CHAPTER II

LITERATURE REVIEW

This section we present the literature review which a review of inventory routing problem (IRP) and its related problem are given. The literatures are presented to show the development of IRP from the early works to recent works.

The inventory problems and transportation problems are considered separately in the past, without paying attention to the integration of the entire system. The early work that considers the integration of inventory and transportation function is the work of Federgruen and Zipkin (1984). The authors study the system consist of an uncapacitated warehouse serves several retailers and a fleet type of vehicles with carrying capacity is used to deliver single product with stochastic under single period for time horizon. Their model determined the frequency of replenishment item under the assumption of continuous review for inventory level and stock out is not allowed.. For routing decision, it is fix route type. The authors selected minimizing cost which holding cost at retailers and distance dependent transportation cost are associated cost as objective function. For the methodology they used Non-Linear Integer Programming to formulate the model and decompose problem into inventory allocation and Many-TSP by Bender's Decomposition and use Modified interchange heuristics for deterministic VRP to solve the problem. With this approach, substantial cost saving can be achieved. The decomposition method presented by Federgruen and Zipkin (1984) provides the basis for the solution algorithm to the model developed by Qu et al (1999) which we will mention further.

The direction of developing this problem was continuing in single product model as in the work of Chien, Balakrishnan and Wong (1989), which develop an integrated inventory allocation and vehicle routing model with the objective function of maximize profit with consideration of holding cost at retailers, unlike other models that have the objective of minimizing total costs. However, the authors do not capture inventory ordering costs. The authors formulate the problem as a mixed integer program and then decomposed into three subproblems: inventory allocation, customer assignment and vehicle utilization. Constructive heuristics and Lagrangian relaxation approach are modified to deal with this problem. The authors also develop UB and LB to evaluate their algorithm.

In the work of Gallego and Simchi-Levi (1990), the authors consider single product with deterministic demand in the system consisting of an uncapacitated warehouse serves several uncapacitated retailers via a fleet type of vehicles with carrying capacity. Decisions are made for different horizon compare with the work of Federgruen and Zipkin (1984). Their work was to develop model for infinite planning horizon. Decision was also made for frequency of replenishment item. The authors used direct shipping policy for transportation. Objective function is to minimize cost which holding cost, non-identical inventory setup cost at retailers and distance dependent transportation cost are associated cost. Inventory level is review continuously. Stock out is not allowed. For the methodology the authors derived analytical proof to evaluate efficiency of their work.

Anily and Federgruen (1990) consider the distribution systems with single item for infinite planning horizon. In addition, the demand rate is constant rate and assumed to be integer multiples of some base rate. The problem is studied for making decision about frequency of replenishment item and a collection of regions covering all retailers, each of which may belong to several regions and each region satisfies a faction of total demand. When a capacitated vehicle visits a retailer in a particular region using static route, it must visit every retailer in that region as well. Objective function of the problem is to minimize cost which setup cost at retailers and distance dependent transportation costs are associated cost. Backlogging is allowed in this model. The authors apply the Modified Circular Regional Partitioning Scheme to partition the set of demand points and propose the Combined Routing and Replenishment Strategies Algorithm to compute lower and upper bounds for total costs.

Anily and Federgruen (1993) extended their previous work into a two-echelon distribution system. The inventory can be held at retailers as well as at a central warehouse while other main assumptions are not changed. Solution approach in this research is developed from their previous work (Anily and Federgruen, 1990).

Anily (1994) also extended the work of Anily and Federgruen (1990) by employing general holding cost rates. One different aspect from the previous work is that the assignment of retailers to routes in the previous work is based merely on their geographical location while this one is based on both the geographical location of retailers and holding cost rates. The author developed the algorithm based on the algorithm of Anily and Federgruen (1990) to solve this problem. An experiment study for both capacitated and uncapacitated systems is presented to demonstrate the algorithm's efficiency.

The multi item cases are less attention than single item so there are a few researches working on it such as the work of Chanda and Fisher (1994). Chanda and Fisher (1994) investigate the value of coordinating production and distribution planning in a multi-period setting. They studied deterministic demand of multi product which is supplied by a warehouse with different production capacity for each product to several retailers where demands occur. A single vehicle with limited capacity is used to serve retailers. Decision is made for T finite periods. Routing decision is dynamic route type. Objective function is to minimize cost which procurement cost inventory which product specific setup cost, holding cost at warehouse and retailers and setup and distance dependent transportation cost are associated cost. Inventory level is review periodically. For the solution approach, they decomposed problem into production lot sizing problem and VRP. For Lot sizing problem, exact algorithm for lot sizing problem is used to solve the sub problem. Some constructive heuristics are selected to solve VRP.

Viswanathan and Mathur (1997) also studied the multi item case. Their work studied an uncapacitated warehouse multi-retailer multi-item distribution system with deterministic demands. The replenishment is made by a single vehicle with limited capacity. This problem was to determine frequency of replenishment item and joint replenishment is used for this problem. The cost structure of their model is similar to the one of our proposed model. In addition to the holding cost, major and minor ordering costs are associated with three components of the transportation cost: fixed dispatching, stopover and variable routing costs. They propose a stationary nested joint replenishment policy (SNJRP) heuristic to solve the problem where replenishment intervals are power of two multiples of a base planning period. Decisions are made for infinite planning horizon. Decision for frequency of replenishment item and joint replenishment is used for this problem. Routing decision is static route type. Objective function is to minimize cost which holding cost at warehouse and retailers and setup and distance dependent transportation cost are associated cost. Inventory level is review continuously. They develop constructive heuristics to solve replenishment interval and assign item to vehicle simultaneously. TSP is solved after assigning. Feedback algorithm is iteratively used to solve in phrase of assign items to vehicle.

After the work of Viswanathan and Mathur (1997) the main consideration is still on the single item model. Chan, Federgruen and Simchi-Levi (1998) studied the system consisting of deterministic demand of single product and a fleet type of vehicles with carrying capacity serve retailer outlets and the frequency constraints are imposed. Decisions are made for infinite planning horizon. They adopted the "Zero inventory ordering" policy which replenishment will occur only when inventory down to zero and "Fixed Partition Policies" for a one origin multi-destination single item network in a deterministic setting. Only holding cost with an identical rate for all retailers is captured in the inventory problem. Computational results are given to show the effectiveness of the proposed strategy. The solution approach was to decompose problem into Region partition solved by bin packing and TSP. Replenishment occurs when zero inventory only. They developed constructive heuristics for region partitioning and TSP. Fixed partition policies are use for clustering retailer in region partitioning phrase.

Chan and Simchi-Levi (1998) extended their prior study by studying a three-level distribution system consisting of a national warehouse ship the item through a number of regional warehouses and the regional warehouse distribute item to retailer outlets. Each regional warehouse acted as transshipment point without holding any inventories. They received fully loaded trucks from the national warehouse and delivered to the retailers and that each retailer is served by exactly on specific warehouse. The problem they considered was very complicated so they simplify the problem by considering a single item with a constant, retailer specific demand rate. Moreover, for the inventory cost, they consider only a holding cost. They developed an efficient algorithm for this integrated inventory control and vehicle routing problem. Their effective strategy could minimize the asymptotic long run average cost.

Bard, et al. (1998) developed a comprehensive decomposition scheme for solving the inventory routing problem in which a central warehouse must replenish inventory of a set of customers on an intermittent basis. The demand is uncertainty and routing decisions taken over the short run might conflict with the long-run goal of minimizing annual operating costs. A unique aspect of the short-run sub problem is the presence of satellite facilities where vehicles can be reloaded and customer deliveries continued until the closing time is reached. For solution approach, three heuristics have been developed to solve the vehicle routing problem with satellite facilities.

Another interesting study on multi item case is the work of Qu, Bookbinder and Iyogun (1999), which develop an integrated inventory and transportation system for joint replenishment with a modified periodic policy in which each replenishment period is an integer multiple of a base period. The system considered in their work is an inbound material-collection problem with a central warehouse sending an uncapacitated vehicle to collect multiple items at geographically dispersed suppliers in multiple periods and a stochastic setting. A heuristic decomposition method is proposed to solve the problem by separating the model into two subproblems namely conventional inventory and vehicle routing models. The inventory subproblem is solved item by item while the transportation one is solved period by period. A lower bound is also constructed to test the effectiveness of the heuristic which performs satisfactorily.

The most of the system studied are in the single warehouse type. For the work dealing with multiple warehouse system, which is just a few works dealing with it, can be found in the work of Chaovalitwongse (2000). The author studied the system with stochastic demand of single product with many capacitated warehouses serve several retailers via a fleet type of vehicles with unlimited carrying capacity. Consider just single period for time horizon. Direct shipping is used in this research. Objective function is to minimize cost which holding cost and setup cost at warehouses also retailers also fixed charge cost and distance dependent transportation cost are associated cost. Inventory level is review continuously. Backlog is allowed with penalty Constructive Heuristics (DSSP) was modified to solve the fix charge problem and Langrange heuristic was used for linear cost problem.

Vendor-Managed Inventory (VMI) system, which a supplier has to manage inventories at retailer outlets by reviewing the retailer's inventory levels and making decisions regarding the quantity and period of replenishment, were studied in the work of Cetinkaya and Lee (2000). The authors studied an uncapacitated warehouse serving several retailers via an uncapacitated vehicle with a stochastic demand of single product. Decisions are made for infinite planning horizon. Inventory policy is (s,S) where s=0. Transportation policy is direct shipping. Objective function is to minimize cost which procurement cost inventory holding and setup cost at warehouse and retailers and setup and distance dependent transportation cost are associated cost. Inventory level is review periodically. They developed analytical model for coordinating inventory and transportation decisions.

Campbell, et al. (2002) studied the inventory problem with the periodic demand and the system was considered in different way of continuous demand system in term of every parameter is consider in per period such as inventory holding cost demand rate also inventory levels were review periodically. A two-phase approach was proposed to solve this problem. They used an integer program to determine which customers to visit in phase I, and then use insertion heuristics to determine delivery routes and quantities in phase II.

Kleywegt, et al. (2002) studied a system which a product is distributed from a plant to a set of customers using a fleet of capacitated vehicles. Customers' demands are the joint probability distribution F that does not change with time. There many constraints are considered such as the travel times and work hours of vehicles and drivers, delivery time windows at the customers, the storage capacities. The inventory routing problem is formulated as a Markov decision process, and the approximation methods are proposed to find solutions.

Ronen (2002) addressed a shipments-planning problem with multiple products. Each production plant with limited storage capacity supplies products via ships to a set of destinations that also have limited storage capacity. The decision of timing, origin, destination, and product quantities of shipments have to be determined. The objective of this model is to minimize costs which compose of penalty on shortest, fixed-charge per shipping and shipping cost per unit of product. A mixed integer-programming model is developed for solution approach. The cost-based heuristic algorithm is developed in order to obtain the acceptable solutions in reasonable time.

Jaillet, et al. (2002) studied the repeated distribution of an item over a long period of time to a number of customers. The problem involves a central warehouse with various satellite facilities which the vehicles can visit during their delivery service to refill the item. The inventory is kept at customer location. The demand is stochastic. In case of a stock out, a penalty cost is incurred. The incremental cost approximations to be used in a rolling horizon framework for the problem of minimizing the total expected annual delivery costs

Bertazzi, et al. (2002, 2005) also applied (s,S) inventory policy for their work. They studied the system comprise of an uncapacitated warehouse serves several retailers via a single vehicle with dynamic and deterministic demand. Decision was made for T finite periods. Main decision in this problem was to determine delivery route in each period and replenishment period for each retailer while the replenishment quantity follow (s,S) policy. Objective function is to minimize cost which holding cost at warehouse and retailer and setup and distance dependent transportation cost are associated cost. For the solution approach, they decomposed the problem into capacitated lot sizing problem and VRP and developed a constructive heuristic and an improvement heuristics for solving this problem.

Hong Deng Chen (2004) consider the IRP problem under deterministic demand and stochastic demand of single product with many capacitated warehouses serve several retailers via a number of vehicles with limited carrying capacity. Objective function is to minimize cost at retailers which inventory holding cost at retailer and setup cost and distance dependent transportation cost are associated cost. Inventory level is review periodically. There is penalty charge for stock out. The Solution approach is to decompose the problem into an inventory sub-problem, a retailer assignment sub problem and a period routing sub problem. Constructive heuristics is used to solve CVRP and feedback transportation cost to EOQ model. EOQ model is used for determining quantity and period to replenish and clustering retailer into regions.

Zhao, et al. (2004) address the problem of deciding the optimal ordering quantity and frequency for a supplier–retailer logistic system in which the transportation cost as well as the multiple uses of the vehicles are considered. The problem was modeled based on the traditional economic order quantity (EOQ) formula. The demand is assumed static during the whole planning horizon and the lead time for delivery of products is considered as a parameter. The deliveries were made by a set of homogeneous vehicles with limited capacity for delivery. The objective of the study is to minimize the whole average costs of the logistic system on the long planning horizon. For the solution approach, a heuristic was developed by the analysis of the problem characteristic.

Campbell and Savelsbergh (2004) considered some flexibility in the routes which may be started earlier or later without affecting feasibility. This can be exploited to increase the amount of product delivered. The objective is to maximizes the total amount of product that is delivered on the route. A linear time algorithm is developed for determining a delivery schedule for a route. The insertion heuristics and local search procedures employed in solution approaches.

Anily and Bramel (2004) considered the Inventory Routing Problem where a number of geographically dispersed retailers are supplied by a central warehouse. The retailers face demand for a single product with a deterministic rate. The holding costs incurs in the retailer stores for keeping inventory. Delivery was made by a fleet of capacitated vehicles. The objective is to minimize the average transportation and inventory costs per unit time over the infinite horizon. The set of fixed partition policies which the retailers are partitioned into disjoint and collectively exhaustive sets are considered. Each set of retailers is served independently of the others and at its optimal replenishment rate. A deterministic (O(n)) lower bound on the cost of the optimal fixed partition policy is derived. A probabilistic analysis of the performance of this bound demonstrates that it is asymptotically 98.5%-effective.

Adelman (2004) developed an approach for stochastic inventory routing problem that approximates the future costs of current actions using optimal dual prices of a linear program. The two linear programs are considered by formulating the control problem as a Markov decision process and then replacing the optimal value function with the sum of single-customer inventory value functions. The resulting approximation yields lower bounds on optimal infinite-horizon discounted costs. An efficient algorithm was developed to both generate and eliminate itineraries during solution of the linear programs and control policy.

Meta heuristics were applied for the IRP in the work of Tamer F. Abdelmaguid and Maged Dessouky (2005). He studied the system comprise of Dynamic deterministic demand of single product with an uncapacitated warehouse serves several retailers via a fleet type of vehicles with carrying capacity. Decision is made for T finite periods. Routing decision is dynamic route type. Objective function is to minimize cost which holding cost at warehouse and retailer and setup and distance dependent Transportation cost are associated cost. Inventory level is review periodically. Decompose problem into capacitated lot sizing problem and VRP. Constructive heuristics developed by Abdelmaguid (2004) and improvement heuristics are sequentially used to solve this problem.

Sindhuchao, et al. (2005) studied stochastic demand of multi product with an uncapacitated warehouse serves several retailers via a fleet type of vehicles with carrying capacity. Decisions are made for infinite planning horizon. Decision for frequency of replenishment item and joint replenishment is adopted in this research. Routing decision is static route type. Objective function is to minimize cost which inventory holding and setup cost at warehouse and retailers and setup and distance dependent transportation cost are associated cost. Inventory level is review continuously. For the solution approach he decompose problem into lot sizing problem and VRP, then exact algorithm, Branch-and-Price algorithm, is used to solve this problem in small problem. Constructive heuristics and improvement heuristics are sequentially used to solve this problem for efficiency.

Rusdiansyah and Tsao (2005) studied deterministic demand of a product with an uncapacitated warehouse serves several retailers via a fleet type of vehicles with carrying capacity. The time windows constraints are considered in the model. Decisions are made for infinite planning horizon. Decision for frequency of replenishment item and replenishment quantity is adopted in this research. Routing decision is dynamic route type. Objective function is to minimize cost which inventory holding and distance dependent transportation cost are associated cost. Inventory level is review continuously. A two-phase method is developed for the solution approach. The initial solution is obtained in the first phase and the solution is improved in the second phase with interchange improvement heuristics.

Al-Khayyal and Hwang (2005) considered maritime routing of a heterogeneous fleet of ships and barges. All ships are able to carry different products simultaneously. The fleet is used to distribute multiple products amongst geographically dispersed ports. Each port is either a producer or a consumer for a certain product, and the average production and consumption rate for each product is known. The problem is to determine replenishment or delivery amount for each product in each ship, the replenishment or delivery period and to schedule the arrivals and departures of the ships. The inventory constraint is to maintain the inventory levels between operating bounds during the planning horizon where the inventory and transportation are coordinated in this problem. The objective of this problem is to minimize the total daily cost of the ships including distance dependent costs and fixed-charges over a finite planning horizon. A Mix-Integer programming is introduced for solving problem.

Aghezzaf, et al. (2006) proposed an alternative model formulation of the inventory routing problem in continuous review setting. A multi-tour concept for routing decision was adopted in this paper. The consideration of multi-frequency and multi-tours instead of tours can lead to considerable cost reduction. Unfortunately, it requires more computational effort when using it, because the problem of routing the different tours in a multi-frequency multi-tour needs to be solved. For the solution approach, the EOQ strategy with the column generation was used to solve the proposed problem.

The pickup and delivery service for transportation operation is found in the work of Savelsbergh, et al. (2007), which considers the IRP problem under several day trip for delivery service deterministic demand of single product with production capacitated warehouses serves retailers with storage capacity via a fleet type of vehicles with carrying capacity. This problem is an extension of TSP-PD. Decision is made for T finite periods. Objective function is to minimize cost which setup and distance dependent transportation cost are associated cost. Stock out is not allowed. The problem is decomposed into delivery volume problem and TSP-PD. Constructive heuristics is developed to solve TSP-PD and improve the solution by GRASP Heuristics.

Recently Bard and Nananukul (2009) studied an inventory routing problem with a production plant supplying an item to a set of retailer. The inventory level is periodically reviewed. Decision for production lot size, replenishment quantity and delivery route is adopted in this research. Routing decision is dynamic route type. Objective function is to maximize the benefit of making replenishment to a set of retailer during a finite time horizon. A series of heuristic are developed for solving the problem. The heuristics are incorporated in the Brach-and-Price algorithm to solve the problem.