OPTIMIZATION OF MULTI-ECHELON SUPPLY CHAIN KANBAN MODEL USING GENETIC ALGORITHM

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Dedicated to my beloved parents who have been a great source of motivation, inspiration, and endless patience and encouragement when it was most required.

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ABSTRACT

A supply chain system (SCS) consists of organizations or companies that utilizes approaches to have an effective relation between suppliers, manufacturers, warehouses, distribution centers, retailers and finally, the customers. Kanban system is an efficient and easy system to be implemented. In a kanban system each plant sends signals to the following plant for needed parts. The kanban withdraws parts instead of pushing parts from one station to another station. The workstations are located along the production lines and only produce or deliver desired components when they receive a card. The number of kanbans can significantly influence the load balance between processes and the amount of orders suppliers need to obtain from subcontractors. Large kanban size results in large amount of WIP inventory at each workstation. On the other side, although reducing kanban size causes a decrease in WIP inventory it leads to transportation increases as well as reduction in the system throughput rate. In this study a multi-echelon supply chain system controlled by kanban system, is considered. Decision making is based on determination of the number of kanbans as well as economic-quantity order of products. Since the adopted model used in this study is mixed integer non-linear programming (MINLP) type and solving it by exact algorithm such as branch and bound (B&B) takes a lot of time, a heuristic method via Genetic algorithm (GA) is presented. Some problems are solved by our proposed GA to illustrate the performance of the method.

ABSTRAK

Satu sistem rantaian bekalan terdiri daripada organisasi atau syarikat-syarikat yang menggunakan pendekatan untuk mempunyai hubungan yang berkesan antara pembekal, pengilang, gudang, pusat pengedaran, peruncit dan akhir sekali, pelanggan. Sistem kanban adalah sistem yang cekap dan mudah untuk dilaksanakan. Dalam sistem kanban setiap pokok menghantar isyarat kepada organisasi berikut bagi bahagian-bahagian yang diperlukan. Kanban menarik balik bahagian-bahagian dan bukannya menolak bahagian dari satu stesen ke stesen yang lain. Stesen kerja yang terletak di sepanjang lini pengeluaran hanya mengemukakan atau menyerahkan komponen yang diingini apabila mereka menerima kad. Bilangan kanban boleh mempengaruhi beban di antara proses dan jumlah pesanan bekalan yang perlu di dapatkan daripada subkontraktor. Saiz kanban yang besar okan memberi saiz inventori WIP yang besar di setiap stesen kerja. Dari segi lain, walaupun mengurangkan saiz kanban menyebabkan pengurangan dalam inventori WIP, ia membawa kepada peningkatan pengangkutan serta pengurangan dalam kadar pengeluaran sistem. Dalam kajian ini, satu multi rantaian bekalan sistem yang dikawal oleh sistem kanban dipertimbangkan. Keputusan dibuat berdasarkan penentuan bilangan kanban serta ekonomi-kuantiti pesanan produk. Oleh sebab model yang digunakan dalam kajian ini adalah jenis pengaturcaraan bukan linear campuran integer dan menyelesaikan ia dengan algoritma yang tepat seperti *branch and bound* mengambil banyak masa, satu kaedah heuristik melalui algoritma genetik telah dibangunkan. Beberapa masalah telah diselesaikan oleh algoritma ini untuk menguji prestasinya.

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CHAPTER 1

INTRODUCTION

1.1 Overview

To better compete in today's global markets, many companies have been trying to improve system managements, increase product and service quality, and reduce manufacturing and inventory costs. For this reason, many new production strategies were developed such as: just-in-time manufacturing, lean manufacturing, kanban systems, and total quality management to improve the supply chain management goals. In a supply chain system, in order to minimize the total system's costs and also to satisfy the service level requirements, the aim is to produce products in right quantities and distribute them to right location, at right time. A supply chain system (SCS) is a set of approaches that utilizes an effective relation between suppliers, manufacturers, warehouses, distribution centers, retailers and finally, the customers (Chopra and Meindl, 2010). There are three main components in any supply chain system, given as manufacturers, wholesalers and retailers, as it is shown in Figure 1.1 (Wang and Sarker, 2006). However, it doesn't mean to have all of the three components in a SCS, necessarily. Depending on the integration of the independent systems, some SCSs may contain only one component while others may contain more than one. This research has focused on the current proposed optimal method that is called Wang method (Wang and Sarker, 2006). The main goal of this investigation is to enhance the performance of the current method. Since this method has applied only the manufacture component, the same status is also used in this study.

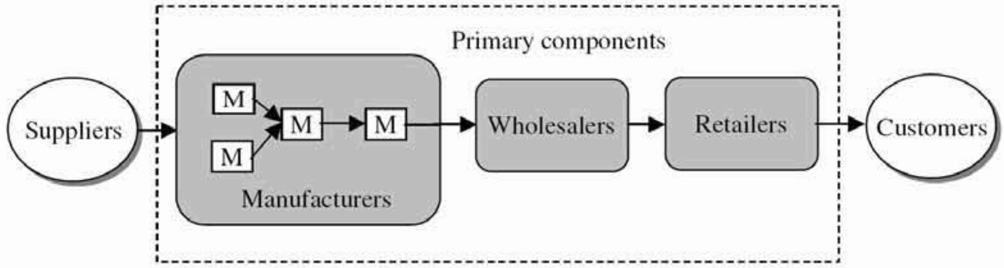

Figure 1.1 Primary Components in a Supply Chain

The procedure in any manufacturing system is like this; at the first plant the raw material from the suppliers is used in order to produce the semi-finished products. Semi-finished products will be sent to the next plants for supplementary processing, until they enter the last plant for final processing to finished products. The manufacturing facilities of a company may be located at the same city, or at different cities or in different states. In this case, there may be considerable material flows between manufacturing facilities which is the consequence of the work-in-process formed by the semi-finished products. The word plants in the study can refer to companies, plants, workshops, workstations, or machines, and Kanban can be a meaning for AVG (Automated Guided vehicle), truck, ship, train, cart, toe, and so on, depending on the situation. Table 1.1 lists the different meanings of kanban in different types of plants.

Proper on time delivery means that the goods should be delivered exactly according to the ordered quantity on the right location. Generally there are two types of SCS:

(a) Single-stage supply chain system (SSSCS);

(b) Multi-stage supply chain system (MSSCS);

Generally the manufacturing system in the supply chain system has at least two plants. If SCS consists of only two plants, it is called SSSCS, but if it consists of more than two plants it is MSSCS. In this study, the focus of the investigation is on

Multi-stage supply chain system (MSSCS). However the model can also be conducted for SSSCS problem.

Table 1.1 Different Meaning of Kanban and Plant

Plant Type	Locations	Transportation	Kanban Transporters
Shop	Intra House	Workstations or work centers	AGV, fork-lifter, toe, trolley
Plant	Inter House	Workstations or work centers	fork-lifter, toe, trolley
Plant or Company	Intra or Inter Cities	Plants or Companies	Truck, Train, Ship
Plant or Company	Inter States	Plants or Companies	Truck, Train, Ship, Air-cargo
Companies	Countries	Companies	Truck, Train, Ship, Air-cargo

In a typical supply chain system, as it is drawn in figure 1.2, the flow of material is downward (from supplier to customer), on the contrary, the flow of information is upward, from customer to supplier.

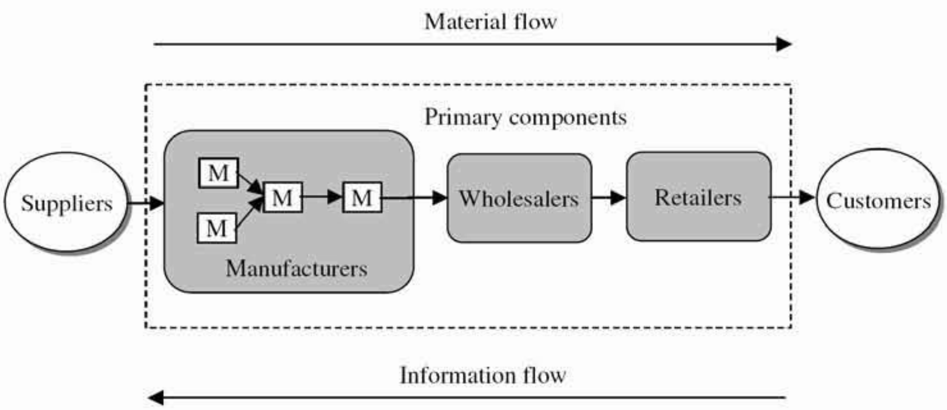

Figure 1.2 A typical supply chain system

Wang and Sarker (2006) have categorized the main operational activities of a supply chain system in order to reflect the basic movement of goods, services, and information in an integrated supply chain system. According to them, these activities are:

(1) Raw materials: sales forecasting, inventory planning, and purchasing, transportation between suppliers and manufacturers,

(2) Work-in-process: processing and managing efficiently the inventories of partially completed products inside the manufacturing plants,

(3) Finished goods: warehousing of finished goods inventory, servicing the customers, and transporting materials among the wholesalers, retailers, and customers.

In this study, the focus is on these three activities, in order to optimize the total cost of the system.

In any supply chain, transportation of materials plays an important role in the system cost. For most firms, transportation is the single highest cost in distribution, usually accounting for 30% to 60 % of distribution cost (Arnold and Chapman, 2001). A supply chain system which is operated with slow transportation is not effective and indicates poor planning, poor communication and insufficient quality levels. In order to remain competitive in the global market, every organization has to focus on increasing productivity, alacrity response to customers, and raising the standards of efficiency. Considering this vital role that transportation plays in the system, managers should be more concerned about that.

Just in Time (JIT) manufacturing was first developed by Taiichi Ohno for Toyota manufacturing plants in order to respond to consumer demands with minimum delays. Major component of JIT philosophy is the kanban information system which is described in detail by Monden (1993). The objective for implementing kanban in a system is to reduce the transportation cost in order to increase the productivity and feasibility of the system.

In a Supply Chain System, the material flow and information flow between two adjacent plants form a kanban stage. The kanban system is an element of just-in-time (JIT) system that has captured the most attention of researchers. Kanban is a Japanese word that means "visible sign" or card (Gupta *et al.*, 1999). Gupta *et al.* described the kanban as an information system which contains some information such as kanban type, component name and number, the station location and the destination station. They mentioned that this kanban system can improve the ability of the system in controlling production and also simplicity in scheduling production, alleviating the force on workers, easily identifying the parts by means of kanbans which attached to the containers and reducing the volume of paper work. Numerous companies have incorporated kanban procedures into their systems and have demonstrated that it is a simple and effective method for implementing JIT philosophy. For testifying the significance of kanban, according to Gupta *et al* (1999), since 1977 a large number of manufacturing companies in the USA have either implemented the JIT system or were seriously considering implementing it.

Kanban systems are normally applied to systems with reliable processes, low set-up times, static demand, and sufficient capacity. It helps companies to maintain production flexibility and responds quickly to minor changes in demand. With these capabilities, kanban systems carry small amounts of safety stock inventories, whilst meeting customer service objectives and requiring simple control systems (Monden, 1993).

In kanban systems, various factors such as the total number of kanbans, transportation sizes (container size), and safety storage sizes have influence on the efficiency of the manufacturing systems (Paris and Pierreval, 2001). For example, the total number of kanbans can control the inventory levels. If too many kanbans are used, it would result in large amount of work-in-process inventory at each workstation. On the contrary, reduction of the number of kanbans will cause lower work-in-process inventory; however it leads to a downfall in the system throughput rate (Savsar and Choueiki, 2000).

In this study, Kanban system is used to control SCS for achieving goals. The supply chain system considered in this study consists of three parts: the suppliers, manufacturers, and retailers. In the supply chain systems, the deliveries of raw material from the suppliers, the work-in-process (WIP) in production stage, and the finished goods to retailers are all controlled by the Kanbans. Determination of the number of Kanbans and batch sizes between two plants to approach the JIT production philosophy are the important factors in this study.

1.2 Problem Statement

Due to the rising cost of manufacturing and transportation costs, enterprises have shown an increasing attention for effective supply chain management. Efficient supply chain management can lead to decrease in production cost, inventory cost and transportation cost. This would results in improvement of customer service throughout at the stages that are all involved in the chain.

As it has been stated earlier there are two kinds of supply chain systems; Single stage supply chain system (SSSCS) and Multi stage supply chain system (MSSCS). SSSCS is the sort which there is just two plants in the supply chain system. In this system the demand is received in the finished goods stage (second stage), since the goods are produced in manufacturing stages, and the raw material is replenished in the raw material stage (supplier). In this system the WIP just happen between these two plants. In MSSCS there are more than two plants in the system and the products manufactured in intermediate stages. The demand receives in the finished goods stage and raw material replenishments happen at the raw material stage. The WIP occurs in each two adjacent plants. The material and information flow between each two adjacent stage compose a Kanban stage.

The series of questions that come to mind in this area are:

(i) How the WIP inventories should be controlled and optimized in order to minimize the cost of the system?

(ii) What is the ordering plan for the suppliers in order to procure raw material?

(iii) What is the delivery policy for the retailers at the finished good stage for dispatching the finished goods?

Supply chain systems controlled by Kanban mechanisms are naturally easier to control. Moreover, it is necessary to consider about submitted models for Kanban mechanism for estimation of Kanban supply chain parameters. This study presents a model in supply chain system with regard to costs under just in time (JIT) philosophy (Wang and Sarker, 2006). Since the model is mixed integer non-linear programming (MINLP) type and solving it by exact algorithm such as branch and bound (B&B) takes a lot of time, and as the larger the size of the problem, the harder to solve the problem optimally. Thus, the following questions must be considered to enhance the model performance and throughput.

(i) How to optimize the Kanban supply chain model to make a successful decision?

(ii) How to optimize the proposed Kanban supply chain system to reduce the calculation time?

1.3 Objective

Controlling the production and reducing work-in-process (WIP) in supply chain system is an effective way in order to minimize the total cost of the system. The Kanban operation system is to be configured based on the optimal results of the model. The general objectives of this study are given as following:

(i) To find the optimal number of Kanbans and the batch size in each stage as well as the total quantity of production over one period in a supply chain system.

(ii) To evaluate and compare the obtained results of the proposed model with Branch and Bound (B&B), in order to understand the performance of current model in solving Kanban models.

1.4 Scope of study

The supply chain system considered in this study consists of three parts: the suppliers, manufacturers, and retailers. (a) The raw material, the input; (b) The manufacturing system, the work-in-process, and; (c) The finished good part, the output. In the supply chain systems, the deliveries of raw material from the suppliers, the work-in-process (WIP) in production stage, and the finished goods to retailers are all controlled by the Kanbans.

The manufacturing system in the supply chain has at least two plants (MSSCS).

In order to optimize the Kanban supply chain model genetic algorithm is developed and Matlab tool is implemented in order to solve the proposed model.

1.5 Significance of study

Since the kanban numbers influence the product inventory level it is very crucial for managers to determine the number of Kanbans used in the system. In addition, the number of Kanbans can extensively influence the load balance between processes and the amount of orders suppliers need to obtain from subcontractors.

The MSSCS controlled by kanbans can be applied to many places. The production companies that deal with the suppliers and retailers and their products' processes are finished in more than two steps; indeed, the WIPs can be shipped in batches. Good examples can be found in the automobile industry, oil industry, grocery supply chain, furniture companies, electronics product companies, or apparel production companies etc. If using the kanban technique, the amount of WIP material, the batch size and the number of batches, and kanban numbers between every two processes in a production cycle are to be determined.

1.6 Study Outline

The background of the problem and some of the concepts described in Chapter 1 provided an introduction to the supply chain system operated under JIT principle by Kanban technique. Chapter 2 presents a literature review on supply chain, JIT philosophy, push and pull systems, and Kanban technique which has been applied to the production. Research framework and the methodology to solve the problem, architecture and solution strategies of the proposed genetic-based algorithm method to solve the problem are presented in Chapter 3. Chapter 4 is about the formulation of the Kanban model in multi stage supply chain systems. Next, in Chapter 5, the optimized kanhan numbers and batch size quantity are obtained by using Matlab tool to solve the problem and evaluate the obtained results. The research summary, conclusions, and recommendations for future research can be found in Chapter 6.

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