INVENTORY CONTROL PROBLEM OF A SINGLE WAREHOUSE AND A MULTI-RETAILER DISTRBUTION SYSTEM (A CASE OF CHOCHO INDUSTRY)

By

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CERTIFICATION

I hereby declare that this submission is my own work towards the Master of Science in Industrial Mathematics degree and that, to the best of my knowledge it contains no material previously published by any other person or the material therein has ever been accepted for award of degree of this or any other university, except where due acknowledgement has been made in the text.

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DEDICATION

DEDICATED TO

My beloved wife Mrs Ivy Vandyck, my children, George and Emmanuella for their constant love, support and encouragement during the writing of this thesis.

ACKNOWLEDGEMENT

My profound gratitude goes to the almighty God for the divine inspiration that I received to produce and successfully complete this research work. Thank you Lord.

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ABSTRACT

In many distribution systems important cost reductions and/or service improvements may be achieved by adopting efficient inventory replenishment strategies for all items and facilities concerned. Such strategies often need to exploit economies of scale that arise e.g. when shipping full (or close to full) rail loads or truck loads of goods. The latter can often only be achieved by combining deliveries to distinct locations into efficient routes. These efficiency improvements and service enhancements clearly require an integrated approach towards various logistical planning functions; in particular the areas of inventory control and transportation planning need to be closely coordinated; for example, shipping in smaller quantities and with higher frequency generally leads to reductions in inventory investments but requires additional transportation costs. In this thesis we considered distribution systems with a single depot and many geographically dispersed retailers each of which faces a specific demand process for a given item. All stock enters the system through the depot from where it is distributed to (some of) the retailers by a fleet of trucks, combining deliveries into efficient routes. Our objective is to determine long-term integrated replenishment strategies (i.e., inventory rules and routing patterns) enabling all retailers to meet their demands while minimizing long-run average system-wide transportation and inventory costs.

We applied Route First Cluster Second approach to determine feasible replenishment strategies (i.e., inventory rules and routing patterns) minimizing (infinite horizon) long-run average transportation and inventory costs. A numerical study exhibits the performance of these heuristics and reduced the distribution cost of the company drastically

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LIST OF ABBREVIATION

The terms below are used frequently in this thesis and for the purpose of this study the following shall apply;

EOQ	Economic Order Quantity
IBM	International Business Machine
FLAGPOL	Flat Glass Products Optimization Model
FGP	Flat Glass Products
JIT	Just In Time
SNJRP	Stationary Nested Jointed Replenishment Policy
SIRP	Strategic Inventory Routing Problem
TIRP	Tactical Inventory Routing Problem
VRP	Vehicle Routing Problem
IRP	Inventory Routing Problem
EDI	Electronic Data Interchange
ABC	Always Better Control
WIP	Work In Progress
PVRPSDP	Period Vehicle Routing Problem with Simultaneous Delivery and pickup
PVRP	Period Vehicle Routing Problem

CHAPTER 1

INTRODUCTION

1.0 OVERVIEW

A distribution system consists of a depot and many retailers. Dispersed retailers have demands that must be supplied by a depot. Retailers' demands result from customers' demands whereas demands occurring at a depot depend on retailers' demands.

The depot has to respond to retailers' demands. Thus, this distribution system involves the replenishment of inventories for geographically dispersed retailers or customers. In a distribution system with one warehouse and many dispersed retailers, the vehicles based at the warehouse are required to travel to retailers. The objective is to distribute commodities to satisfy customers' demands. Each retailer possesses a specific demand that must be satisfied. The warehouse has to decide how and when to replenish the commodities. For example, for a distribution centre with many retailers at different location, the distribution centre has to assign vehicles to visit and supply its retailers according to recurring demands. A vehicle, which is loaded with many items, travels to a given area and replenishes the inventory at each retailer until all retailers are visited or the vehicle is empty. The vehicle then returns to the warehouse and reloads.

Since retailers have different demands and vehicles have limited capacities, a shortage or excess inventory may occur. The different demand rates will give varying replenishment periods and quantities. Retailers with higher consumption rates need a higher frequency of inventory replenishment or lager order sizes. Therefore, when a vehicle visits a group of retailers, some retailers' demands may not be met because of inappropriate replenishment policies including periods and quantities. Some retailer's inventories may not be satisfied by the existing vehicle capacity and a shortage of product will occur. Some retailers may not receive products at the right time. If the vehicle arrives before the replenishment periods, the retailers have to hold more products and incur holding cost.

The one warehouse and multi-retailer distribution system involves transportation cost as well. Since vehicle capacity is limited, all retailers' demands may not be fulfilled with one trip of a vehicle. The travelling distance of vehicles and the number of trips obviously affect transportation cost. The transportation cost will be minimized if the vehicle capacity is utilized and a vehicle is assigned to visit a group of retailers that are close together. However, for a given replenishment period, a retailer may be located far away from other retailers. Naturally, the retailer that is located far away from the warehouse and has low demand may not be replenished very often. Therefore, the depot has to decide the appropriate routes to minimize the travelling distance so that vehicle capacity is utilized while inventory requirements are satisfied.

1.1 BACKGROUND OF STUDY

Inventories are essential for keeping the production wheels moving, keep the market going and the distribution system intact. They serve as lubrication and spring for the production and distribution systems of organizations. Inventories make possible the smooth and efficient operation of manufacturing organizations by decoupling individual segments of the total operation. Purchased parts inventory permits activities of the purchasing and supply department personnel to be planned, controlled and concluded somewhat independently of shop-product operations. These inventories allow additional flexibility for suppliers in planning, producing and delivering an order for a given product's part, Loner (2003).

Inventory is essential to organization for production activities, maintenance of plant and machinery as well as other operational requirements. This results in tying up of money or capital which could have been used more productively. The management of an organization becomes very concerned if inventory stocks are high. Inventory is part of the company assets and is always reflected in the company's balance sheet. This therefore calls for its close scrutiny by management (Salleem, 2004).

Management is very critical about any shortage of inventory items required for production. Any increase in the redundancy of machinery or operations due to shortages of inventory may lead to production loss and its associated costs. These two aspects call for continuous inventory control. Inventory control and management not only looks at the physical balance of materials but also at aspects of minimizing the inventory cost.

The classic dilemma in inventory management is maintained in high service levels to meet the needs of customers while avoiding high stocks regardless of the type of items or even the department for which such stock is purchased.

Dobler and Burt (2000) argues that well and efficiently controlled inventories can contribute to the effective operation of the firm and hence the firm's overall profit. Proper management of inventory plays a big role in enabling other operations such as production, purchases, sales, marketing and financial management to be carried out smoothly. Basic challenge however is to determine the inventory level that works most effectively with the operating system or system existing within the organization.

Inventory management is pivotal in effective and efficient organization. It is also vital in the control of materials and goods that have to be held (or stored) for later use in the case of production or later exchange activities in the case of services. The principal goal of inventory management involves having to balance the conflicting economics of not wanting to hold too much stock. Thereby having to tie up capital so as to guide against the incurring of costs such as storage, spoilage, pilferage and obsolescence and, the desire to make items or goods available when and where required (quality and quantity wise) so as to avert the cost of not meeting such requirement.

Inventory problems of too great or too small quantities on hand can cause business failures. If a manufacturer experiences stock-out of a critical inventory item, production halts could result. Moreover, a shopper expects the retailer to carry the item wanted. If an item is not stocked when the customer thinks it should be, the retailer loses a customer not only on that item but also on many other items in the future. The conclusion one might draw is that effective inventory management can make a significant contribution to a company's profit as well as increase its return on total assets. It is thus the management of this economics of stockholding, that is appropriately being refers to as inventory management. The reason for greater attention to inventory management is that this figure, for many firms, is the largest item appearing on the asset side of the balance sheet.

Essentially, inventory management, within the context of the foregoing features involves planning and control. The planning aspect involves looking ahead in terms of the determination in advance:

(i) What quantity of items to order; and (ii) How often (periodicity) do we order for them to maintain the overall source-store sink coordination in an economically efficient way?

The control aspect, which is often described as stock control involves following the procedure, set up at the planning stage to achieve the above objective. This may include monitoring stock levels periodically or continuously and deciding what to do on the basis of information that is gathered and adequately processed.

Effort must be made by the management of any organization to strike an optimum investment in inventory since it costs much money to tie down capital in excess inventory. In recent time, attention was focused on the development of suitable mathematical tools and approaches designed to aid the decision-maker in setting optimum inventory levels. Economic order quantity model (EOQ) has thus been developed to take care of the weaknesses emanating from the traditional methods of inventory control and valuation, which to some extent has proved useful in optimizing resources and thus, minimizing associated cost.

Financial analysts have sounded enough warning on the danger expose to the long run profitability as well as continuity of business concern when its inventories are left unmanaged.

First, a company, which neglects it management of inventory, runs the risk of production bottlenecks and subsequently unable to maintain the minimum investment it requires to maximized profit. Second, inventories that are inefficiently managed may apart from affecting sales create an irreparable loss in market for companies operating in highly competitive industry. Invariably, a company must neither keep excess inventories to avoid an unnecessary tying down of funds as well as loss in fund due to pilferage, spoilage and obsolescence nor maintain too low inventories so as to meet production and sales demand as at when needed.

The Economic Order Quantity is the number of units that a company should add to inventory with each order to minimize the total costs of inventory such as holding costs, order costs, and shortage costs. The EOQ is used as part of a continuous review inventory system, in which the level of inventory is monitored at all times, and a fixed quantity is ordered each time the inventory level reaches a specific reorder point. The EOQ provides a model for calculating the appropriate reorder point and the optimal reorder quantity to ensure the instantaneous replenishment of inventory with no shortages. It can be a valuable tool for small business owners who need to make decisions about how much inventory to keep on hand, how many items to order each time, and how often to reorder to incur the lowest possible costs (Muhammad and Omar, 2011).

The EOQ model assumes that demand is constant, and that inventory is depleted at a fixed rate until it reaches zero. At that point, a specific number of items arrive to return the inventory to its beginning level. Since the model assumes instantaneous replenishment, there are no inventory shortages or associated costs. Therefore, the cost of inventory under the EOQ model involves a trade-off between inventory holding costs (the cost of storage, as well as the cost of tying up capital in inventory rather than investing it or using it for other purposes) and order costs (any fees associated with placing orders, such as delivery charges). Ordering a large amount at one time will increase a small business's holding costs, while making more frequent orders of fewer items will reduce holding costs but increase order costs. The EOQ model finds the quantity that minimizes the sum of these costs (Bhavin et al., 2007).

The purpose of the EOQ model is simply, to find that particular quantity to order which minimizes the total variable costs of inventory. Total variable costs are usually computed on an annual basis and include two components, the costs of ordering and holding inventory. Annual ordering cost is the number of orders placed times the marginal or incremental cost incurred per order. This incremental cost includes several components: the costs of preparing the purchase order, paying the vendor's invoice, and inspecting and handling the material when it arrives. It is difficult to estimate these components precisely but a ball-park figure is good enough. The EOQ is not especially sensitive to errors in inputs (www.usersolutions.com).

The holding costs used in the EOQ should also be marginal in nature. Holding costs include insurance, taxes, and storage charges, such as depreciation or the cost of leasing a warehouse. One should also include the interest cost of the money tied up in inventory. Many companies also add a factor to the holding cost for the risk that inventory will spoil or become obsolete before it can be used (www.usersolutions.com).

Inventories are essential for keeping the production wheels moving, keep the market going and the distribution system intact. They serve as lubrication and spring for the production and distribution systems of organizations. Inventories make possible the smooth and efficient operation of manufacturing organizations by decoupling individual segments of the total operation. Purchased parts inventory permits activities of the purchasing and supply department personnel to be planned, controlled and concluded somewhat independently of shop-product operations. These inventories allow additional flexibility for suppliers in planning, producing and delivering an order for a given product's part, Lonergan (2001).

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From a financial accounting viewpoint, the cost assigned to inventory directly affects net income. If ending inventory is overstated, then net income is overstated and conversely, if ending inventory is understated then net income is understated.

Also, the use of direct costing rather than absorption costing can affect net income. From a management accounting viewpoint, there are variety of inventory decisions that affect net income. Decisions regarding inventory can be placed in two general categories:

(1) those decisions that affect the quantity of inventory and (2) those decisions that affect the per unit cost of inventory.

Decisions that affect the quantity of inventory

(i) Order size

(ii) Number of orders

(iii) Safety stock

(iv) Lead time

(v) Planned production

Decisions that affect the cost per unit of inventory

(i) Suppliers of raw material (list price and discounts)

(ii) Order size (quantity discounts)

(iii) Freight

In addition, decisions pertaining to labour and overhead also indirectly affect the per unit cost of inventory. In a manufacturing business, the costs of labour and overhead do not become operating expenses until the manufacturing costs appear as part of cost of goods sold. Labour and overhead costs are deferred in inventory until the inventory has been sold.

The main management accounting tool that may be used to make inventory purchase decisions is the EOQ model. This tool recognizes that there are two major decisions regarding the materials inventory: (i) orders size and (ii) number of orders.

There are consequently two major questions:

(i) How many units should be purchased each time a purchase is made (order size)?

(ii) How many purchases should be made (number of orders)?

To understand an EOQ model, it is essential that the concept of average inventory be understood. Inventory is never static and is constantly rising and falling over time, even in the very short term. Inventory, for example, rises when raw materials are purchased and falls when raw material is used. Because inventory in a business is constantly changing, it is necessary to think in terms of average inventory levels.

The high points and low points of inventory are easy to explain and illustrate, if a purchasing policy is consistently applied and the rate of usage of raw material is uniform. Inventory is at its highest and lowest levels when a new shipment of material arrives. Theoretically, in absence of a need for safety stock, a new shipment should arrive at the moment inventory reaches zero. Immediately, upon arrival of a new shipment, inventory is then at its highest level again.

1.2 PROBLEM STATEMENT

For many organizations, there is no doubt that inventory management enhances their operations. Organizations with high levels of finished goods inventory can offer a wide range of products and make quick delivery from their backyards to the customers.

The one warehouse and multi-retailer distribution system involves transportation cost as well. Since vehicle capacity is limited, all retailers' demands may not be fulfilled with one trip of a vehicle. The travelling distance of vehicles and the number of trips obviously affect transportation cost. The transportation cost will be minimized if the vehicle capacity is utilized and a vehicle is assigned to visit a group of retailers that are close together. However, for a given replenishment period, a retailer may be located far away from other retailers. Naturally, the retailer that is located far away from the warehouse and has low demand may not be replenished very often. Therefore, the depot has to decide the appropriate routes to minimize the travelling distance so that vehicle capacity is utilized while inventory requirements are satisfied.

Our study focuses on one warehouse multi-retailer distribution problem for finding replenishment policies that specify delivery quantities, delivery intervals and vehicle routes that minimize inventory and transportation costs of Chocho Industry.

1.3 OBJECTIVES

The objectives of this study are as follows:

(i) To find replenishment policies that specify delivery quantities, delivery intervals and vehicle routes that minimize inventory and transportation costs.

(ii) To determine whether or not inventory management in the Company can be evaluated and understood using the various existing tools of optimization in inventory management and,

(iii) To determine the optimality in the company inventory policies.

1.4 METHODOLOGY

Optimization procedures of the one warehouse multi-retailer inventory distribution problem is an effective tool to model, analyze and optimize any inventory systems. It is useful in forecasting the behaviour of systems with both continuous and discrete variables like a typical inventory system. Discrete and continuous systems need to be modelled or designed into complex systems. This complex system or model must be linked with a specific simulation optimization technique that best calculate the output.

In our methodology, we shall apply Cluster First Route Second methods in solving our problem.

1.5 JUSTIFICATION

The objective of the one warehouse multi-retailer distribution problem is to find replenishment policies that specify delivery quantities, delivery intervals and vehicle routes that minimize inventory and transportation costs.

Since each retailer has a different demand, the warehouse has to supply each retailer with different order quantities and replenishment periods. In addition, the warehouse has to decide which retailer can be served by the same route. Thus, to solve this distribution system, we must include both the inventory problem and the vehicle routing problem, hence the reason for the study.

1.6 SIGNIFICANCE OF THE STUDY

The findings of the study will provide well–researched information, which can be useful to researchers for academic purposes in the area of inventory management. To the stores and Procurement department staff, the study hopes to provide them with useful information like the recommended techniques of inventory control so as to meet their customer's and organization's needs. To the firm's management, the recommendations of the study may enable them to design inventory management policies to improve the smooth running of the firm, thereby satisfying customers and generally minimizing costs.

1.7 SCOPE OF THE STUDY

The scope of the study will be limited to the impact of inventory management on the performance of an organization. The study will be carried out at Chocho Industry.

1.8 LIMITATIONS OF THE STUDY

The scope of the study will be limited to the impact of inventory management on the performance of an organization. The study will be carried out at Chocho Industries Limited in Suhum, and would involve the staff of the firm's Stores, Procurement Unit, Transport Departments and Management.

1.9 ORGANIZATION OF THE THESIS

In chapter one, we presented a background study of inventory control and economic order quantity models.

In chapter two, related work in the integrated inventory and economic order quantity model would be discussed.

In chapter three, the cluster first route second optimization procedures and methods that would be applied in solving our problem will be introduced and explained.

Chapter four will provide a computational study of the algorithm applied to our integrated inventory control and economic order quantity instances.

Chapter five will conclude this thesis with additional comments and recommendations

2.0 SUMMARY

The inventory system has diverse decision variables that can be considered as continuous like regular orders, demand on the stock, regular supply et cetera. On the other hand, there are discrete variables like special orders that come in at a particular time, theft or accidents that occur without any warning. Based on the kind of information that management or decision makers need to enable them plan properly for their inventory, these discrete and continuous variables always play an important role in determining the results.

This study seeks to solve an economic order quantity problem with quantity discount and proposed the economic order quantity with discount model optimization procedures and methods in solving the problem.

The next chapter is devoted for relevant literature on integrated inventory control and economic order quantity problems.

CHAPTER 2

LITERATURE REVIEW

In a fairly recent review paper, Bhatnagar et al., (1993) addressed the issue of coordination in organizations. They identify two levels on it, coordination between functions, which they call the General Coordination problem, and coordination within the same function at different echelons in an organization, called the Multi-Plant Coordination problem. The focus of their work is on the Multi-Plant Coordination problem, whereas ours is on the General Coordination one. In spite of the focus of their work, the authors present a good categorization and some literature review for the general coordination problem. Within this problem they distinguish three categories that represent the integration of decision making pertaining to: (i) supply and production planning, (ii) production and distribution planning, and (iii) inventory and distribution planning.

Thomas et al (1996) presented a review on the coordination of functions in these three areas and list some topics for future research. We adopt the last two categories in our work since they most typically consider the distribution function. The principal difference between our work and that of Thomas et al (1996) is that we focus on research that explicitly considers the transportation system.

The problem presented by the analysis of inventory-production-distribution systems is so complex that optimal solutions are very hard to obtain. Within this problem, different considerations and levels of analyses have been proposed along with heuristic solution approaches. Cohen and Lee (1988) presented a strategic model structure and a hierarchical decomposition approach. The scope of their work is to analyze interactions between functions in a complete supply chain network. To model these interactions they consider four submodules where each represents a part of the overall supply chain: (i) material control, (ii) production control, (iii) finished goods stockpile, and (iv) distribution network control. Stochastic considerations are incorporated in the submodules and relevant costs for set-up, inventory holding and shortage are considered. In the hierarchical decomposition, each submodule is optimized in a given sequence, subject to some service level target defined for that submodule, and the output of a submodule solution is used as the input data to all other subproblems.

From a much more simplified perspective, Mak and Wong (1995) proposed the use of a genetic algorithm to solve the inventory-production-distribution problem. Their model consists of three echelons composed of several suppliers, one manufacturing plant and several retailers respectively. Their interest is to simultaneously obtain optimal stock levels, production quantities and transportation quantities so as to minimize total system costs. These costs are inventory holding, shortage, manufacturing and transportation costs. They formulate the problem as an integer program, but a number of simplifying assumptions, restricts its applicability in practical situations. In specific, the model assumes delivery costs known and fixed for every period, direct shipments between all locations and weight limits for transporting products and materials between every pair of locations, in every period.

Cohen and Lee (1989) developed a model that supports resource deployment decisions in a global manufacturing and distribution network. The decisions considered involve both, the design of the international network and the management of material flow within the network. The network considers raw materials suppliers, manufacturing plants, distribution channels, warehousing locations and customers' geographical dispersion. The problem is formulated as a mixed integer, non-linear program whose objective is to maximize after-tax profits in all countries in which the firm operates. Costs considered are: variable and fixed for procurement, production, distribution and transportation as well as tariffs, duties and transfer pricing. The model is a useful tool for the evaluation of global manufacturing strategy alternatives. For an extensive review on strategic production-distribution models in a global supply environment, the reader is referred to the work of Vidal and Goetschalckx (1997).

Substantial savings have been achieved by companies that applied an integrated analysis to their operations and developed decision support tools that accounted for this integration. Three such cases are presented by Blumenfeld *et al.,* (1987), King and Love (1980) and Martin *et al.,* (1993).

Blumenfeld *et al.,* (1987) developed a decision support tool for the analysis of the logistics operations at General Motors that identified a logistics cost savings opportunity of $ 2.9 Million per year. While keeping the analysis and models as simple as possible, the authors developed a tool that allowed the Delco Electronics Division to examine the impact on total corporate cost due to different shipping strategies for its products. The authors recognized that the minimization of total network cost required the simultaneous determination of optimal routes and shipment sizes and they focussed on analyzing the trade-offs between inventory and transportation costs. A model for the analysis of these trade-offs was included in the decision support tool along with a solution technique to determine the minimum cost for the network under consideration. Results obtained from the research done at each stage of the project are reported in a series of papers (Blumenfeld et al., 1985a, 1985b; Burns *et al.*, 1985).

King and Love (1980) put forward a case study of a system implemented by Kelly-Springfield, a major tire manufacturer with four factories and nine major distribution centers located throughout the United States. The system coordinates sales forecast, inventory control, production planning and distribution planning. The rapid proliferation of products and the characteristics of the economy at the time the system was developed (inflation, energy shortages, cutbacks in customer spending, record interest rates, etc.) forced the company to improve the efficiency of its operations in order to remain in the market place, in a time when tire manufacturing plants were reporting losses or closing operations. The system is composed by four submodules (production, inventory control, distribution and forecasting), each of which obtains input information from its preceding stage and processes this information to deliver an optimal output to its succeeding stage. The use of feedback loops between production and inventory control and between distribution and inventory control assures the interaction between these functions. However, the optimization of the parameters of interest (reorder points, lot sizes, shipment sizes, etc.) is not done simultaneously but sequentially by the different functions. The implementation of this system resulted in an increase in customer service level and a reduction in inventory levels which represented substantial savings for the company.

Martin *et al.* (1993) presented the development of a system called FLAGPOL (FLAt Glass Products Optimization modeL) for the Flat Glass Products Group of the Libbey-Owens-Ford Glass company. FLAGPOL is a linear programming model that includes decision variables for production (levels of production), inventory and distribution (to customers and interplant shipments). At the time FLAGPOL was developed, the Flat Glass Products group (FGP) consisted of four manufacturing plants that served approximately 300 customers and produced above 200 product types. The group of people involved in the goal setting for the model included corporate staff members from finance, marketing, management information systems, materials management, transportation, production planning and representatives from the plants, such as managers of production scheduling and cost analysts. One of the goals of the model was to optimize production, inventory and distribution in the multi-plant system based on a 12-month planning horizon. The model was originally conceived to be of tactical and operational scope, however, the implementation of the model proved it to be very valuable to strategic decisions as well. By providing the ability to plan on a system-wide basis rather than by plants in isolation, as was previously done, the use of FLAGPOL has resulted in substantial benefits to Libbey Owens-Ford. The authors report annual savings estimated at over $ 2.0 Million. Some of the sources of these savings are the realignments in the assignment of customers to plants, the justification of the investment in rail-car capacity for interplant shipments and the modification in production schedules.

The problem presented by a system with one depot (warehouse) that supplies multiple geographically scattered customers (retailers) in the context of *integrated analysis* has been analyzed by Federgruen and Zipkin (1984), Federgruen *et al.*, (1986), Burns *et al.*, (1985), Anily and Federgruen (1990), Viswanathan and Mathur (1997) and Chandra (1993). The problem is quite recent and not much literature is available on it. A discussion of our view of the differences between these two problems is given at the end of that section. The "one-depot, multiple-retailers" problem is a tactical problem that considers a depot that allocates a product (or products) to several retailers in such a way that overall costs are minimized. These costs generally include holding and shortage at retailers (shortage costs in cases that consider stochastic demand at retailers, Federgruen and Zipkin, 1984; Federgruen *et al.*, 1986) and transportation costs which can include fixed and variable costs.

The decision variables of interest in the problem are shipment sizes and delivery routes. Given that the formulation of the problem is NP-hard, heuristic solutions have been developed. The general approach taken to the solution of the problem is to analyze the case of direct shipments between depot and retailers and use this analysis as a base for the development of algorithms for the case when delivery routes are to be determined as well. With the exception of Anily and Federgruen and Viswanathan and Mathur which only present the routing case, all other authors present both cases: (i) direct shipments, in which case the decision variables of interest are the shipment sizes only, and (ii) shipments through routes, in which case delivery routes are to be determined along with shipment sizes.

Federgruen and Zipkin (1984) considered a one-period problem in which the amount of product at the depot is limited. Their work was one of the first (if not the first) to integrate the problems of product allocation and vehicle routing into a single model. They propose a heuristic solution based on the decomposition of the main problem into a non-linear inventory allocation subproblem and a number of Traveling Salesman subproblems (one for each vehicle considered).

Federgruen *et al.*, (1986) extended this work to the case in which the product considered is perishable. A perishable product is one that has a determined usage life span, after which it has to be discarded at a given cost. The problem is also a one-period problem, and the product in the system is classified into two age classes, "old" units which are the ones that will perish in the present period and "fresh" units which are those that are at least one period away from their perish dates. To reduce the number of out-of-date units, a number of distribution policies can be considered in practice. The model by Federgruen *et al.*, (1986) accounted for at least the following distribution policies: (i) A rotation policy that removes all "still usable" product from the individual locations' inventories at the end of every period and returns it to the depot for redistribution, together with the fresh quantity, (ii) A retention policy that maintains product received by each location at that location until it is used or outdated, and (iii) A combination of (i) and (ii).

The problem of obtaining shipment sizes and delivery routes is an extension of the work by Federgruen and Zipkin (1984) to two product classes in the system. The solution approach used is the same as in Federgruen and Zipkin (1984) with the variation that the inventory allocation subproblem accounts for two product classes. To solve this sub-problem the authors use a Lagrangean dualization approach. Their work accounts for different cost parameters at different locations.

Both of these papers present a comparison of the integrated to the sequential approach. Federgruen and Zipkin (1984) showed that about 6-7% savings can be achieved by using the combined approach and Federgruen *et al.,* (1986) show that travel costs are substantially less using the combined approach and find that for most instances of the problem considered, the delivery requirements can be met with one vehicle less than those required by the sequential approach.

Burns *et al.,* (1985) considered an infinite horizon problem and develop an analytical method to minimize overall costs. They are interested in comparing the cost performance of the two distribution strategies: direct shipping and peddling. Rather than considering specific locations for each customer in a detailed network, the authors consider the density of customers in a given region, and find optimal region sizes as well. Inventory costs are included in the objective function in an aggregate form, i.e. the cost of holding inventory at the depot, on transit and at the retailers is obtained by approximating the time that the product spends in the system and multiplying it by an interest factor. For direct shipping they obtain an EOQ type of solution by trading off inventory and transportation costs. If the shipment size obtained from the solution is greater than the capacity of the truck (which is given) then a full-truck load is scheduled. For the peddling strategy a full-truck load is the optimal shipment size. The analysis presented in this paper provides guidelines for the distribution problem rather than precise answers to it, given the number of simplifying assumptions and heuristic derivations.

Anily and Federgruen (1990) considered a problem very similar in structure to that of Burns *et al.,* (1985). They derive upper and lower bounds for the system-wide long-run average costs. They show that under weak probabilistic conditions these bounds are asymptotically optimal. They develop a solution procedure whose computational requirements grow roughly linearly with the number of locations considered.

Viswanathan and Mathur (1997) considered the same problem as Anily and Federgruen (1990) with the generalization of multiple products in the system. They develop a heuristic based on a joint replenishment problem to obtain a stationary nested joint replenishment policy (SNJRP). The authors considered vehicles with limited capacity and present computational results comparing the performance of the proposed heuristic with the heuristics proposed by Anily and Federgruen (1990), for the case of a single product. Their results show that the SNJRP policy performs better in the majority of cases in terms of cost. The authors report that no other heuristic was known to handle multiple products, therefore a comparison was not possible for problems that considered more than one product in the system.

Blumenfeld *et al.,* (1985b) analyzed the trade-offs between safety stock at the second echelon and expediting costs at the first one. Expediting is a function of the order-up-to level and cycle length; for this reason, their analysis focuses on these two variables. Expedited shipments are considered to have a zero traveling time and to contain enough material to last until the next ordering epoch. These assumptions are taken to simplify the model so that the trade-offs can be better visualized.

The work considers an unconstrained regular transportation fleet and there is only one trip per cycle. No explicit allocation of inventory costs is done, so following the approach of Burns *et al.,* (1985) and Blumenfeld *et al.,* (1985a) the average time that the inventory spends in the system (at first echelon, in transit and at second echelon) is calculated and an interest rate is applied to this quantity. The authors calculated the probability that an order needs to be expedited, which includes the uncertainty due to fluctuations in material consumption and in travel time. Their objective is to find the optimal inventory level and cycle length that will trade-off expediting.

In Just-In-Time environments, frequent, small shipments are usually required between suppliers and manufacturers and many times transportation contracts for specific volumes are made to assure proper supply. In such situations emergency shipments are contracted by suppliers whenever customer's demand presents a sudden increase and a higher amount of product is required at the customer's location. The problem faced by the logistic manager is to decide the number of vehicles required to make the shipments in such a way that a balance between spare capacity in contracted vehicles and use of emergency shipments is achieved. Yano and Gerchak (1989) analyze this problem and present a solution methodology to simultaneously determine safety stock level at the location in the second echelon (customer), number of vehicles required for regular delivery and time between shipments in such a way that overall operational costs are minimized. These costs include inventory holding and shortage costs at the customer's location and emergency and regular transportation costs.

The integrated analysis showed that the time between shipments is smaller than the value obtained from the appropriate EOQ computation. In our opinion, two important contributions of this work are the following. First, it deals with the transportation system at a strategic level, i.e. it determines the optimal size for the regular fleet and establishes the time between shipments. Second, it shows that full-truck loads and one-vehicle per shipment are not always optimal, this is due to the fact that depending on demand variability it can be more profitable to have spare space in the regular vehicles, even if more than one truck is needed per trip.

Originally motivated by the study of an IBM operation in Italy, Speranza and Ukovich (1994) developed a model to simultaneously minimize inventory and transportation costs in a system that considers shipments of multiple products between two locations. In our opinion, two important contributions of this work are the following. First, the system is analyzed under the consideration that shipments can only take place at discrete epochs in time. Second, it explicitly considers individual products for allocation into trucks as opposed to considering an aggregation of the multiple products.

Using a small example, the authors show that the results obtained by Blumenfeld *et al.* (1985a) are not applicable for the case in which discrete shipping times are considered and that transportation costs increase considerably (not off-setting the reduction in inventory costs) when the solution obtained is rounded up to obtain integrality.

As in Yano and Gerchak (1989), the authors found out that shipping less-than-full truck loads may lead to improved policies. They consider the following two cases for shipping frequencies: (i) a product is assigned a single frequency, and (ii) a product can be assigned to more than one frequency (order splitting). For consolidation, they consider the following two options: (i) only products shipped at the same frequency may share the same truck, and (ii) all products whose shipments happen to be simultaneous may share the same truck. The combination of frequency assignment and consolidation strategy results in four problems that are analyzed by the authors. The distribution system is also viewed from a strategic point of view; the problem determines the number of trucks to be used and allocates different products to trucks.

Chandra (1993) analyzed the "one-depot, multiple-retailers" problem with two new considerations. The product ordering cost at the depot is included in the model, and customers face dynamic demand. He solves the problem with the use of an iterative approximate algorithm, which starts with an initial feasible solution to the sequential problem. It then evaluates how the depot ordering decisions are affected if the delivery schedules for customers are changed. The change that leads to the greatest reduction in overall costs is adopted and the process is repeated until there is no further gain from coordinating the two decisions. The algorithm estimates the benefits of integration in

terms of cost reduction over the case when the depot and customer decisions are made independently. The author presents an experimental study which investigates the effect of coordination between depot's ordering policy and its distribution schedules. Results show that costs savings from the integrated
approach over the sequential one range between 3 to 11%.

Ernst and Pyke (1993) extended the model of Yano and Gerchak (1989) to included the consideration of the inventory level at the first echelon. They analyzed two forms of transportation costs, linear and concave forms. The interest of this work is to simultaneously obtain the base stock levels at both echelons, the optimal vehicle capacity and shipping frequency. The two papers consider emergency shipments to be unconstrained in capacity and availability and assume a close coordination between the two echelons.

Chandra and Fisher (1994) combined the production scheduling and vehicle routing problems to investigate the value of coordination between these functions with the use of a computational study. To our knowledge this is the first work that analyzed the integration of these functions. The authors considered a two-level system with one manufacturing plant which has a finished goods stockpile in the first echelon, and several retailers in the second echelon. An analysis of different scenarios in the system is conducted. These scenarios are obtained by the variation of the following parameters: length of planning horizon, number of products and number of retailers, and set-up, inventory holding and vehicle travel costs. The authors compare the integrated approach to the sequential optimization of the problem and find that a reduction in operational costs can be achieved, ranging between 3-20%, if the integrated analysis is preferred.

A very important observation made by the authors is that, depending on the system parameters, the analysis of coordinated functions may or may not be worth the effort of integrated analysis. This observation was made earlier by Benjamin (1989), but the authors also present conditions under which coordinating efforts are most beneficial and show that under the right conditions the value of coordination can be extremely high.

Haq *et al.,* (1991) considered a three echelon system with one production facility, several warehouses and several retailers. A multi-stage model is used for the production facility. They formulate the integrated problem as a mixed integer program whose objective is to determine the production and distribution batch sizes and the inventory levels at all the locations, in such a way that total system cost is minimized. This total cost considers production, set-up and recycling costs at production stages, distribution cost, which is consider as a linear function, inventory holding costs at all echelons and backlogging costs at retailers.

Ishii *et al.,* (1988) put forward a three echelon system with one manufacturer, one wholesaler and one retailer respectively. They assume a Pull system in which products have short life cycles since product models change frequently in the market place. Their objective is to minimize situations of dead stock (obsolete products) and shortages. They consider the presence of two types of products in the system, new products and products that are in the final stage of their life cycle. The variables of interest are the transportation ordering levels, the stock levels and the production ordering level that minimize the dead stock inventory at the retailer. They propose an algorithm for the solution of the problem and present a numerical example to illustrate the algorithm.

Blumenfeld *et al.* (1985a) and Benjamin (1989) consider several locations on each echelon for the integrated analysis of production, inventory and transportation from a tactical perspective and present formulations of deterministic models. Blumenfeld *et al.,(1985a)* are interested in analyzing the existing trade-offs between transportation, inventory holding and production set-up costs in the network. The authors analyze the cases of direct shipping between nodes in the echelons, shipping through a consolidation terminal and a combination of both, and obtain shipment sizes that trade-off these costs. They present an interesting approach to the analysis of more complex networks. The approach is based on the subdivision of the original network into subnetworks and on the application of results obtained for the cases of one supply point shipping to one demand point and one supply point shipping to many demand points.

Blumenfeld *et al..(1985a)* are not concerned with the specification of the distribution system (capacity and number of vehicles) but on obtaining the value of the shipment size (cycle length) that trade-off the respective costs. It does not consider explicitly the different inventory costs (at plants, in transit and at retailers) but combines them into a single aggregate one. A number of simplifying assumptions are made in the model (e.g. deterministic demand, specified vehicle capacity) however, these simplifications are justified by the objective of the paper which is to provide insight into the trade-offs existing among the considered costs.

Benjamin (1989) considered the simultaneous optimization of the production lot size problem, the transportation problem and the economic order quantity problem. He accounts for supply constraints and explicitly considers inventory costs; his interest is to find optimal production sizes for supply points and order quantities for demand points. The model assumes an unconstrained transportation system and direct shipments between each node, therefore, no routing decisions have to be taken.

Although this work considers multiple products, no product to truck allocation decisions are made. Benjamin presents a comparison between the simultaneous and the separate optimization approaches and finds that the magnitude of the advantage of optimizing the problem simultaneously, depends on the relative size of setup and holding costs at each of the supply and demand points. This is an interesting remark since it highlights the fact that simultaneous optimization is not always better.

Chien (1993) analyzed the case of direct shipments between a single supply location and a single demand point. Demand for the product follows a known probability distribution. The transportation cost is fixed per shipment and the truck has limited capacity. The objective is to maximize the expected profit of the operation by determining a joint optimal production rate and shipment size. Expression for production costs, per-unit inventory carrying costs (at plant and at retailer), transportation costs, shortage penalty cost, regular revenue and salvage revenue are obtained as functions of the demand density. The problem is solved by an iterative procedure which yields solutions that are within 0.2-3.8% of optimality in terms of expected profits.

The Inventory/Routing Problem considers that shortage costs are incurred by the distribution firm while holding costs (whatever their form) are the responsibility of the customer. Larson (1988) distinguished two types of Inventory/Routing Problems, Strategic Inventory/Routing Problems (SIRP) and Tactical Inventory/Routing Problems (TIRP). SIRP focuses on estimating the minimum size (or cost) vehicle fleet required by the firm, over the long term, to serve its customers when only the probability distribution for the per unit demand is known for each customer. TIRP deals with routing an existing vehicle fleet to supply customers over the short term, whose actual demands for replenishment can be estimated. According to Webb and Larson (1995), a major difference between the strategic and tactical versions of the problem is that in solving the SIRP all possible realizations of the TIRP must, at least implicitly, be considered simultaneously.

Bell *et al.,* (1983) described the development of a decision support system for the IRP at Air Products and Chemicals Inc. This work was awarded the TIMS Practice Prize for 1983. The system consists of several modules that include customer usage forecasting, a distance-network and a shortest path algorithm, a mathematical optimization module to produce delivery routes and an interface for possible manual modification of schedules and of operational parameters. The optimization module uses a sophisticated Lagrangian relaxation algorithm to solve mixed integer programs with up to 800,000 variables and

200,000 constraints to near optimality. The benefits obtained from the implementation of the system include a significant reduction in operating costs (over $2 million annually), an increase in vehicle productivity and a higher utilization of the firm's computer network.

Golden *et al.*, (1984) developed a heuristic for the optimization of an integrated delivery planning system for a large energy-products company that distributes liquid propane. The study was done for a distribution district that serves approximately 3,000 customers. The purpose of the study was to compare the distribution rule used by the company to the heuristic algorithm proposed by the authors. The company's rule for distribution was based on the re-supply point for each customer. Based on historical data the company calculated an average consumption rate for each customer and kept a record of the last replenishment date for each customer. This information was used to calculate when each customer would hit the re-supply point and the next replenishment was scheduled based on this information. The authors developed a heuristic that includes a customer selection algorithm that is able to select the set of customers to be visited on each day in a cost-effective manner. The heuristic also accounts for vehicle routing and trip to truck assignment. Each of these components was solved as effectively as possible and a simulation experiment was used to evaluate the integrated performance of the components. Results from the simulated comparison of the proposed heuristic to the distribution rule used by the company showed that the heuristic had a superior performance. The number of gallons/hour delivered was improved by 8.4%, the number of stockouts was reduced by 50% and total costs were reduced by 23%.

Trudeau and Dror (1992) developed an algorithmic procedure to solve the stochastic IRP which takes explicitly into account route direction, costs of stockouts, route failures and their interrelations. This study permits a better understanding of the interdependent factors that impact the efficiency of the delivery system. Many of the simplifying assumptions made in past studies are not made in this work, for instance, the authors do not consider the demand rate to be the expected value of the demand distribution for each customer as an estimated consumption rate, also, they do not rely on the artificial capacity device to account for route failures as done in the solution of the standard Vehicle Routing Problem (VRP) with route failures. The authors recognize the fact that a short term myopic approach has the tendency to defer as many deliveries as possible to later planning periods. To solve this problem, they include a temporal "cost" of selecting the customers for service and assigning them to specific days so that the long-time horizon objective is properly projected into the weekly tactical planning. A simulation experiment is presented to illustrate the interrelation between stockouts and route failures. Since no tractable exact solution methodology exists, the authors compare their results with the industry standards, showing that their procedure is far superior to industry practices.

Dror and Ball (1987) recognized the fact that a short-term optimization approach has the tendency to postpone as many deliveries as possible to later periods, and present a procedure to convert the long-term problem into a single-period problem that can be solved with the use of standard routing algorithms. Their objective is to minimize annual costs subject to no customer shortages. The reduction procedure considers the definition of single-period costs that reflect longterm costs, the definition of safety stock level and a specification of the customer subset to be considered during a single period.

Considering a set of vehicle routes for the IRP, Dror and Levy (1986) developed a heuristic route improvement scheme that is capable of examining and operating in all the routes simultaneously. The scheme is based on a node interchange operation. They solve the annual IRP based on a sequence of consecutive weekly solutions. Two sets of customers are considered, those who need replenishment done in the present planning period and those who do not. A feasible solution to the problem is obtained which (i) includes the scheduling of all those customers who require service in the planning period, and (ii) satisfies vehicle capacity constraints. After this feasible solution is found, an improvement scheme is applied to it to improve the quality of the solution. This scheme is designed to examine the given feasible solution and to search for favorable trade-offs when interchanging customers' positions on a route and between different routes. The goal of the improvement stage is to reduce the total distribution cost for the planning period while maintaining route capacity constraints. Three routing improvement procedures are presented along with results of the comparison performed via computational experiments.

Chien *et al.* (1989) analyzed the IRP when a limited amount of product is available at the depot. They assume that the entire demand of customers need not be satisfied at the time customers are visited by the delivery truck. Their objective is to maximize total profit, which is defined as the revenue obtained from units delivered minus fixed and variable routing costs and possible shortage costs incurred. They formulate the problem as a mixed integer program and develop a solution approach based on Lagrangean relaxation. Computational experience reported by the authors shows that the procedure is able to generate good quality solutions for several instances of the problem which are generated with a variety of revenue and cost structures, and vehicle availability and vehicle capacity combinations.

Larson (1988) presented the characteristics of an SIRP that was implemented into a decision support system developed to assist strategic decisions taken by the City of New York in the design of its new sludge transport and disposal system. The key decision outcome of the model is the least cost fleet size and fleet mix. While the system considers the assignment of customers to specific clusters, a basic assumption is that all replenishments are made on a single route visiting all customers in a cluster. This assumption caused some locations to be visited more frequently than required. Motivated by this inefficiency of the system, Webb and Larson (1995) considered a period/phase approach to solve the SIRP. They present the development of routing solutions based on the period and phase of replenishment of each customer, and develop a simple model for the tactical routing problems the fleet will eventually encounter. Estimates of the fleet size required are developed on the basis of these routing solutions. The period/phase approach can be generalized to take long-term operating costs into account.

Other work related to IRP is presented in Dror (1983), Dror *et al.*, (1986) and Assad *et al.* (1982). Inasmuch as IRP modeling is relatively new, it is not possible to say that a general standard formulation exists yet. Further research is needed to characterize the

optimal solution methodology of different problem instances and to reduce the computational complexity of the problems, especially for large ones. As noted by Golden and Assad (1986) research is needed to identify the appropriate strategy for incorporating long-run inventory-related costs and short-term routing costs into the same model. Also, it is necessary to include electronic data interchange considerations between customers and the central depot, in the light of EDI advancements and other technologies alike.
Further work on strategic IRP is also needed, Larson (1988) identified several areas for further research in this respect. He proposes the consideration of transshipment points, their number and optimal locations, and also, the consideration of strategic decisions other than fleet size and mix (e.g., customer inventory holding capacities).

Ball (1988) described application environments in which Inventory/Routing problems arise, presents formulations for several versions of the problem and reviews some solution procedures. He also identifies areas where further research is needed.

The inventory routing problem is one of important and practical problems in logistics. It involves the integration of inventory management and vehicle routing, both of which are known to be NP-hard. Hoong et al., (2003) combined local search and network flows to solve the inventory management problem, by utilizing the minimum cost flow sub-solutions as a guiding measure for local search. We then integrate with a standard VRPTW solver to present experimental results for the overall inventory routing problem, based on instances ex- tended from the Solomon benchmark problems.

Inventory is essential in an organization for production activities, maintenance of plant and machinery and for other operational requirements (Jessop 2003). The normal tendency is to have more inventories so that most of the items are available when needed. As seen earlier, this results in blocking of money which otherwise could have been used more productively. Inventory is part of the company's assets in its balance sheet and is therefore always under close scrutiny of management. The management is very concerned about any shortage of items required for production. This is so because any increase in the down time of the the machines due to shortage of raw materials leads to production loss. The two aspects therefore call for inventory control not only looking at the physical balance of various materials but also looking into aspects of minimizing the inventory cost.

However, Saxena (2003) advised that avoiding shortages, excessive stocking and increasing inventory turnover, are some of the main issues concerning inventory control. Further, methods of reducing the component of materials cost in the product cost, is an important consideration in cost reduction.

Economic Order Quantity (EOQ) attempts to reconcile the problem of storage costs and ordering costs. Ford Harris when working as an employer at Westing House, derived Economic Order Quantity Model 1915. Its function is to determine the optimal order that minimizes quantity that will minimize carrying costs and ordering costs. Economic Order Quantity is therefore the Order Quantity that will minimize both carrying costs and ordering costs (Fuller 2003). According to Morrison and Jossep (2003), the Economic

Order Quantity is the quantity, which minimizes the sum of the acquisition cost and inventory carrying out cost. The Economic Order Quantity minimizes the total annual cost.

Sallem (2004) agued that possession of high amount of inventory for long time periods of time is not usually good for business because there are inventory storage obsolescence and spoilage costs. However, possessing not enough inventory is not good either because runs the risk of losing out potential sale and markets.

As noted by Fuller (2000), it is possible to utilize the concept of ABC in the formation of rational inventory policy which should give the best possible service level to production while minimizing investment cost. Saxena (2003) stresses that various studies have shown that only 20% of the items have 80% of the annual inventory consumption and 80% of the items have 20% of annual inventory consumption, this is based on the findings of an Italian static Ian Vilfred Pareto (2004).

However Fuller (2000) argued that categories of inventories of items should be controlled differently. For class A items, they should be controlled tightly, need accurate recording of receipts and issues, scheduled should be constantly reviewed and minimum buffer stocks probably less than 2 weeks. Class B items require moderate level of control, all receipts and issues should be recorded, schedules should be moderately reviewed and later buffer stocks 6-8 weeks. Class C items need lower level of control, there should be minimal recording of receipts and issues, need lower level of schedule and review and need large safety stocks of 12 weeks.

According to Saleem (2004) the ABC is the selective approach popularly known as Always (A) Better (B) Control(C). The ABC analysis goes by its name. It always controls the best, then better and lastly good. Its importance lies in the determination of priority, which enables the management to exercise control over the managed subjects according to priority fixed for a purpose or selective basis. A items call for more careful attention as compared to items in (B) or (C) which may require less careful attention on behalf of Material Managers.

Morrison and Jessop (1999), argued that ABC analysis is based on 80:20 rule, as a rule of thumb, it will be found in any store or stockyard that about 80% of the total value of issues in a year will be accounted for by perhaps 20% of the items. Category „A‟ items, small in number, high in usage value. “The vital few” from financial point of view. Category B items, medium in number, medium usage value. “The normal” items. Category C items, high in number, low usage value. “The trivial many”.

Gerald Hobson (2003) said only 10% of the inventory items cover about 70% of the annual inventory usage and are categorized as „A‟ category items, 20% of the items cover about 20% of annual usage and are categorized as „B‟ category items and the remaining 70% items cover only about 10% of the annual inventory usage and are categorized as „C‟ category items.

Class C items need lower level of control, there should be minimal recording of receipts and issues need lower level of schedule and review and need large safety stocks of 12 weeks. According to Saleemi (2004) the ABC is the selective approach popularly known as Always (A) Better (B) Control (C). The ABC analysis goes by its name. It always controls the best, then better and lastly the good. Its importance lies in the determination of priority, which enables the management to exercise control over the managed subjects according to priority fixed for a purpose or selective basis. A items call for more careful attention as compared to items in (B) or (C) which may require less careful attention on behalf of Material Managers.

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Huller (2003), asserted that ABC analysis is an important tool to control the inventory investment in an organization. It provides good guidelines for adopting appropriate inventory management.

According to Jessop and Morrison (2000), it will be appreciated that under the action level of provisioning, commodities are ordered at unspecified intervals from day to day as and when ordering levels are reached. This means that order can only be placed usually for one item at a time and this may not produce the best purchase prices.

Saxena (2003) call this approach theoretical inventory control model. As pointed out, for normal inventory operation, the inventory moves up and down between minimum and maximum levels. Inventory crossing the maximum level means overstocking and when it goes below the minimum level, it could result into a stock-out. The re-order level should be set between the maximum and minimum levels and an order for replenishment only when the inventory reaches the re-order point. The order quantity is equal to the working capital.

By the time inventory reaches the minimum level the quantity ordered is received. On receipt of the ordered quantity of the material, the inventory, which had reached the minimum level, increases to the maximum level and consumption cycle restarts. According to this model the reorder point is by keeping in view the lead time for obtaining the items and making the same available for use. This control model helps to avoid stock-outs with its costs and overstocking which again may tie-up working capital and may also lead to deterioration of stock (Obsolescence).

According to Fuller (2000), in situations where fixed order Quantity is not suitable, Materials Requirements Planning approach has been developed as a means of managing inventory. The system is used for controlling inventories of raw materials, work in progress, component parts and sub assemblies. Material Requirement Planning Inventory has been proven to be a very powerful tool in the planning and control of manufacturing firm.

Gerald Hobson (2004) explained that material requirement planning is basically an information system in which sales are converted directly into loads on the facility by sub unit and time period. Material are scheduled more closely there by reducing inventories and delivery times become shorter and more predictable. And only fervors smaller firms and the computer system is only one part of the total project which is long term.

According to Salem (1997), Inventory control refers to a planned method of purchasing and storing materials at the lowest possible costs without affecting the production and distribution schedule. Inventory Control therefore is a scientific method of determining what, when and how to have in stock for a given period of time.

Lysons and Gillingham (2003), defined Just In Time as an inventory control philosophy whose goal is to maintain supply just enough, at the right place at the right time to make just the right amount of the products. The aim is that by limiting production and assembly to what is actually needed, both materials and work in progress inventories can be limited or significantly reduced. Just in Time implies a low or zero inventories and at times it is referred to as stockless buying. However Saleem (2004) points out that just in time inventory is only an approach which works to eliminate inventories rather than optimize them. The inventory of raw materials and work in progress fall to that needed in a single day. This is accomplished by reducing set up times and lead times so that small lots may be ordered. Stock Control is an operational process where inventory management is a management process. Inventory control therefore forms the basis of materials control without which the entire functioning of store-keeping may be rendered either ineffective or aimless to a certain extent. The inventory control hence gives birth to materials control. Inventory control precedes stock-keeping which predetermines the scope of inventories and investment therein.

Dobler and Burt (2002) stressed that from the managerial point of view; two categories of Costs are associated with inventories. However Lysons and Farrington (2006) also stated that the economics of inventory management and stock control are determined by an analysis of the costs incurred in obtaining and carrying inventories under these two categories:

Many of the costs incurred in placing an order are incurred irrespective of the order size; so for example, the cost of an order will be the same irrespective of whether 1 or 1000 tonnes are ordered. Ordering costs includes: Preliminary costs – preparing the requisition, vendor selection, negotiation. Placement costs – order preparation, stationary, postage. Post-placement costs – progressing receipt of goods, materials handling, inspection and payment of invoices. Farrington (2006) explained that cost control is an operational process in the management process therefore forms the basis of material control without which the entire functioning of store keeping may be reduced.

Gerald (2004) explained that there two types of holding cost: i Costs proportional to the value of the inventory such as: Financial costs like the interest on capital tied up in inventory, which may be bank rate pr, more realistically, the target return on capital required by the enterprise.

Cost of insurance. Loses in value due to deterioration obsolescence and pilfering.

Costs proportional to the physical characteristics of the inventory such as:

Storage costs – storage space, store rate, lighting heating and power.

Labour costs relating to handling and inspection.

Clerical costs relating to stores‟ records and documentation.

Fuller (2003) explained that in many production and construction undertaking the cost of inventories account for nearly two thirds of the total costs. Therefore the determining factor is obviously the efficiency of the materials Management.

Lysons and Gillingham (2003) pointed out that the costs of being out of Inventories are: Loss of production output, Cost of idle time and of fixed overheads spread over a reduced level of output, Costs of bad action taken to deal with the stock-out, such as buying from another stockiest at an enhanced price, switching production, obtaining substitute materials, Loss of customer goodwill due to the inability to supply or late delivery.

Hobson (2005) argued that if inventory is un available when customers request for it or if inventory is unavailable when it is needed for production a stock out occurs a stock out of an item demanded by customer can result in lost sales or demand, loss in good will and cost associated with backorders processing such as extra paper work expediting special handling and higher shipping costs.

Saleemi (2004) considered inventory management to be an important issue in any organization that cannot be overlooked. The idea is of conserving valuable capital, reduction of costs and increasing competitiveness. He goes ahead to stress that the primary objective of inventory control is to minimize idle time caused by shortage of inventory and non-availability of inventories, inventory carrying cost obsolescence losses. Achieving of these objectives will result in more on return capital, which is materially, the prime objective of an organization whether commercial or industrial. A reduction in working capital, high percentage of which is locked up in inventories, is possible and there is a scope of increasing the profit earning capacity of the organization.

Gerrad and Hobson (2004), presented efficient management of inventories may result in more profit margin since it will reduce the operational and inventory cost resulting in reduction of production costs, more competitive capacity, increased turnover and profitability. Surpluses cause financial hardships because they tie up capital and shortages lead to poor operational results. But satisfactory and specific inventory control eliminates the shortcomings hence its importance.

Morrison and Jessop (2000), Salem (2004) presented the impact of inventory management on the profitability of the organization. They contend that, it would not be possible for an enterprise to maintain a reasonable profit margin if it had a poor inventory management system in the place, but the increasing business and industrial activities call for an efficient and effective inventory control and management system. The size itself calls for more economical operations so as to affect savings thereby depriving the advantages of large-scale business and industrial operation.

Saxena (2003) said that cost reduction and inventory control continue to constantly get the attention of the top and middle management are an important performance indicator of the stores function. Efficient operations of stores division and inventory management is one of the most important factors in maintaining high operational efficiency as well as achieving high productivity in an industrial plant. Productivity of any organization can be increased if materials of the right quality are made available in the right quantity at the right time and place. This will mean that there is neither a shortage of materials nor an excess of inventory. This again requires strong inventory control and management in place. Furthermore, materials are available when needed and their quality does not deteriorate during shortage.

Fuller (2000) considered inventory management to be an important asset for allowing production and sales operations to remain functioning smoothly by the stock service levels meeting the demands of production and resale. In fact it is the achievement of high levels of stock service on a minimum of stock investment that is at the heart of inventory management. Production and marketing would of course like to meet all demand immediately from current stock and would therefore call for strict inventory control and procurement management. According to the World Magazine (2002), no inventory system will work efficiently unless stock is tightly controlled and stock records are accurately managed. If the inventory is overstated there is risk of stock – outs. If the Inventory balance is under-stated, there will be excess inventory. All decisions on when and how much to order are based on the Inventory balance is of individual items, which can be identified under a strong inventory management system in place.

Poor Inventory Management creates a chain of problems which include; lost sales, shortages, late delivery, loss of customer goodwill and image, failure to satisfy internal customers which affects their operations, excess expenditure and high premium freight costs. All these affect the performance of the supply chain management. These will result in ordering more than what is needed, which creates excess inventory and high obsolescence (Zenz, 1999).

According to International Records Management Trust (2001), accurate stock records and inventory control are important aspect of financial accounting as well as the cornerstone of procurement management.

Inventory constitutes the most significant part of current assets of larger majority of Nigerian manufacturing industries. Because of the relative largeness of inventories maintained by most firms, a considerable sum of an organization's fund is being committed to them. It thus becomes absolutely imperative to manage inventories efficiently so as to avoid the costs of changing production rates, overtime, sub-contracting, unnecessary cost of sales and back order penalties during periods of peak demand. The main objective of this study is to determine whether or not inventories in the Nigeria Bottling Company, Ilorin Plant can be evaluated and understood using the various existing tools of optimization in inventory management. The study methods employed include the variance analysis, Economic Order Quantity (EOQ) Model and the Chi-square method. The answer to the fundamental question of how best an organization which handles inventory can be efficiently run is provided for in the analysis and findings of the study. Consequently, recommendations on the right quantity, quality and timing of material, at the most favourable price conclude the research study.

There is need for installation of a proper inventory control technique in any business organization in developing country like Nigeria. According to Kotler (2000), inventory management refers to all the activities involved in developing and managing the inventory levels of raw materials, semi-finished materials (work-in- progress) and finished good so that adequate supplies are available and the costs of over or under stocks are low.

Rosenblatt (1977) put forward that, the cost of maintaining inventory is included in the final price paid by the consumer. Goods in inventory represents a cost to their owner. The manufacturer has the expense of materials and labour. The wholesaler also has funds tied up. Therefore, the basic goal of the researchers is to maintain a level of inventory that will provide optimum stock at lowest cost.

Morris (1995) stressed that inventory management in its broadest perspective is to keep the most economical amount of one kind of asset in order to facilitate an increase in the total value of all assets of the organization – human and material resources.

Keth et al., (1994) in their text also stated that the major objective of inventory management and control is to inform managers how much of a good to re-order, when to re-order the good, how frequently orders should be placed and what the appropriate safety stock is, for minimizing stockouts. Thus, the overall goal of inventory is to have what is needed, and to minimize the number of times one is out of stock.

Drury (1996) defined inventory as a stock of goods that is maintained by a business in anticipation of some future demand. This definition was also supported by Schroeder (2000) who stressed that inventory management has an impact on all business functions, particularly operations, marketing, accounting, and finance. He established that there are three motives for holding inventories, which are transaction, precautionary and speculative motives. The transaction motive occurs when there is a need to hold stock to meet production and sales requirements.

A firm might also decide to hold additional amounts of stock to cover the possibility that it may have under estimated its future production and sales requirements. This represents a precautionary motive, which applies only when future demand is uncertain. The speculative motive for holding inventory might entice a firm to purchase a larger quantity of materials than normal in anticipation of making abnormal profits. Advance purchase of raw materials in inflationary times is one form of speculative behaviour.

Anily and Federgruen (1990) considered distribution systems with a depot and many geographically dispersed retailers each of which faces external demands occurring at constant, deterministic but retailer specific rates. All stock enters the system through the depot from where it is distributed to the retailers by a fleet of capacitated vehicles combining deliveries into efficient routes. Inventories are kept at the retailers but not at the depot. We wish to determine feasible replenishment strategies (i.e., inventory rules and routing patterns) minimising (infinite horizon) long-run average transportation and inventory costs. We restrict ourselves to a class of strategies in which a collection of regions (sets of retailers) is specified which cover all outlets: if an outlet belongs to several regions, a specific fraction of its sales/operations is assigned to each of these regions. Each time one of the retailers in a given region receives a delivery, this delivery is made by a vehicle who visits all other outlets in the region as well (in an efficient route). We describe a class of low complexity heuristics and show under mild probabilistic assumptions that the generated solutions are asymptotically optimal (within the above class of strategies). the authors also showed that lower and upper bounds on the system-wide costs may be computed and that these bounds are asymptotically tight under the same assumptions. A numerical study exhibits the performance of these heuristics and bounds for problems of moderates size.

Ahmad and Tsao (2006) presented an integrated approach for solving the Period Vehicle Routing Problem with Simultaneous Delivery and Pickup (PVRPSDP). The problem considers a distribution system consisting of a warehouse and many dispersed location retailers, where each of which having two type of demands to be delivered and collected, respectively. A fleet of capacitated vehicle is employed for delivering products from the warehouse to the retailers, and collecting the reusable empty-containers in the reverse direction for all day during a given *T*-day period. Precisely, at each retailer's location, a pickup operation must be established immediately after a delivery operation. The retailers are typically required to be visited once or several times over the period, and once a day at the most. The days of visits must follow one of the allowable visit-day patterns that were built based on stationary-interval inventory property. The objective of the problem is to minimize the inventory and traveling system-wide costs subject to the vehicle capacity constraint. We highlight the influent role of the visit frequency. Instead of a given parameter, the visit frequency for each retailer is treated as a decision variable, and dynamically determined. The novelty of our integrated approach is comprised in maintaining the appropriate balance between the inventory costs and the traveling costs to seek the best visit frequency for each retailer while constructing the tours. We develop heuristic algorithms for the PVRPSPD and establish some experiments to show the performance and the behaviour of our approach.

The Period Vehicle Routing Problem (PVRP) has received considerable attention over the last two decades. The PVRP is generally viewed as a period version of the well-known Vehicle Routing Problem (VRP) working with a given planning horizon of *T*-day period. Many efforts in the literature have been established to extend the basic PVRP model to incorporate additional constraints or different objective functions. One of the extensions of the PVRP considered in this paper is that accommodates such business environments where the company - generally driven by environmental or economical motivation - is not only responsible for the distribution of products from a warehouse to the retailers but also the transportation of the reusable empty-containers of the products in reverse direction. For example, in the soft drink industries, the company deals with the distribution of the full-bottles as well as the redistribution of the empty-bottles (Dethloff, 2001).

SUMMARY

In this chapter we presented relevant literature on inventory control EOQ. The next chapter is devoted for the research methodology of the study.

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Since the one warehouse and multi-retailer distribution system involves a vehicle routing problem (VRP) and an inventory problem, we may combine the heuristics of these two problems together. A possible solution can be divided by clustering all retailers and routing them for each cluster. The schematic representation of the system is shown in Figure 3.1.

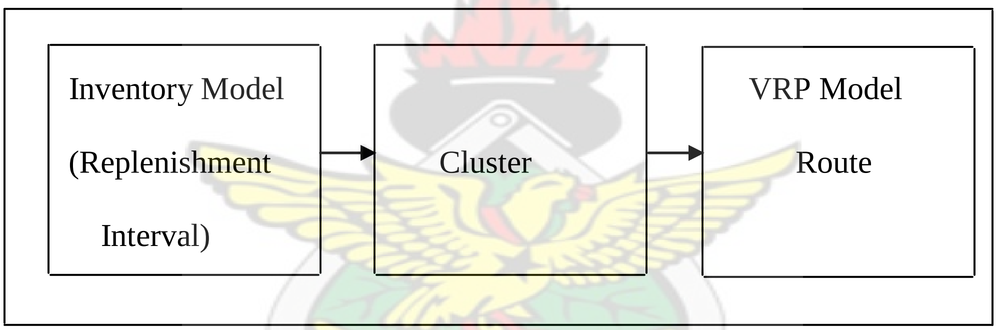

Figure 3.1: A schematic model of single warehouse and many retailers distribution system

The above system begins by clustering the retailers by using replenishment intervals. The new clusters will be created when the vehicle capacity is reached. Then, each cluster will be routed by using the VRP model. The final solution of the system will be a set of clusters of retailers for each replenishment period so that each cluster contains an optimal route.

3.1 THE BASIC EOQ MODEL

The inventory control model can be broadly classified into two categories: Deterministic inventory Problems, and Probabilistic or Stochastic inventory problems.

The general inventory model is represented graphically as in Figure 3.1.

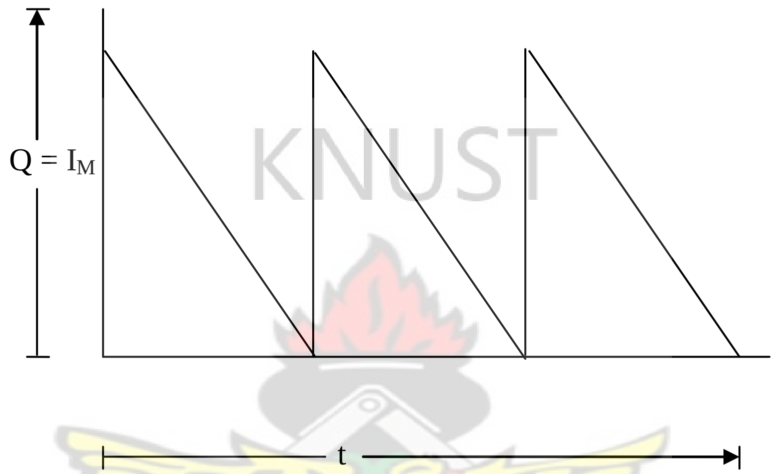

Figure 3.2: The general inventory

In this model at time t = 0, we order a quantity Q which is stored as maximum inventory I_M. The time t denotes the time of one period or it is the time between orders or it is the cycle time. During this time, the items are depleting and reaching a zero value at the end of time t.

At time t, another order of the same quantity is to be placed to bring the stock up to Q again and the cycle is repeated. Hence this is a fixed order quantity model.

The total cost for this model for one cycle is made up of three cost components.

Total Cost/ Period (TC) = Item Cost (C_P) + Setup Cost (C_S) + Holding Cost (C_H). (1)

Item Cost (C_P) = Cost of Item (C_I) x Number of items ordered/ period (Q) (2)

Thus, $C_P = C_I * Q$ (3)

Setup Cost (C_S)/ period = Cost of Setup/period (C_S), which is incurred only once. (4)

Holding Cost per period(C_H)

= Holding Cost (C_h) * Average inventory/period (Q/2) * item per period (5)

Thus, $C_H = \frac{C_h Q}{2t}$ (6)

Hence,

$$TC = C_I Q + C_S + \frac{C_h Q}{2t} \quad (7)$$

For one time period, $t = \frac{Q}{D}$ (8)

where;

Q = Quantity per order

D = Demand which is at a constant rate

Now, total cost per unit time, $C = \frac{TC}{t}$ (9)

Thus,

$$C = C_I D + C_S \frac{D}{Q} + \frac{C_h Q}{2} \quad (10)$$

The Cost component of the above equation can be represented as shown in Figure 3.2.

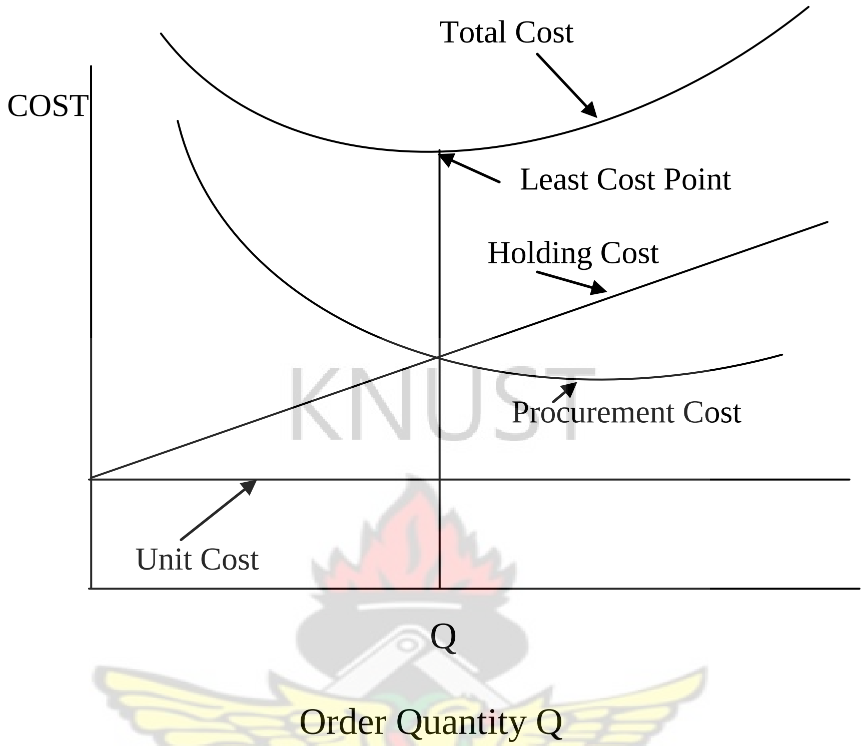

Figure 3.2: Cost Graph

The optimum order quantity (Q*) for a period is found when;

Purchasing or Procurement cost = Item Holding Cost

Thus the system is in equilibrium, and hence

$$C_S \frac{D}{Q} = \frac{C_h Q}{2} \qquad (11)$$

For which $Q^* = \sqrt{\frac{2C_S D}{C_h}}$ (12)

Alternatively, the minimum inventory cost per unit time can also be found by differentiating C with respect to Q and equating it to zero. Thus, from

$$C = C_I D + C_S \frac{D}{Q} + \frac{C_h Q}{2} \qquad (13)$$

$$\frac{\partial C}{\partial Q} = - C_S \frac{D}{Q2} + \frac{C_h}{2} = 0 \quad (14)$$

From which

$$Q^* = \sqrt{\frac{2C_S D}{C_h}}$$

This value Q* is the economic order quantity and any other order quantity will result in a higher cost.

The corresponding time period t* is found from

$$t^* = \frac{Q^*}{D} \quad (15)$$

The optimum number of order per year is determined from

$$N^* = \frac{D}{Q^*} \quad (16)$$

Where, D is the demand per year.

3.2 CLUSTER FIRST-ROUTE SECOND ALGORITHM

According to Bodin and Golden (1981), there are many solutions for vehicle routing problems. Basically, there are two types of algorithms that can be used to solve the problem: Optimal and heuristic. Optimal algorithms are those that will yield exact solutions in a finite number of steps; often these algorithms are time consuming when solving a large problem. On the other hand, heuristic algorithms are faster and practically obtain near-optimal solutions especially for large problems.

The cluster first-route second algorithm is a heuristic approach used extensively in the research efforts. Customers are first clustered into feasible groups and then efficient routes are designed for each cluster. For more examples of this idea, refer to Gillet and Miller (1974) and Christofides, Mingozzi and Toth (1979). The basic procedure can be classified into two phases. The first phase involves clustering based on the location of the customers and vehicle capacity constraints. The second phase utilizes routing by solving the travelling salesman problem for every set of customers.

3.2.1 THE SWEEP ALGORITHM (Gillet AND Miller, 1974)

This involves two phases.

Phase I involves clustering all retailers.

The various steps used are:

Step1 Calculate polar coordinates (r_i, θ_i) with the depot at r_0= 0 and arbitrary customer i* at θ_i = 0 and order customers in increasing θ values.

Step 2 Choose a seed customer and assign to vehicle k.

Step 3 Starting from the unrouted customer I with the smallest angle θ_i, include consecutive customers i+1, i+2, … in the route until the capacity constraint of the vehicle k is reached.

Step 4 If all customers are swept or if all vehicles have been used, go to phase II, otherwise return to step 1.

Phase II involves routing each cluster.

Step 5 Solve the TSP for every cluster of customers to form the final routes.

3.2.2 THE TWO-PHASE METHOD (Christofides, Mingozzi and Toth, 1979)

This also involves two phases.

Phase I involves clustering retailers.

Step 1 (Sequential trial) Choose an unrouted customer to be a seed and assign to a vehicle k.

Step 2 Include unrouted customers in increasing order of insertion cost relative to the customer seed until the vehicle capacity is reached. If all customers are clustered or all vehicles are used, go to step 3, otherwise repeat from step 1.

Step 3 (Parallel trial) Using the seeds chosen in the sequential trial, free all customers from their clusters.

Step 4 Calculate the insertion cost for every customer relative to every seed and keep the best insertion for the customer.

Step 5 Allocate the customer that gives the minimum insertion cost to its corresponding cluster.

Step 6 Repeat step 4 for any customer whose previously best insertion is no longer feasible until all customers are clustered or vehicle capacity is reached.

Phase II involves routing each cluster.

Step 7 For all clusters from both sequential trials and parallel trials, solve the TSP for each cluster and keep the best of the two as the VRP solutions.

We apply the concepts of cluster first-route second algorithms to the one warehouse and multi-retailer distribution problem based on the following assumptions:

(i) The retailers have deterministic, constant and continuous demands;

(ii) We have a known lead time;

(iii) The product is the single item;

(iv) No inventory is held at the warehouse;

(v) There is no allocation between retailers;

(vi) The vehicles are identical and capacitated; and

(vii) The associated costs are setup costs, holding costs, fixed transportation costs and variable transportation costs.

3.3 THE POWER OF TWO POLICIES

As stated above, our distribution problem incorporates both the inventory problems and the vehicle routing problems. Since the retailers have to decide how much to order and when to order, the solution to the inventory issue is the classical EOQ model. However, one difficulty with the EOQ model is that the optimal reorder interval may take any value and thus might lead to highly impractical policies. For instance, the reorder interval of $\sqrt{3}$ weeks would not be easy to implement. The model might specify a schedule of orders that may not be an easily recognizable pattern; for example, Monday of the week, Thursday of the next week and Friday of the next week. Therefore, it is practical to consider the policies where the reorder intervals are restricted to values that are easy to implement.

In a paper by Viswanathan and Mathur (1997), the power of two policies are adopted for clustering and routing customers or product items that have the same replenishment intervals. According to Bramel and Simchi-Levi (1997), the power of two policies is the restriction where the reorder interval (T) is restricted to be a power of two multiples of some fixed base planning periods T_B. That is,

$$T = T_B 2^k \quad , k \in \{0, 1, 2, 3, \ldots\}. \qquad (17)$$

The base planning period T_B may represent a day, week, month, etc. If we let T be the optimal power of two-reorder interval, the optimal k in the above equation is the smallest integer k satisfying

$$f(T_B 2^k) \leq f\,(T_B 2^{k-1}) \tag{18}$$

where

$$f\,(T) = \frac{C}{T} + \frac{HRT}{2} \tag{19}$$

We have so far discussed the algorithm that solves the clustering phase in the vehicle routing problem and the one warehouse and multi-retailer distribution problem. However, we have not considered the routing phase for both problems. As discussed earlier in the VRP, the routing phase solution is to solve the travelling salesman problem. In Lawler et al., (1985), the travelling salesman problem finds the minimum travelling distance when starting from one point and visiting each customer on a given list once and then returning to the starting point. The nearest neighbor algorithm is a heuristic approach that determines the closest point on the current tour.

3.3.1 THE NEAREST NEIGHBOUR ALGORITHM

Based on the previous assumptions, the one warehouse and multi-retailer distribution problem consists of an inventory problem and vehicle routing problem. To solve this problem, the key concepts are clustering retailers based on the inventory restriction and routing each cluster based on retailers' location. Applying the classical EOQ model with the power of two policies can solve the inventory problem. As stated previously, the power of two policies makes the EOQ model practical. Therefore, the replenishment periods are generally in the form of 2, 4, 8, 16 and so on. Retailers whose replenishment intervals are the same will receive products at the same time and all retailers with smaller replenishment periods are also included in the same cluster. For instance, retailers with replenishment periods of two receive products every two weeks. At week 4, all retailers whose replenishment periods are 2 and 4 are served together.

Afterwards, the nearest neighbour algorithm will be solved for each cluster subject to vehicle capacity constraint.

Step 1 Calculate the EOQ, reorder interval (T) and total annual inventory costs for all retailers. These solutions are independent solutions.

$$Q = \sqrt{\frac{2CR}{H}} \tag{20}$$

$$T = \frac{Q}{R} \tag{21}$$

Total annual interval cost = order cost + holding cost

$$TC\,(Q) = \frac{C}{T} + \frac{HRT}{2} \tag{22}$$

Step 2 Round down and round up the reorder intervals into 2^k and recalculate their Inventtory costs and delivery quantities. Choose the one that gives lower inventory costs.

Step 3 All retailers that have the same reorder intervals will be clustered in the same group and the next cluster will be the next period of replenishment which includes the smaller value of reorder intervals as well.

Step 4 For each cluster or each replenishment period, create vehicle routes by starting at the warehouse and choose the closest retailer to the warehouse. Consider the next closest retailer to the routed retailer until the vehicle capacity is reached and then return to the warehouse. If including the next retailer results in exceeding the vehicle capacity, that retailer will not be included in the route and a new route will be created.

Step 5 Repeat step 4 until all retailers are routed.

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.0 INTRODUCTION

In this chapter, we shall consider a computational study of the Cluster First Route Second Algorithm applied to a Single Depot and Multiple Retailer Distribution Problem. Emphasis will be placed on a Single Depot and Multiple Retailer Distribution system, which is modelled as an Inventory Control Problem. Data from the CHOCHO Industry in Suhum which is a manufacturer of CHOCHO soap shall be examined.

4.1 Data Collection and Analysis

CHOCHO Industry, a manufacturer of CHOCHO soap operates a distribution system of one depot and six retailers in a suburb of Suhum Kraboa Coaltar District. The following set of data for the six retailers in 2012 financial year are shown in Table 4.1

Table 4.1 Inventory Information For the year 2012

DEPOT	DEMAND(UNIT)	SETUP COST	HOLDING COST	PURCHASE PRICE
RETAILER 1	5,000	200	20	200
RETAILER 2	2,000	200	20	200
RETAILER 3	100	200	20	200

RETAILER 4	4,000	200	20	200
RETAILER 5	500	200	20	200
RETAIER 6	200	200	20	200

The distances of the location of the various retailers are shown in Table 4.2

Table 4.2 Matrix of Distances of the location of various retailers in miles

	Depot 0	Retailer1	Retailer2	Retailer3	Retailer4	Retailer5	Retailer6
Depot 0	-	2	4	5	6	7	2
Retailer1	2	-	2	4	5	9	5
Retailer2	4	2	-	6	6	12	7
Retailer3	5	4	6	-	13	6	4
Retailer4	6	5	6	13	-	13	11
Retailer5	7	9	12	6	13	-	4
Retailer6	2	5	7	4	11	4	-

- The Vehicle Capacity is 300 Units
- Transportation Cost is 50 cedis per mile
- Fixed transportation cost is 200 cedis per route
- A year in the company's distribution plan equals to 40 weeks.
- A distributor load goods from the depot and is expected to deliver to the various retailers as possible on each route within each journey at a minimum distance in a day in order to minimize cost.

The problem at hand is to find the minimum distance that an officer could cover and visit all the retailers while meeting their Economic Order Quantity Demand (EOQ).

First, Modeling the above problem as an inventory control problem and calculating the EOQ, replenishment time and Total Annual Inventory Cost, we obtain

$$Q_i = \sqrt{\frac{2CR}{H}} \tag{23}$$

$$T_i = \frac{Q_i}{R} \tag{24}$$

$$TC(Q)_i = \frac{C_i}{T_i} + \frac{HRT_i}{2} \tag{25}$$

Thus, by applying Steps 1, and 2 of our algorithm with our data in Table 4.1, we obtain the following solution as shown in Table 4.3

Table 4.3: Solution to our Problem by applying the classical EOQ Model

Independent Model				Power of Two (round down)			Power of Two (round up)			Min. Cost Power of two policy	
EOQ (unit)	T (yr)	T (wk)	Cost (c/yr)	EOQ (units)	T (wk)	Cost (c/yr)	EOQ (units)	T (wk)	Cost c/yr	EOQ units	T wk
223.6	0.04	1.8	8944	125.0	1	10500	250.0	2	9000	250	2
141.4	0.1	2.8	5657	100.0	2	6000	200.0	4	6000	100	2
31.6	0.3	12.6	1265	20.0	8	1400	40.0	16	1300	40	16
200.0	0.1	2.0	8000	200.0	2	8000	400.0	4	10000	200	2
70.7	0.1	5.7	2828	50.0	4	3000	100.0	8	3000	50	4
44.7	0.2	8.9	1789	40.0	8	1800	80.0	16	2100	40	8

By applying Step 3, we Cluster all retailers who have the same reorder intervals in the same group and the next cluster will be the next period of replenishment which includes the smaller value of reorder intervals as well. This is shown in Table 4.4

Table 4.4: Cluster for Delivery Schedule

	Week2	Week4	Week8	Week16
Retailer No.	1,2,4	1,2,4,5	1,2,4,5,6	1,2,3,4,5,6

The Figures show the various routes for the clusters from the Depot showing the distances from the Depot to the various destinations and back to the depot by using the nearest neighbor heuristics. Hence, the problem for these sub tour becomes a Travelling Salesperson Problem (TSP) since a distributor has to travel from the Depot to the various retailers and back to the depot once.

The TSP can be easily stated as follows. A salesman wants to visit n distinct cities and then returns home. He wants to determine the sequence of the travel so that the overall traveling distance is minimized while visiting each city not more than once. Although the TSP is conceptually simple, it is difficult to obtain an optimal solution. In an n-city situation, any permutation of n cities yields a possible solution. As a consequence, n! possible tours must be evaluated in the search space.

By introducing variables x_{ij} to represent the tour of the salesman travels from city i to city j, one of the common integer programming formulations for the TSP can be written as:

$$\text{Minimize } z = \sum_{\substack{j=1 \\ j \neq i}}^{m} d_{ij} x_{ij} \tag{26}$$

Subject to

$\sum_{i=1}^{m} x_{ij} = 1 \qquad j = 1, 2, \ldots, m;\ i \neq j.$

$\sum_{j=1}^{m} x_{ij} = 1 \qquad i = 1, 2, \ldots, m;\ i \neq j.$

$u_i - u_j + m x_{ij} \leq m - 1 \quad i, j = 2, 3, \ldots, m;\ i^1\ j.$

All $x_{ij} = 0$ or 1, All $u_i \geq 0$ and is a set of integers

The distance between city *i* and city *j* is denoted as d_{ij}. The objective function Z is simply to minimize the total distance travelled in a tour. The first constraint set ensures that the salesman arrives once at each city. The second constraint set ensures that the salesman leaves each city once. The third constraint set is to avoid the presence of sub-tour. Generally, the TSP formulated is known as the Euclidean TSP, in which the distance matrix d is expected to be symmetric, that is $d_{ij} = d_{ji}$ for all i, j, and to satisfy the triangle inequality, that is $d_{ik} \leq d_{ij} + d_{jk}$ for all distinct *i, j, k*.

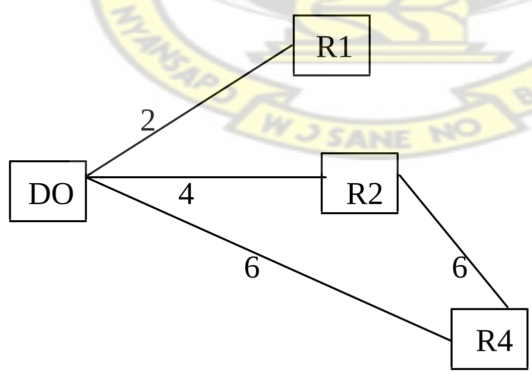

Figure 4.1: Routes for Week 2 Cluster Delivery Schedule

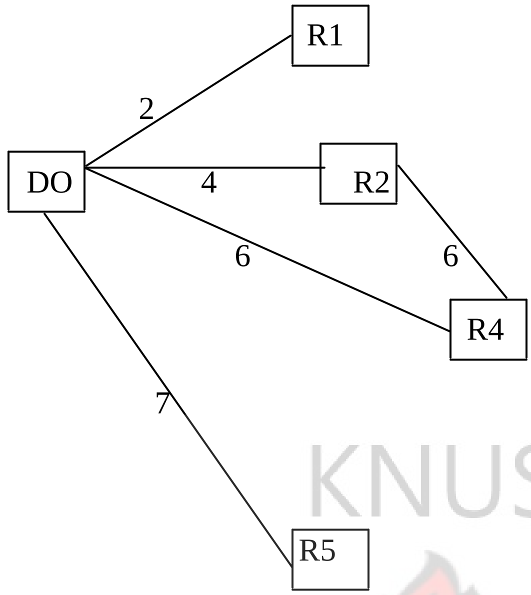

Figure 4.2: Routes for Week 4 Cluster Delivery Schedule

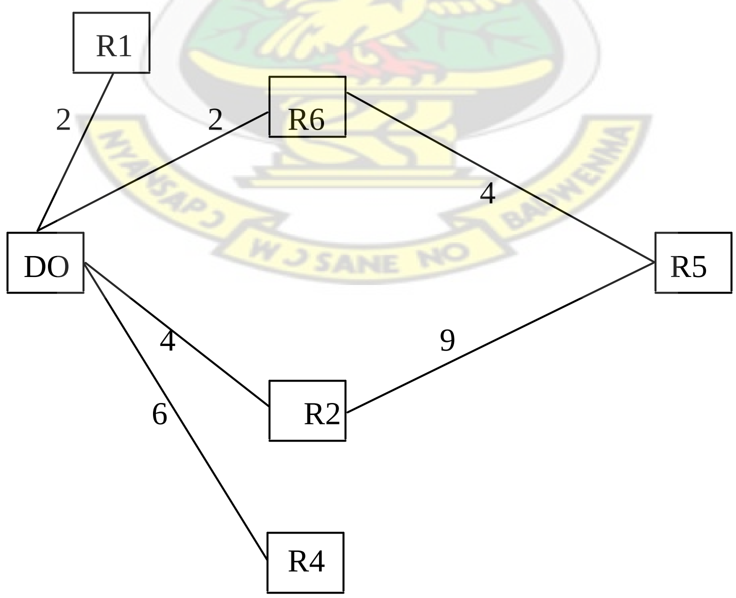

Figure 4.3: Routes for Week 8 Cluster Delivery Schedule

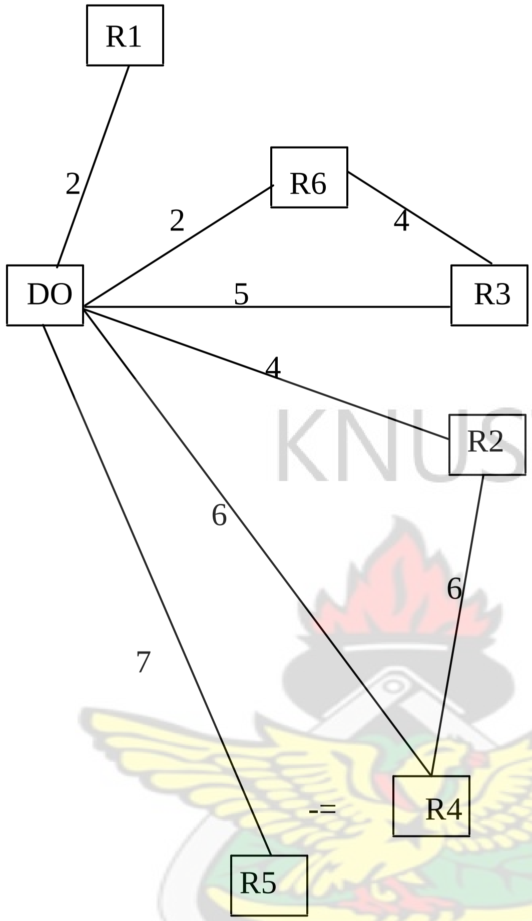

Figure 4.4: Routes for Week 16 Cluster Delivery Schedule

For each cluster or each replenishment period, we create vehicle routes by starting at the warehouse or depot and choose the closest retailer to the warehouse by using the nearest neighbor heuristics as in Steps 4 and 5. These give the solutions as shown in Table 4.5

Table 4.5 Solution by applying the cluster first route second

Week	Route	Q	Distance	Transport Cost
2	(0,2,4,0)	300	16	800
	(0,1,0)	250	4	200
	Total	550	20	1000
4	(0,1,0)	250	4	200
	(0,2,4,0)	300	16	800
	(0,5,0)	50	14	700
	Total	600	34	1700
8	(0,6,5,2,0)	190	19	950
	(0,1,0)	250	4	200
	(0,4,0)	200	12	600
	Total	640	35	1750
16	(0,6,3,0)	80	11	550
	(0,1,0)	250	4	200
	(0,2,4,0)	300	16	800
	(0,5,0)	50	14	700
	Total	680	45	2250

Total annual transportation cost

= $\sum(Variable\ Costs + Fixed\ Costs)$ * (period of distribution)

= GH₵ (1000 + 400) * 10 + (1700 + 600) * 5 + (1750 + 600)*3 + (2250 + 800)*2

= GH₵38,650.00

Total annual inventory cost

= $\sum(Annual\ inventory\ cost\ of\ retailer\ i)$

= (9,000 + 6,000 + 1,300 + 8,000 + 3,000 + 1,800)

= GH₵29,100.00

System annual cost = Transportation cost + Annual inventory Cost

= GH₵38,6500 + GH₵29,100

= GH₵67,750.00

RESULTS

The various feasible clusters of routes to be selected to achieve optimal distribution plan at minimum cost can be seen from Table 4.5.

The total cost to be incurred using this distribution plan is GH¢67,750.00, as against GH¢580,000.00 the company uses in distributing the goods yearly.

CONCLUSIONS

The solution to one warehouse and many retailers distribution system by applying cluster first route second is effective in giving optimal solution as compared with unplanned means of distributing a commodity. According to the concept of cluster first route second, the solution to this distribution problem consist of many feasible routes of neighbor retailers where the vehicle capacity is not violated.

Transportation costs involve fixed costs and variable costs. Fixed transportation costs, such as cost of hiring drivers and renting a car, are incurred once per trip whereas variable transportation costs, such as fuel expense and depreciation of trucks, depends on travelling distances and operating time. If fixed transportation costs are relatively high, an organization will naturally try to minimize the number of trips. Hence clustering the retailers in order to utilize the vehicle capacity is one way to minimize system costs.

We therefore recommend that our model should be adopted by the company for its distribution system planning.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 SUMMARY

Inventories are essential for keeping the production and distribution system moving as well as keeping the market going and the distribution system intact. They serve as lubrication and spring for the production and distribution systems of organizations. Inventories make possible the smooth and efficient operation of manufacturing organizations by decoupling individual segments of the total operation. Purchased parts inventory permits activities of the purchasing and supply department personnel to be planned, controlled and concluded somewhat independently of shop-product operations. These inventories allow additional flexibility for suppliers in planning, producing and delivering an order for a given products part. Inventory is essential to organization for production activities, maintenance of plant and machinery as well as other operational requirements. This results in tying up of money or capital which could have been used more productively.

The management of an organization becomes very concerned if inventory stocks are high. This therefore calls for its close scrutiny by management. Management is very critical about any shortage of inventory items required for production. Any increase in the redundancy of machinery or operations due to shortages of inventory may lead to production loss and its associated costs. These two aspects call for continuous inventory control. Inventory control and management not only looks at the physical balance of materials but also at aspects of minimizing the inventory cost.

The classic dilemma in inventory management is maintained in high service levels to meet the needs of customers while avoiding high stocks regardless of the type of items or even the department for which such stock is purchased.

Inventory Control Problem is a very attractive problem for the research community because it arises as a natural problem in many applications concerning the everyday life. Indeed, each application, in which an optimal ordering of a number of items has to be chosen in a way that the total cost of a solution is determined by adding up the costs arising from two successively items, can be modelled as an inventory control instance. Thus, studying inventory control problem can never be considered as an abstract research with no real importance.

5.1 CONCLUSIONS

In this thesis we have studied the concept of the inventory model, the power of two policies and the vehicle routing problem model to solve the one warehouse and multi-retailer distribution problem. Most studies have never considered both the inventory and the transportation problem together. Our solutions to the one warehouse and multi-retailer distribution system by applying our developed model gave optimal system cost.

According to the developed model, retailers are supplied according to their economic order quantities replenishment periods after applying our proposed methods and delivery policies. Retailers who are neighbors are supplied in the same route, based on cluster first route second. The solution shown gave remarkably better results than the independent model normally used by the company.

5.2 RECOMMENDATIONS

The use of mathematical models has proved to be efficient in the computation of optimum results and gives a systematic and transparent solution as compared with an arbitrary method. Operation has become one of the key competitive advantages with optimization-based approaches being expected to play an important role. Using optimization-based approaches to model industrial problem gives a better result. Management will benefit from the proposed approach for officers who would be assigning to distributing the company's product in order to minimize the systems cost on a route at a minimized distance. We therefore recommend that our model should be adopted by company for its distribution system planning.

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