congress, Prague, 4–8 July 2005

Baybars I (1986) A survey of exact algorithms for the simple assembly line balancing problem. Manage Sci 32:909–932

Hoffmann TR (1992) EUREKA: a hybrid system for assembly line balancing. Manage Sci 38:39–47

Johnson RV (1988) Optimally balancing large assembly lines with “FABLE”. Manage Sci 34:240–253

Kim YK, Kim Y JU, Kim Y (1996) Genetic algorithms for assembly line balancing with various objectives. Comput Ind Eng 30:397–409

Qin AK, Huang VL, Suganthan PN (2009) Differential evolution algorithm with strategy adaptation for global numerical optimization. IEEE Trans Evol Comput 13:398–417

Scholl A (1999) Balancing and sequencing of assembly lines. Physica-Verlag publication, Germany

Scholl A, Klein R (1997) SALOME: a biderectional branch and bound procedure for assembly line balancing. INFORMS J Comput 9:319–334

An Exploration of GA, DE and PSO in Assignment Problems

Tassin Srivarapongse and Rapeepan Pitakaso

Abstract The optimum solution of assignment problem might not be found by using exact method for a large size assignment problem. The heuristic methods that will take acceptable time should be introduced to solve the problem. The common and well-known methods that are used in this study are genetic algorithm (GA), differential evolution (DE), and Particle Swarm Optimization (PSO). The goal of these three algorithms is the best solutions with appropriate time. We believe one of these three algorithms stands out from the others. We will focus on the best solution and shortest time consuming. In this study, we will classify our study into 3 parts. Firstly, we investigate similarities and differences of each heuristic. Secondly, test our theory by using the same assignment cost matrix. Finally, we compare the results and make conclusions. However, different problem might get different results and conclusions.

Keywords Genetic algorithm · Differential evolution · Particle swarm optimization · Assignment problem

1 Introduction

The assignment problem is the problem that needs to find an exact match between agent and job. One agent comes with his experiences which make him specialization. When an agent with specialization does a job, he will do it with his full

T. Srivarapongse (✉) · R. Pitakaso
Department of Industrial Engineering, Faculty of Engineering, Ubon Ratchathani University, Ubonratchathini, Thailand
e-mail: tassin66@hotmail.com

R. Pitakaso
e-mail: enrapepi@ubu.ac.th

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7_184,

experiences. If we compare this agent with the other agents that do not have a specialization, the agent without a specialization will produce more output compare to an agent with less specialization. We can say this is “Give a right man on a right job”. The cost of giving a right agent to a right job will be low. If we can match all pairs of agent and jobs, the overall cost will be the best solution.

There are two main directions to solve the assignment problem. Firstly, the exact method is a technique that can find the best solution. These are some examples of the exact method: Hungarian method, Branch and bound, simplex method and so on. We also have a computer program such as LINGO is used to find an exact answer. Secondly, heuristic or metaheuristic are alternative method to find an answer that is close to the best answer within acceptable time. Heuristic method is tailored made for a specific problem. Metaheuristic method can solve general problems or can be applied to many problems.

One of the most important different between those two ways is the time that are used in order to find answer. The answer from exact method is the best answer that is time consuming because of it concerns all possible answers. The heuristic or metaheuristic can find the acceptable answer within satisfied time. For small size problem, exact method and heuristic or metaheuristic tend to be no different in time consuming. On the other hand, large size problem must take longer time for exact method but shorter time for heuristic or metaheuristic.

Heuristic is tailored for specific problem. It cannot use to solve general problem. For general problem, we have to switch to metaheuristic. We select some of metaheuristic methods which are more general methods. They can adopt to fit in many problems. Some of them can be suitable to solve in one problem but might not be fit in another problems. The selected problems are GA, DE and particle swarm optimization (PSO). GA and DE use some common techniques such as crossover and mutation which come from an ordinary reproduction of any life on earth. PSO adopt techniques of animal instinct to find their food like a swarm of bees or school of fish.

2 Genetic Algorithm

GA is an algorithm that uses a genetic of life form to create a new generation. GA is a consist of

1. Chromosome encoding
2. Initial population
3. Fitness function
4. Genetic operator (Selection, Crossover, and Mutation)

Chromosome encoding
In this study, we use value encoding for both of agents and jobs. The method that we use in chromosome encoding will cause the efficiency of algorithm. Time consumption will be more or less depends on this encoding (Table 1).

Table 1 Assignment cost table

Agents	Jobs										Total	Rank
	1	2	3	4	5	6	7	8	9	10		
1	89	70	38	94	4	70	18	15	79	6	483	2
2	57	41	4	47	88	83	46	43	18	75	502	3
3	23	53	87	12	45	97	8	65	68	82	540	5
4	33	73	66	63	86	3	4	12	85	80	505	4
5	86	49	33	21	6	50	9	37	30	2	323	1
6	74	11	31	98	76	94	82	43	83	52	644	10
7	67	6	75	62	51	2	97	65	40	89	554	6
8	82	34	5	88	45	27	76	63	49	89	558	7
9	33	19	89	100	82	87	3	82	83	42	620	9
10	26	76	87	94	2	83	24	69	85	54	600	8

The agent that will be the first assignment has the minimum sum of overall cost of each agent. This example, agent 5 is selected to be the first assigned agent. Thus, job that is assigned to agent 5 is job 10 because assignment cost of agent 5 to job 10 has lowest cost. After we assign a job to an agent, we will cut it off. Next, the second agent is agent 1 and he is assigned to job 5. It continues this process until the last agent is selected. However, if the minimum cost of assigning an agent to a job is already selected for that job, we will choose a next minimum cost and assign this job for this agent. For instances, the minimum cost of rank 7 or agent 8 is 5 for job 3 but job 3 is already assigned for agent 2. Therefore, we will assign job 2 for agent 8 instead of job 3. These are chromosome encoding that we use for all algorithms.

Initial population

For the first generation, we will use greedy random as a method to select initial population. The minimum cost of assignment should have more opportunity to be selected. We will convert assignment cost by using one over cost. Thus, the lowest cost will become new value that have more chance to be select.

Fitness function

After we have initial population, we have to define the fitness function that minimizes objective function under some constraints. The important constraints are the one to one assignment problem. Only one agent must be assign to a specific job. At the same time, only one job must be assign to a specific agent. The fitness function is the objective function and constraints are specified here.

The objective function

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} a_{ij} x_{ij}$$

Constraints

$$\sum_{j=1}^{n} x_{ij} = 1$$

$$\sum_{j=1}^{n} x_{ij} = 1$$

$$x_{ij} \in \{0, 1\}$$

Decision variable

$$x_{ij} \begin{cases} 1 & \text{if agent i is assigned to job j} \\ 0 & \text{otherwise} \end{cases}$$

a_{ij} is an assignment cost for assigning agent i to job j

This fitness function can be used again in other algorithms. Therefore, the fitness function in others will refer to this function.

Genetic operators

GA starts from selecting first generation parents from initial solutions. After selection, we will make them breeding and we called this is crossover. The crossover in this study, we use 2 points crossover method. For second generation, we make a decision that the new generation will mutate for how much depends on mutation probability which is 10 %. If we have 100 genes in each chromosome, we will have 10 % mutation or 10 genes. For this research, we will use insertion mutation as a technique for mutation. First, we select gene that we want to insert then select the insertion point. When it is done, we compute fitness function. We will use this new generation to be a parent for the next one. GA process will repeat over and over again until satisfied end condition.

GA Pseudo Code

1. Chromosome encoding

Value encoding

2. Generate initial solutions
3. Compute fitness functions
4. Select parents to be first generation
5. Crossover

Two point crossover

6. Mutation

Insertion mutation
7. Repeat 4, 5, and 6 until meet end requirement

3 Differential Evolution

DE is an evolutionary algorithm. Some parts of DE use the same name as GA which are mutation and selection. For every algorithm, they have to begin with chromosome encoding. This encoding will have an effect to all algorithms thus we will use the same encoding which is value encoding.

The final solutions should not be difference. The process of DE is as follow.

1. Initialization
2. Mutation
3. Recombination
4. Selection

Initialization

Firstly, define number of parameter and populations. Then specify upper and lower bound of each parameter. The samples that are in preferred range will be randomly selected. This process is called initialization and will be used in next step.

Mutation

All of selected sample have to go through all processes which are mutation, recombination and selection over and over again until meet end condition. Mutation will increase in the search area. It tends to move away from local area to another area. It might be close to the global optimization. Mutation vector is a vector that use three vectors combine together. The new mutated vector comes from one vector plus difference between another two vectors. This will move from one place to another place. It might be find a global optimization.

$$v_{i,G+1} = x_{r1,G} + F\left(x_{r2,G} - x_{r3,G}\right)$$

where F is mutation factor which is between 0 and $2 v_{i,G+1}$ is called the donor vector.

Recombination

The recombination is a selection between the donor vector ($v_{i,G+1}$) and the target vector ($x_{i,g}$). The chosen vector is called the trial vector ($u_{i,G+1}$). The donor vector will be the trial vector if the random number is less than CR. CR is the specified probability.

$$u_{j,i,G} = \begin{cases} v_{j,i,G} \; if \; rand_{j,i} \leq CR \, AND j = I_{rand} \\ x_{j,i,G} \; if \; rand_{j,i} > CR j \neq I_{rand} \end{cases}$$

where i = 1, 2, 3, …, n
j = 1, 2, 3, …, d

$$rand_{j,i} \leq CRj = I_{rand}$$

Selection

$$X_{i,G+1} = \begin{cases} u_{i,G} & if\, f(u_{i,G}) \leq f(x_{i,G}) \\ x_{i,G} & otherwise \end{cases} \quad i = 1, 2, \ldots, N$$

DE pseudo code

1. Chromosome encoding

Value encoding
2. Generate initial solution
3. Compute fitness function
4. Mutation
5. Recombination
6. Selection

4 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is an algorithm that applies the perception of social interaction to the problem. PSO adopts social interaction of animals but not just one individual animal such as snake, eagle, and so on. PSO adopts social interaction of animals that depend heavily on their group for instances; swarm of bees, school of fish, or pack of dogs. They live together and also seeking for their food together and stored in their warehouse. One life depends on another one within their group. Hence, this algorithm is called Particle Swarm Optimization (PSO).

Each particle maintains its' path to find best solution. This is called personal best. As mention before, it is not alone thus it also depend on the neighbors. The best solution from the neighbors is called global best. Each particle finds its best solution within its area and tends to move and stick with their groups. Though, they will find the global best solution together.

Pseudo code of PSO

1. Initialize population
2. Evaluate fitness function
3. Find personal best fitness

4. Identify neighbors and find global best fitness
5. Change velocity and positions

Mathematical model for PSO

$$v_i^{k+1} = v_i^k + c_1 rand_1 \left(pBest_i - current_i^k\right) + c_2 rand_2 \left(gBest - current_i^k\right)$$

where v_i^{k+1} = velocity of agent i at iteration k
c_j = weighted factor
$rand_j$ = random number between 0 and 1
$current_i^k$ = current position of agent i at iteration k
$pBest_i$ = personal best of agent i
$gBest$ = global best of the group

5 Results and Conclusions

To prevent unexpected error from chromosome encoding, we will use value encoding for all algorithm in this study. Hence, the results show consequences of each algorithm. To test all algorithms, we generate three different size samples. The small and big samples are 15 × 15 and 100 × 100 respectively. Small size problem runtime is 15, 30 and 60 s. Big size problem runtime is 1:30, 3:00, and 6:00 min. The results that show in these tables are the percentage difference from optimal solutions of each sample size (Tables 2 and 3).

For big size problem, PSO has a better algorithm than GA and DE. It is close to the optimal solution than the others. The result in small size problem is different from bid size problem. DE's results are close to the optimal solution than the others. GA tends to be no different neither big size problem nor small size problem. For the future research, researcher should increase run time for DE on big size problem. Because the results from small size problem are closer to the optimal for both mean and minimum value. Another future topic for researcher is the test

Table 2 Results for big sample size (100 × 100)

Algorithms	Runtime (min)	Mean	Minimum
DE	1:30	26.36	25.15
	3:00	27.88	23.64
	6:00	21.82	19.70
GA	1:30	40.30	30.61
	3:00	25.15	18.48
	6:00	34.55	31.82
PSO	1:30	6.36	0.00
	3:00	1.52	0.91
	6:00	6.36	3.33

Unit percentage of the differences from optimal solution

Table 3 Results for small sample size (15 × 15)

Algorithms	Runtime (s)	Mean	Minimum
DE	15	20.51	19.66
	30	0.00	0.00
	60	0.00	0.00
GA	15	43.59	40.17
	30	44.44	31.62
	60	24.79	0.00
PSO	15	33.33	26.50
	30	19.66	19.66
	60	7.69	0.00

Unit percentage of the differences from optimal solution

of problem on more advance assignment problem such as location-allocation, p-median problem, quadratic assignment problem, generalize assignment problem or the others related problem.

References

Burkard RE (2000) Selected topics on assignment problems. Discrete Appl Math 123(2002):257–302

Das S, Abraham A, Konar A (2008) Particle swarm optimization and differential evolution algorithms: technical analysis, applications and hybridization perspectives. Stud Comput Intell (SCI) 116:1–38

Frieze AM, Yadegar J (1983) On the quadratic assignment problem. Discrete Appl Math 5(1983):89–98

Khan K, Sahai A (2012) A comparison of BA, GA, PSO, BP and LM for training feed forward neural networks in e-learning context. Int J Intell Syst Appl. doi:10.5815/ijisa.2012.07.03

Storn Rainer, Price Kenneth (1997) Differential evolution—a simple and efficient heuristic for global optimization over continuous spaces. J Global Optim 11:341–359

Taillard ED (1995) Comparison of iterative searches for the quadratic assignment problem. Location Sci 3(2):87–105

Author Index

Y.-K. Lin et al. (eds.), *Proceedings of the Institute of Industrial Engineers Asian Conference 2013*, DOI: 10.1007/978-981-4451-98-7,

Z