CHAPTER I

INTRODUCTION

Logistic management has been considered as a key success factor of a variety of businesses. A good arrangement of supply chain should lead to a decrease in operation cost and an increase in service quality ultimately bringing about the company financial profitability and the customer satisfaction. In order to achieve these goals, organization must concern about inventory control and distribution activities. These two activities are two of main activities in supply chain which directly relate to operating cost in supply chain and service capacity of organization. Hence, these two activities must be closely coordinated to increase the competitive advantage of organization in aspect of total operating cost and service quality.

However, the decisions of inventory control and transportation planning are conventionally made separately for each part of the system: inbound logistics, operations, and outbound logistics. Different departments usually are responsible for inventory and transportation managements. Since higher requirement of customers, all competitors in this industry have to improve their service level, response time and price in order to maintain their position in this business. Consequently, industries are motivated to design and implement more efficient and effective logistics systems so as to reduce system-wide cost and improve system-wide performance. The development of information technology such as internet and information sharing software, and the fast development of other information and communication technologies, together with the high competition in real-world business have changed the way for operating and managing in every stage of the logistics system. Hence there are opportunities to coordinate the inventory control and transportation planning with the emerging technology.

This chapter provides the importance of the coordination of the inventory control and transportation planning. Moreover, the academic aspect of coordination of the two functions is presented. The outline of this chapter is organized as follows: Firstly, the general background is stated to provide the definition of inventory routing problems and its function in real world. Secondly, the statement of problem is addressed. In this section, some main characteristics of problem are described. The next section is the dissertation objectives. The dissertation scope which presents the main assumptions and limitation of the system is provided in section 1.4. The dissertation contributions are given in the fifth section of this chapter. Then, the dissertation methodology and its rational are presented in section 1.6. Finally, the organization of the dissertation is presented in the last section.

1.1 General background

1.1.1 Definition of inventory routing

The type of problem considering the coordination of inventory control and transportation planning, which particularly interests us, is the inventory routing problem (IRP). The inventory routing problem (IRP) is an extension to the vehicle routing problem (VRP). The basic type of VRP has three components: depot, customer, and vehicle. Depot provides customers with certain products or services via vehicles. The objective is to identify frequency and routes for vehicles to visit customers at the least cost or the maximum efficiency. VRP models determine the best routes to serve customers by a fleet of vehicles assuming predetermined inventory policies, such as time and quantity. However, some Supply Chain Management strategies, such as cross docking and vendor managed inventory (VMI), require the supplier to determine inventory policy and vehicle scheduling simultaneously, that is when IRP becomes relevant.

The objective of the IRP is to construct an inventory policy and a transportation strategy, specifying vehicle routes and schedules and the transporting frequency, so as to minimize system-wide inventory and transportation costs. The decisions in IRP are about inventory control and transportation planning, which have two major decisions to be made. The first decision is replenishment quantity of each item for each outlet. The last one is vehicle routing from depots to a set of outlets.

The purpose of these decisions is to serve all customer demands without any lost sale whereas the total of inventory and transportation costs is minimized in the planning horizon. Consequently, managers have to consider the problem under many restrictions and coordination of each decision. For the order quantity decision at the depots, the delivery lead time, the stocking areas, inventory holding cost and setup cost are considered. Like the decision at depot, those factors are concerned in the replenishment quantity decision at the outlets. However, the vehicle routing cost is studied in terms of the setup cost. For the vehicle routing decision, the availability of vehicles, the capacity of vehicles and the condition of traffic are the major restrictions in this kind of problem. These decisions have to be well coordinated to satisfy customer demands and to maintain inventory status in a suitable level and, ultimately, the total costs are able to be reduced by coordinating these decisions.

1.1.2 The inventory routing function in retail business

Logistic management in retailer business is one of the key success factors of the business because it gets involve in distribution cost and customer satisfaction. The efficient logistic management can lead to the low distribution cost which composes mainly of inventory cost and transportation cost. This will make the company in retail business have to manage their inventory control and transportation planning in the system efficiently and effectively in order to maintain customer satisfaction and low logistics cost, which cause the entire cost for operating entire logistic system low.

The logistic system usually includes some of the following stages: suppliers, manufacturers, wholesalers and distribution centers, outlets, and customers. Policies and strategies seeking optimality separately at one stage may not be effective and efficient for the entire supply chain. Thus, integrated logistics systems become increasingly relevant and important in the decision making process.

The logistic function in which is chosen to study in this research comprises of two components: inventory control and transportation management. Both of them play an important role in logistics management and the way to reduce the total inventory routing cost is to coordinate these two functions closely. Coordination between these two areas is difficult, but it can result in significant savings for businesses and eventually for customers. The vast popularity of supply chain management among industries and academia demonstrates that integrated approaches have great economic consequences and are becoming the necessity for logistics management.

In conventional way, dealing with inventory control and transportation planning is to consider each of them separately such as determining the route for delivery first and fixing these routes of delivery and then finding the replenishment plan for all outlets in each route. Another way is to find replenishment policy such as EOQ for each outlet and then set routes to delivery items to the set of outlet. Those approaches do not reflect on both functions simultaneously but separately. This will cause an increase in total inventory transportation cost for entire system, because when we try to decrease one cost, another cost will be increased such as when we try to reduce lot size for delivery we have to deliver more trips to meet demand which causes higher transportation cost and vise versa. The coordination of these two functions which is finding the trade-off between the cost of inventory control and transportation planning is the key to get lower total inventory transportation cost.

1.2 Statement of the Problem

In this dissertation, the Inventory Routing Problem (IRP) with multi-depot and multi-item is studied. The system considered in this problem is the distribution system of retail business which there are many transshipment points for supplying multi-item into outlet network via a certain number of identical vehicle. All outlets have geographically dispersed location. All of them are point of sale where customer's demand for all items is satisfied. Items have different holding cost per unit per period due to their buying price per unit though they are identical in size and dimension.

This dissertation considers the modified version of lot sizing problem in which the setup cost in the problem consists of variable and constant parts rather only the constant part in the original lot sizing problem. The variable part, which is considered in this dissertation, is the routing cost of distribution items to outlets.

The routing cost makes the problem more complicated in that it has to be determined by solving many vehicle routing problems in order to obtain the routing costs and routing schedules for decision process in determining the replenishment quantity in lot sizing model. The complexity of solving the vehicle routing problems (VRP) is well known that the VRP is an NP-Hard problem which is difficult problem to be solved in polynomial time. The consideration about routing in this dissertation makes the problem not only more perplexing but also more general in aspect of delivery mode from only direct shipping with constant cost ,which is the fix setup cost in lot sizing model, into routing mode of delivery.

In conclusion, this dissertation deals with the problem which considers both routing and inventory decisions in the same model. This kind of problem is called the inventory routing problem (IRP). This dissertation addresses the inventory routing problem in a multi depot multi item problem in which holding cost are outlet and item specific, and demand is periodic dynamic demand.

1.3 Dissertation Objectives

The objective of this research is to develop efficient heuristics to solve the problem of an integrated inventory transportation system with multi-depot multi-item multi-outlet multi-period in order to satisfy demands from outside outlets at the minimum total inventory and transportation costs over the considered period.

1.4 Dissertation Scope

This study focuses on Multi-item Multi-depot inventory routing problem (MMDIRP) in finite planning horizon. The objective of the problem is to minimize total inventory transportation cost which includes inventory holding cost, vehicle fixed-charge cost and routing cost. The general scopes of the system which are about details of demand, inventory and transportation are described as follow.

1.4.1 Demand

We assume that demand is dynamic and deterministic. Dynamic demand means that its value changes over time and the value of demand is known in advance, so the deterministic demand is considered in this dissertation. Deterministic demand cases in real world system may occur by made-to-order system or precisely forecasting demand. However, the value of demand may not be constant in each period, but it can be different for diverse period.

Moreover, we assume that the demand for each period is outlet specific and item specific. They are generated using a uniform distribution. Outlet specific demand means demand is not identical for different outlet. This case is realistic as each outlet is located in different locations which have versatile buying powers and demands. For item specific demand means demand for each item is different from other items.

1.4.2 Policy

No stock-out policy is allowed in the system. Due to a competitive environment of retail business, this policy is allowed to maintain good customer satisfaction level. The no stock-out policy will make customers satisfied by serving their demand without the shortage of inventory.

For inventory holding, inventory is kept at the outlets' locations, and managed and paid for by the depot. Depots operate as the transshipment points and do not hold any inventory, so inventory is kept at outlets only.

We assume that all demand will be met during the considered time horizon. This assumption can be realistic by sufficient supply of external suppliers which are not considered in this dissertation.

There will be delivery service starting from a depot to a set of outlet only. Transshipment between depots is not considered in this research, because it may cause additional cost for transshipment and more decisions.

Outlets are geographically dispersed in a service area (a unit square) according to a uniform distribution. Each replenishment quantity of an item in an outlet can belong to one and only one depot for certain period, but can be reassigned to another depot in other periods.

This dissertation does not consider on product shelf life because it can effect the limitation of the system such as a maximum period of holding inventories, therefore we are interested in only the imperishable product. In addition, all items have the same weight and dimension.

For delivery service, all regions considered in the system can be served within a period by a set of homogeneous vehicles without any traffic problem. Each item (but not all items in a single delivery) at outlets is fully served according to the schedules (split delivery is not allowed).

1.4.3 Capacity

There are two types of capacity which are studied in this dissertation. Inventory storage capacity of each outlet is outlet specified and item specified. It is a linear function of inventory level of each item in the outlets. For vehicle capacity, all vehicles have limited and identical capacity. There are a limited certain number of vehicle of each depot and these vehicles are available to serve all outlets during planning horizon.

1.5 Dissertation Contribution

This section addresses the contribution of this dissertation based on two main attractions of this problem: difficulty of the problem aspect and practical application aspect. First, in difficulty of the problem aspect, multi item multi depot inventory routing problem is a category of inventory routing problems where most inventory routing problems are difficult to solve because it is an extension of Vehicle routing problem (VRP) which includes inventory control into consideration. VRP and inventory problem such as Lot-sizing problem are known as NP-hard problem. Hence, the inventory routing problem is at least that difficult, and is well worth studying. Second, in the practical application aspect, most inventory routing problems can find applications in the real world such as clothing franchise network, beverage chain store, optical franchise network, etc. These chain stores have multiple outlets which sell many items.

The difficulty of this problem is not only its hardness as the extension of VRP, but also the limitation considered in this model. The model studied in this research emphasizes on the multi-item multi-depot inventory routing problem (MMIRP) for inventory and transportation planning with limited storage and vehicle carrying capacity systems in order to satisfy demands from customers. The limitation of this model such as vehicle carrying capacity and limited number of vehicle can lead to more intricacy in solving the problem. The major difficulty of this model comes from many depots system. It causes decision maker to make decisions more than for the typical single depot model such as the allocation of outlets to a set of depots. Moreover, the limitation of number of vehicle in this multi depot model affects the complicatedness of model in term of allocation of vehicles to make a delivery at specific depot in each period of time. This limitation will have an effect on the solution if the capacity and number of vehicle is tighten in some level compared to all demand or each period demand. The replenishment quantity will not only be limited on storage capacity and supply capacity of depots, but on number of vehicle and vehicle capacity as well. Even though these complexities make this problem challenging for finding good solution approach, they make this model more similar to real world application which comprises of many limitations for business operation.

The inventory routing problem in the literature review usually studies the single depot problem. While interesting results have been obtained for these cases, there has been less work done on the multi depot model. Thus, the complexity level would significantly increase as it extends to multi depot model, because there are a lot of additional decision variables of assigning the outlet to be served by the depot.

Besides, although the inventory routing problem has been widely studied in the literature, most of the studies related to inventory routing problems are concentrated on problems with single item, see for instance. In this research, the multi item, nevertheless, is considered, that is, there are periodic demand which is outlet and item specific. The multi item case is more general than the single case for the reason that the single item case is just the special type of multi item case which the holding cost of all items are identical.

To simplify the problem, supply capacity of depot is seldom considered in the inventory routing problem. It is usually set as unlimited capacity. This dissertation considers the capacitated case of depot supply capacity. The supply capacity of depot can shape the result of assigning the outlet to be served by depot. In case of unlimited capacity, the outlets can be assigned to their closest depot by distance or the depot which have the minimum routing cost to reach them. With capacity of supply capacity the assignment of outlets are limited and they may not be assigned to their closest depot.

1.6 Dissertation Methodology

This section addresses the dissertation methodology. This dissertation adopts decomposition technique for solving this problem. The main problem which is multi-depot inventory routing is decomposed into two sub problems; lot-sizing problem and vehicle routing problem. Each of sub problems is iteratively solve using updating information of another sub problem from previous solving iteration.

The decomposition approach is used for our problem because its popularity for solving this kind of problem. The idea about decomposing the problem into sub-problem is adapted to many researches such as Bertazzi, et al. (2002, 2005); Campbell, et al. (1998) and Hong (2005). These works applied the decomposition for the inventory routing problem, and many researches also apply this technique for their solution approach.

Since the complexity of this problem, this dissertation provides a set of heuristics to solve it. Firstly, the solving algorithms consider all items in each outlet as an individual outlet. All of these individual outlets are named as item-outlet. For instance, the outlet named "1" has two items named "X" and "Y". These items will be considered as item-outlet name "1X" and "1Y" which stand for item "X" and "Y" in outlet "1". The algorithms will determine replenishment quantity and delivery route for all item-outlet during planning horizon.

After that the algorithms start with solution under lot-for-lot policy. The algorithm iteratively solve lot-sizing problem and vehicle routing problem to determine the suitable replenishment period and quantity and delivery routes for achieving total inventory routing cost. Both of the two sub problems use information from previous iterative for solving their problems. For example, in solving lot-sizing problem heuristic will determine ordering cost of considered set of item-outlet from routing cost of having these item-outlets in each period. Notice that the ordering cot can be different over the time. It depends on number of item-outlet and replenishment quantity of them. For vehicle routing the replenishment quantities which are examined from lot-sizing problem are the input information to determine delivery route. These sub problems are solved until the terminating criteria are met.

1.7 Dissertation Organization

The outline of this thesis is as follows. The relevant literature is reviewed in Chapter II. In Chapter III, the multi-item multi-depot inventory routing problem (MMDIRP) is formulated by combining the lot-sizing problem with capacitated vehicle routing problem. The simplified problem is studied in Chapter IV. The heuristic algorithms for the multi-item multi-depot inventory routing problem are developed in Chapter V, VI and VII. The computational results are provided in those chapters also. The proposed algorithms are the modified version of the shortest path algorithm for lot-sizing problem. Finally, the conclusion and thought of future research are presented in Chapter VII.