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Using GA to dispatch the obtaining quantity for minimizing the total cost based on consideration of patient safety in HSCM

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ABSTRACT

The objective of this paper is to study how to minimize the total system cost (*TSC*) when patient safety is considered in the hospital's supply chain management (HSCM). Owing to the HSCM explored in material flow, service level (*S.L*) is used as the index of patient safety level in this paper. HSCM includes three hospitals and a centralized purchasing center (CPC). A genetic algorithm (GA) is applied in the CPC to compute the dispatched quantity for each hospital. The results show that the CPC coordinates the total obtaining quantity for each hospital and assists the hospital's decision makers to estimate the total cost for each hospital. Also, the sensitivity analysis shows that to increase the same *S.L* for each hospital, these three hospitals should have almost the same incremental total cost when one unit quantity is dispatched.

1. Introduction

The supply chain management (SCM) for most industries is complicated because the supply chain network includes suppliers, manufacturers, and customers. The most important connection of SCM from suppliers to customers is the inventories flow. How to coordinate and integrate the mechanisms of the SCM is a key factor to success (Christopher, 2000; Cooke, 1997; Lee & Ng, 1997; Stock, Greis, & Kasarda, 1998). In relation to this, Romano (2003) analyzed three case studies of SCM interventions on the importance of coordination and integration mechanisms in managing the logistics process across different supply networks. Kim and Park (2008) developed a set of e-business application strategies for the efficient coordination and integration of the overall SCM. Xue, Shen Wang, and Yu (2007) considered coordination through Internet-enabled coordination mechanisms to improve the construction performance in SCM. Liang and Huang (2006) developed a multi-agent system to integrate and coordinate different systems in SCM using information technology and effective communication.

Additionally, to understand the dynamic behavior of SCM, a widely used approach to study it has been adopted based on the dynamic systematic simulation methodology. Donsellar, Nieuwenhof, and Visschers (2000) proposed a simulation experiment to explore how unstable planning in a supply chain might become if the wrong demand information was used. Fleisch and Tellkamp (2005) simulated a three-echelon supply chain to examine the relationship between inventory inaccuracy and performance in a retail supply chain. Kao, Huang, and Li (2005) proposed a dynamic simulation network to represent the cause-and-effect relationship in an industrial supply chain. Vlachos, Georgiadis, and Iakovou (2007) tackled the development of efficient capacity planning policies for remanufacturing facilities in a reverse supply chain, which was analyzed through a simulation model based on the principles of the system dynamic methodology. Zhang and Zhang (2007) developed a simulation approach that was applied to understand one practical business problem in order to quantify firms' business operations and performances in a multi-tier supply chain. Longo and Mirabelli (2008) presented an advanced modeling approach and a simulation model for supporting the multiple performance measures of SCM. Ozbayrak, Papadopoulou, and Akgun (2007) built a system dynamic approach to form the operation model of the supply chain network under study, and obtain a true reflection of its behavior to measure the performances of the supply chain system in terms of key metrics such as inventory, backlogged orders, and customer satisfaction.

However, most SCM coordination studies are in the industrial field, and only a few are in the hospital research field. Schut and Bergeijk (1986) researched on price discrimination in the pharmaceutical industry. They indicated that in most developing countries medicine had high medical costs and suggested that purchasing should go through a centralized government agency in order to decrease the general price level of pharmaceuticals. Chaulet (1992) recommended that to decrease medical cost, offer the best prices, and guarantee the quality of the products sold, the supplier should centralize the purchase of medicine. Gilbert (2001) emphasized that the establishment of the e-health system could help hospitals decrease procurement costs. However, buyers and suppliers must work together toward standardization in order to agree on a universal product numbering system. Nyalnder, Suominen, Nenonen,

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Rintanen, and Pelanteri (2002) analyzed a hospital's total cost and showed that improving the affecting factors of HSCM could increase overall efficiency. E-health is an information communication that can be provided for the decision makers by using existing register data on the suppliers, hospitals, and customers (More & McGrath, 2002.

Currently in Taiwan, improving patient safety is an important issue to enhance the high quality care of hospitals. Schmidt (2003) examined the barriers in reporting medication errors and considered that the application of periodic monitoring in medical inventory could improve inventory control to increase patient safety relatively. Dimick, Birkmeyer, & Upchurch (2005) concluded that the strengths and weaknesses of the provider volume are a medical quality indicator and considered that the provider volume should be put into the health policy for patient safety. Menachemi & Brooks (2006) used patient safety-related health information technology to computerize physicians' identification and notification of individual patients about important changes in their drug therapy. Rogers, Jones, & Oleynikov (2007) used radio frequency identification to implement an automatic inventory record to reduce the incidences of human factor and improve patient safety.

Based on the above studies and their significance, the purpose of this paper is to establish a dynamic simulation model of HSCM to obtain the minimization of the total system cost (*TSC*) based on each hospital's patient safety level. The research structure of HSCM is based on the strategic alliance of three hospitals in central Taiwan. The HSCM must appropriately dispatch the obtaining quantity of medicines for each hospital. A genetic algorithm (GA) is applied to compute the dispatched obtaining quantity. The next section of this paper is the statement of the HSCM problem. Section 3 uses GA to solve this problem and analyze the result of the computation. Section 4 presents the summary of the findings and contributions.

2. Statement of the HSCM problem

The HSCM's scheme is grounded on three hospitals in central Taiwan as a strategic alliance for a centralized purchasing center (CPC). Most medicines have patent right limitations and drug maker monopolies, making the prices higher. Through the CPC, each hospital can obtain a discount advantage in total ordering quantity; thus, the CPC will play a role in the competitive advantage of reducing these hospitals' total cost. However, the most difficult problem in a centralized purchasing is the distribution problem (Spekman, Kmamuff, & Myhr, 1998), that is, dispatching the appropriate quantity of the total obtaining quantity to each hospital. The situation on the different quantities dispatched to each hospital can affect patient safety and the total cost of these hospitals. By obtaining more quantities, patient safety will improve because of the decrease in inventory shortage probability. However, the inventory will increase the total cost; thus, patient safety and total cost will show the effect of the trade-off. To solve the effect of the trade-off in the hospital, most decision makers consider the level of patient safety first and then minimize the total cost because most hospitals in Taiwan belong to non-profit organizations.

To solve the problem of a dynamic HSCM, this paper used the simulation method and GA to obtain the optimal dispatched quantity for each hospital. By using the simulation method, the setting of the parameters for a dynamic HSCM will be further understood. This paper assumes that the demand random variable D_{lt}(uncertain demand in each period t for hospital l) is the Normal probability distribution $N(\mu_l, \sigma_l^2)$, in which μ_l is the mean $\left(\frac{\text{units}}{\text{month}}\right)$ and σ_l^2 is the variance $\left(\frac{\text{units}^2}{\text{month}^2}\right)$. Due to each hospital's demand random variable being independent of each other, the CPC collects the total demand from the three hospitals to form the random variable of the total ordering quantity, which aggregate the three hospitals' Normal probability distribution $N\left(\sum_{l=1}^{3}\mu_l, \sqrt{\sum_{l=1}^{3}\sigma_l^2}\right)$. After aggregating the ordering quantity, the CPC will compute the dispatched obtaining quantity to each hospital, and then the information will be transmitted to the pharmaceutical company. The strategy of dispatching the obtaining quantity for each hospital adopted here is a lot-for-lot strategy. The pharmaceutical company then transports the dispatched obtaining quantity to each hospital. In addition, the transportation capacity is limited to the vehicle capacity of the transportation cost.

Based on the HSCM, the model for the established simulation is as follows:

The *TSC* of the HSCM is expressed as Eq. (1) including purchasing cost, inventory cost, ordering cost, and transportation cost.

$$TSC = \sum_{l=1}^{n}\sum_{t=1}^{T} PQ_{lt} + \sum_{l=1}^{n}\sum_{t=1}^{T} I_{lt}P * h_l + \sum_{t=1}^{T} K + \sum_{l=1}^{n}\sum_{t=1}^{T}\left\lceil\frac{Q_{tl}}{N_l}\right\rceil q_l \quad (1)$$

where P is the unit cost, Q_{lt} is the dispatched obtaining quantity for hospital l in period t, I_{lt}, is the inventory level for hospital l in period t, h_l is the rate of unit cost in the holding cost for hospital l, K is the ordering cost of CPC for each ordering, N_l is the transportation capacity for each vehicle for hospital l, $\left\lceil\frac{Q_{lt}}{N_l}\right\rceil$, is computed by ceiling function and q_l is the transportation cost for each vehicle for hospital l.

In addition, *TSC* is considered based on the level of patient safety. The prevention of medicine shortage is an important factor in analyzing the patient safety for HSCM based on the HSCM explored in material flow (Dimick et al., 2005; Menachemi & Brooks, 2006; Rogers et al., 2007; Schmidt, 2003). Service level (*S.L*) is a feasible index to measure the shortage level of medicine. Therefore, in this paper, *S.L* is the index of patient safety level. *S.L* is defined as $\frac{\sum_{t=1}^{T}Q_{lt}}{\sum_{t=1}^{T}D_{lt}}$ for each hospital l. Furthermore, to understand the variation of situation in *TSC*, which is subjected to *S.L*, Eq. (2) is used to show the range of *S.L*.

$$r_l \leqslant S.L \leqslant 1, \text{ for } l = 1, 2, \ldots, n \quad (2)$$

where r_l is the lower bound of *S.L* for hospital l, D_{lt} is the demand for hospital l in period t.

Eq. (3) shows the dispatched obtaining quantity which is subject to the total ordering quantity

$$\sum_{l=1}^{n} Q_{lt} \leqslant Q_t, \text{ for } t = 1, 2, \ldots, T \quad (3)$$

where Q_t is the random variable of the total ordering quantity in period t, Finally, the inventory level and shortage level are defined in Eq. (4)

$$I_{l(t-1)} + Q_{lt} - D_{lt} = I_{lt} - S_{lt}, \text{ for } l = 1, 2, \ldots, n, \ t = 1, 2, \ldots, T \quad (4)$$

where I_{lt} is the inventory level for hospital l in period t, S_{lt} is the shortage level for hospital l in period t.

From the above Eqs. (1)–(4), we can obtain the decision variable as Q_{lt}. The other variables are set in Table 1. GA is used to obtain the solution for the dispatched quantity Q_{lt}.

Table 1
The values of the variables in the GA procedure.

$D_{1t} = N(1000, 210^2)$	$P = 300$	$h_2 = 0.05$	$q_3 = 10$
$D_{2t} = N(600, 70^2)$	$N = 500$	$h_3 = 0.03$	$r_1 = 0.8$
$D_{t3} = N(500, 83^2)$	$K = 1000$	$q_1 = 12$	$r_2 = 0.8$
$Q_t = N(2100, 236.41^2)$	$h_1 = 0.08$	$q_2 = 9.5$	$r_3 = 0.8$