OPTIMIZATION OF TRANSPORTATION COSTS IN SUPPLY CHAIN MANAGEMENT

(A CASE STUDY OF COCA-COLA PLANTS IN NIGERIA)

BY

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CERTIFICATION

I certify that this work "**Optimization of Transportation Costs in Supply Chain Management (A Case Study of Coca-Cola Plants in Nigeria)"** was carried out by **NNANNA INNOCENT.** (Reg. No: **20064738318**). In partial fulfillment for the award of the degree of (M. Eng. in Industrial Engineering in the department of Mechanical Engineering) of the Federal University of Technology, Owerri

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DEDICATION

This work is dedicated to the Almighty God and my family.

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ABSTRACT

In the manufacturing sector management of the supply chain expenses has been identified as major costs driven problem. For many years, researchers and practitioners have concentrated on the individual processes and entities within the Supply Chain. Recently, however, many companies have realized that important cost savings can be achieved through the reduction of transportation costs throughout their Supply Chain. As companies began realizing the benefits of optimizing transportation costs in their Supply Chain as a single entity, researchers began utilizing operations research techniques to better the model. In this thesis, optimization model using linear programming technique was developed to solve the transportation costs problem of Coca-Cola Company with respect to the operations of its plant at Aba, Owerri, Port Harcourt, and Enugu, and its depots in Mbaise, Orlu, Umuahia, Calabar and Uyo. Also considered were the truckload movements between the cities. The transportation costs problem was solved to obtain the plants-to-depots optimal truckload schedules using cost minimization as the objective function. Extensive surveys were carried out and data obtained were analyzed using a software package- TORA. The minimizing cost was obtained as N3,946million, which was found to be significant compared with the original cost of N21,412million. The problem was also subjected to sensitivity analysis and an efficient improvement on the model was achieved. The results showed that 39.20% of the company total expenditure in the transportation sector for six years was on maintenance, while 20.50%, 8.79% and 5.05% were on Fuel, drivers welfare and loading/offloading respectively.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The Nigerian Bottling Company Plc (NBC) was incorporated in November 1951, as a subsidiary of the A.G. Leventis Group with the franchise to bottle and sell Coca-Cola products in Nigeria.

From a humble beginning as a family business, the company has grown to become a predominant bottler of non-alcoholic beverages in Nigeria, responsible for the manufacture and sale of over 33 different Coca-Cola brands. Other popular brands of beverage produced by the company are Eva Water, Five Alive fruit juice and the newly introduced Burn energy drink.

The company has 13 bottling facilities and over 80 distribution warehouses located across the country. Since production started, NBC Plc has remained the largest bottler of non-alcoholic beverages in the country in terms of sales volume, with about 1.8 billion bottles sold per year, making it the second largest market in Africa.

Today, the company is part of the Coca-Cola Hellenic Bottling company (CCHBC), one of Coca-Cola Company's largest anchor bottlers worldwide.

CCHBC operates in 28 countries, serving 540 million consumers and selling over 1.3 billion unit cases of beverage annually.

The company recently embarked on a restructuring exercise to expand further its market share and growth profit. Watch Reporting Date: July 1, 2008 new state of the art can filling and packing line at the Apapa plant. The plant has since begun to produce the first soft drink can that is wholly packaged in Nigeria. The Company has four major plants and five major depots in south-south and south-east of Nigeria.

Considering a transportation problem faced by this company for six years. This problem involves the transportation of a truckload of their products from the four plants to the five depots at a minimal transportation cost. Production capacities of the Plants are adequate to satisfy their customers, but with limited available of number trucks.

1.1.1 SUPPLY CHAIN MANAGEMENT

Supply chain management is a field of growing interest for both companies and researchers. A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products and the distribution of these finished products to customers (Eksioglu, 2001). Supply chain exists in both service and manufacturing organizations, although the complexity of the chain may very greatly from industry to industry and firm to firm.

However, a supply chain (SC) can be defined as an integrated process where different business entities such as suppliers, manufacturers, distributors, and retailers work together to plan, coordinate, and control the flow of materials, parts, and finished goods from suppliers to customers (Sumis et al, 2001). This chain is concerned with two distinct flows: a forward flow of materials and a backward flow of information.

As mentioned above, a supply chain is an integrated manufacturing process wherein raw materials are converted into final products, then delivered to customers. At its highest level, a supply chain comprises two basic, integrated processes: (1) the Production Planning and Inventory Control Process, and (2) the Distribution and Logistics Process.

These processes, illustrated in Figure 1.1, provide the basic framework for the conversion and movement of raw materials into final products

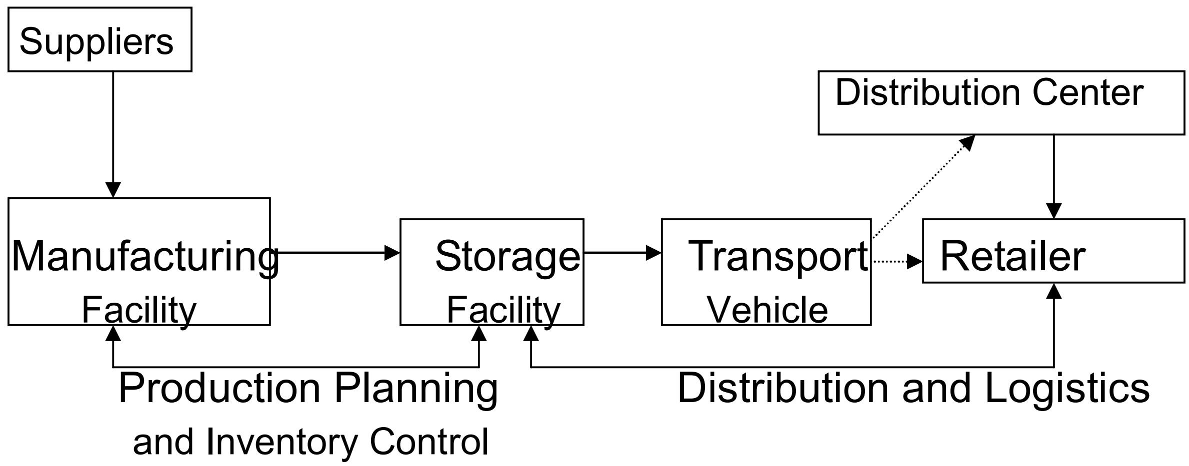

Figure 1.1 The Supply Chain Process

The Production Planning and Inventory Control Process encompasses the manufacturing and storage sub-processes, and their interface(s). More specifically, production planning describes the design and management of the entire manufacturing process (including raw material scheduling and acquisition, manufacturing process design and scheduling, and material handling design and control). Inventory control describes the design and management of the storage policies and procedures for raw materials, work-in-process inventories, and usually, final products.

The Distribution and Logistics Process determines how products are retrieved and transported from the warehouse to retailers. These products may be transported to retailers directly, or may first be moved to distribution facilities, which, in turn, transport products to retailers. This process includes the management of inventory retrieval, transportation, and final product delivery. These processes interact with one another to produce an integrated supply chain. The design and management of these processes determine the extent to which the supply chain works as a unit to meet required performance objectives.

A good supply chain consists of many entities interacting directly or indirectly to fulfill a customer's request. There are five major drivers within the supply chain that determine its performance in terms of responsiveness and efficiency. These drivers are facilities, production, inventory, transportation and information (Eksioglu, 2001).

Supply chain management (SCM) is the term used to describe the management of the flow of materials, information, and funds across the entire supply chain, from suppliers to component producers to final assemblers to distribution (warehouses and retailers), and ultimately to the consumer. In contrast to multiechelon inventory management, which coordinates inventories at multiple locations, SCM typically involves coordination of the following functions and activities along the supply chain:

- Planning and managing of supply and demand
- Acquiring material
- transportation and logistics
- Inventory control and forecasting
- Producing and scheduling the product or service

– Delivery and customer service

Supply chain management as stated earlier is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that each merchandise is produced and distributed in the right quantities, to the right locations and at the right time, in order to minimize system-wide cost while satisfying service level requirements. Supply chain optimization is a key to successful supply chain management.

From the definition of Supply Chain Management, it is obvious that optimization plays a key role in supply chain management. Optimization begins with the development of a mathematical model that defines the problem and its parameters. Each business issue is represented as a "variable," while the relationships between business issues are formulated as "constraints" and the desired "objective" (such as, to minimize total cost) is imposed. All input data have to be collected and analyzed before they are fed into the model. At last, the model is processed by using a "solver" which processes the data and applies different algorithmic approaches to find an optimized solution. This "modeling" process is necessary for virtually every optimization problem.

Generally, the model must represent the important aspects of a supply chain in order to provide a useful solution. For example, strategic supply decisions typically use aggregate models, which do not include every factor (Jayamaran, 2000). On the other hand, operational supply chain decisions use models that include almost all factors and require detailed data.

Optimization is a technique for calculating the best possible utilization of resources (people, time, processes, vehicles, equipment, raw materials, supplies, capacity, etc.) needed to achieve a desired result, such as minimizing cost or maximizing profit.

1.1.2 OPERATIONS RESEARCH IN SUPPLY CHAIN MANAGEMENT

The mission of operations research is to support real-world decision-making using mathematical and computer modeling, (Luss and Rosenwein, 2000). Supply Chain Management is one of the areas where operations research has proved to be a powerful tool.

Many times this leads to a more effective performance of the supply chain while maintaining or even improving the customer service level. There are many examples of different scientific approaches used in the development of decision support systems.

The vast literature devoted to quantitative methods in Supply Chain Management also suggest the importance of Operations Research in supply chain management. Geunes and Chang (2000), give a survey of models in Operations Research emphasizing the design of the supply chain and the coordination of decisions.

1.1.3 COORDINATION IN SUPPLY CHAIN

A company delivers its products to its customers by using a logistics distribution network typically consisting of product flows from the producers to the customers through transshipment points, distribution centers (warehouses), and retailers. In addition, it involves a methodology for handling the products in each of the levels of the logistics distribution network, for example, the choice of an inventory policy, or the transportation mode to be used.

Designing and controlling a logistics distribution network involve different levels of decision-making, which are not independent of each other but exhibit interactions. At the operational level, day-to-day decisions like the assignment of the products ordered by individual customers to trucks, and the routing of those trucks must be taken. The options and corresponding costs that are experienced at that level clearly depend on choices that have been made at the longer term tactical level. The time horizon for these tactical decisions is usually around one year (Geunes and Chang, 2002). Examples of decisions that have to be made at this level are the allocation of customers to warehouses and how the warehouses are supplied by the plants, the inventory policy to be used, the delivery frequencies to customers, and the composition of the transportation fleet. Clearly, issues that play a role at the operational level can dictate certain choices and prohibit others at the tactical level. For instances, the choice of a transportation mode may require detailed information about the current transportation costs which depend on decisions at the operational level. Similarly, the options and corresponding costs that are experienced at the tactical level clearly depend on the long-term strategic choices regarding the design of the logistics distribution network that have been made. The time horizon for these strategic decisions to be made at this level are the number, the location and size of the production facilities (plants) and distribution centers (warehouses), but again, issues that play a role at the tactical level. When designing the layout of the logistics distribution network may requires detailed information about the actual transportation costs, which is an operational issue as mentioned above.

To ensure an efficient performance of the supply chain, decisions having a significant impact on each other must be coordinated. For instance, companies believe that capacity is expensive (Bradley and Arntzen, 2002). This has a twofold consequence. Firstly, the purchase of production equipment is made by management, while the production schedules and the inventory levels are decided at lower levels in the company. Therefore, the coordination between those decisions is often used to full capacity, which leads to larger inventories than necessary to meet the demand and causes an imbalance between capacity and inventory investments. Bradley and Arntzen (2002), proposed a model where the capacity and the show the opportunities for improvement in the performance of the supply chain found in two companies.

Coordination is not only necessary between the levels of decision- making but also between the different stages of the supply chain, like procurement, production and distribution.

1.1.4 SUPPLY CHAIN DECISIONS

Supply chain decisions can be classified in the following way: (Arntzen, 2002)

1) Strategic level. These are long-term decisions that have long-lasting effects on the firm such as the number, location and capacities of warehouses and manufacturing facilities, or the flow of material through the supply chain network. The time horizon for these strategic decisions is often around three to five years.
2) Tactical level. These are decisions that are typically updated once every quarter or once every year. Examples include purchasing and

production decisions, inventory polices and transportation strategies including the frequency with which customers are visited.

3) Operational level. These are day-to-day decisions such as scheduling, routing and loading trucks. The effort in these type of decisions is to effectively and efficient manage the product flow in the “Strategically” planned supply chain.

There are major decision areas in Supply Chain Management namely:

(1) Location (2) Production (3) Inventory (4) Transportation (distribution)

1.1.4.1 LOCATION DECISIONS

The geographic placement of production facilities, stocking plants, and sourcing points is the natural first step in creating a supply chain. The location of facilities involves a commitment of resources to a long-term plan. Once the size, number, and location of these are determined, so are the possible paths by which the product flows through to the final customer. These decisions are of great significance to a firm since they represent the basic strategy for accessing customer markets, and will have a considerable impact on revenue, cost and level of service. These decisions should be determined by an optimization routine that considers production costs, taxes, duties and duty drawback, tariffs, local content, distribution costs, production limitations, etc.

1.1.4.2 PRODUCTION DECISIONS

The strategic decisions include what products to produce, and which plants to produce them in, allocation of suppliers to plants, plants to Distribution Center's (DC's) and Distribution Center's (DC's) to customer markets. These decisions have a big impact on the revenues, costs and customer service levels of the firm. These decisions assume the existence of the facilities, but determine the exact path(s) through which a product flows to and from these facilities. Another critical issue is the capacity of the manufacturing facilities and this largely depends on the degree of vertical integration within the firm. Operational decisions focus on detailed production scheduling. These decisions include the construction of the master production schedules, production on machines, and equipment maintenance. Other considerations include workload balancing, and quality control measures at production facility.

1.1.4.3 INVENTORY DECISIONS

These refer to means by which inventories are managed. Inventories exist at every stage of the supply chain as either raw materials, semi-finished goods. They can also be in-process between locations. Their primary purpose to buffer against any uncertainty that might exist in the supply chain. Since holding of inventories can cost anywhere between 20 to 40 percent of their value, their efficient management is critical in supply chain operations. It is strategic in the sense that top management sets goals. However, most researchers have approached the management of inventory from an operational perspective. These include deployment strategies (push versus pull) control policies – the determination of the optimal levels of order quantities and reorder points, and setting safety stock levels, at each stocking location. These levels are critical, since they are primary determinants of customer service levels.

1.1.4.4 TRANSPORTATION DECISIONS

The aspects of these decisions are the more strategic ones. These are closely linked to the inventory decisions, since the best choice of mode is often found by trading-off the cost of using the particular mode of transport with the indirect cost of inventory associated with that mode. While air shipments may be fast, reliable and warrant lesser safety stocks, they are expensive. Meanwhile shipping by sea or rail may be much cheaper, but they necessitate holding relatively large amounts of inventory to buffer against the inherent uncertainty associated with them. Therefore customer service levels and geographic location play vital roles in such decisions. Since transportation is more than 30 percent of the logistics costs, operating efficiently makes good economic sense (Dinesh et al, 2003).

Shipment sizes (consolidated bulk shipments versus lot-for-lot), routing and scheduling of equipment are keys in effective management of the firm's transport strategy.

For many years, researchers and practitioners have concentrated on the individual processes and entities within the Supply Chain recently; however, there has been an increasing effort in the optimization of the entire Supply Chain (Dinesh et al, 2003). As companies began realizing the benefits of optimizing the Supply Chain as a single entity, researchers began utilizing operations research (OR) techniques to model supply chains. Typically, a Supply chain model tries to determine

- the transportation modes to be used,
- the suppliers to be selected,
- the amount of inventory to be held at various locations in the chain
- the number of warehouses to be used, and
- the location and capacities of these warehouses.

1.1.5 SUPPLY CHAIN MODELING APPROACHES

Clearly, each of the levels of decisions requires a different perspective. The strategic decisions are, for the most part, global or "all encompassing" in that they try to integrate various aspects of the supply chain. Consequently, the models that describe these decisions are huge, and require a considerable amount of data. Often due to the enormity of data requirements, and the broad scope of decisions, these models provide approximate solutions to the decisions they describe. The operational decisions, meanwhile, address the day to day operation of the supply chain. Therefore the models that describe them are often very specific in nature. Due to their narrow perspective, these models often consider and provide very good, if not optimal, solutions to the operational decisions.

To facilitate a concise review of the literature, and at the same time accommodate the above polarity in modeling, the modeling approaches was divided into two areas namely: Network Design and Linear programming methods. The network design methods, for the most part, provide normative models for the more strategic decisions. These models typically cover the four major decision areas described earlier, and focus more on the design aspect of the supply chain; the establishment of the network and the associated flows on them. Linear programming method is a method by which a comprehensive supply chain mode can be analyzed, considering both strategic and operational elements. However, as with all transportation models, one can only minimize cost and also maximize the company's profit. It is the traditional question of "What If?" versus "What's Best?"

Most of these supply chain problems can be modeled as mathematical programs that are typically global optimization problems.

1.2 STATEMENT OF PROBLEM

The Company is one of the leading soft drinks producers and distributors in the world, dealing with different kinds of mineral drinks, Eva water, e.t.c. The company developed its product exponentially recently and it is presently in 17 countries including Nigeria. Considering Nigeria only, it has bought 20 other companies between 2002 and 2006, including 8 from Nigeria. Its shares have been doubled since 2001.

The company intends to expansion both globally and in Nigeria. The management is faced with new challenges because of the sudden increase in the number of affiliated depots in South-East and South-South. The producing capacities distributed in plants were coordinated to minimize the transportation costs. Considering this situation, this work developed new optimization model (Linear programming) for solving transportation costs problems of the Company with linear cost structure. This will help to produce optimal or near optimal solutions to transportation problem (cost minimization).

1.3 OBJECTIVE OF THE STUDY

The objectives of this research work are as follows:

- To optimize the supply chain management operations with respect to cost of transportation.

- To use TORA software package to obtained the result.

- To determine the best transportation schedule that minimizes the total transportation costs with supply and demand limits.

1.4 JUSTIFICATION OF THE STUDY

For many years, researchers and practitioners have concentrated on the individual processes and entities within the supply chain. Recently; however, many companies have realized that important cost savings can be achieved by reducing transportation costs throughout their Supply Chain. However, as companies began realizing the benefits of optimizing their Supply Chain, researchers began utilizing operations research techniques to better model supply chains (Hamdy, 2008). Transportation model deals with get the minimum cost plan to transport a product from a number of sources to number of destinations. Minimizing cost is very beneficial to the companies in order to maximize their profits.

1.5 SCOPE OF THE STUDY

This study concentrates on Coca-cola plants in the South-East and South-South geopolitical region of Nigeria.

It also concentrates on model formation, computations in LP and the use of TORA software package to produce optimal solution of the problem.

CHAPTER TWO

2.0 LITERATURE REVIEW

Literature shows a number of approaches for modeling supply chain optimization situations. Jonathan et al (2001), show an example of how expert systems techniques for distributed decision-making can be combined with contemporary numerical optimization techniques for the purposes of supply chain network system with the manufacturing component being optimized through mathematical programming with the objective of reducing operating cost while maintaining high level of customer order fulfillment. Jen et al (2004), propose a hybrid approach for managing supply chain that incorporates simulation, Taguchi techniques, and response surface methodology to examine the interaction among the factors, and to search for the combination of factor levels throughout the supply chain to achieve the ‘optimal’ performance. Dimitris et al (2004), suggest a general methodology based on robust optimization to address the problem of optimally controlling a supply chain subject to stochastic demand in discrete time. Optimal supply chain management has been extensively studied in the past using dynamic programming (Dimitris et al, 2004).

Supply chain problems are characterized by decisions that are conflicting by nature. Pinto (2003), says that modeling these problems using multiple objectives gives the decision maker a set of pareto optimal solutions from which to choose. His paper discusses the use of Multi-objective evolutionary algorithms to solve pareto optimality in supply chain optimization problems using non-dominated sorting genetic algorithm-II.

Recently researchers have started developing models based on multi-objective functions (Min and Melachrinoudis, 2000; Nozick and Turnquiest, 2001).

Dinesh et al (2003), developed a Goal Programming (GP) model with penalty functions for management decision-making in oil refineries in the context of transshipment problems.

Eksioglu (2001), discussed some of the recent models that address the design and management of global supply chain networks.

Elif Kongar et al (2003), illustrate a GP approach to the remanufacturing supply chain model, in the context of environmentally conscious manufacturing. They present a quantitative methodology to determine the allowable tolerance limits of planned/unplanned inventory in a remanufacturing supply chain environment based on the decision maker's unique preferences, by applying an integer GP model that provides a unique solution for the allowable inventory levels. The need for a multi-objective based decision support model is emphasized in a paper due to the environmentally conscious manufacturing set up, it is no linger realistic to use a single objective function since the introduction of restrictive regulations makes the decision procedure more complicated and mostly multi-objective. The need for a multi-objective decision criterion, which is more flexible to changes in decision criteria and governmental regulations, is emphasized in a paper. The model, while fulfilling an acceptable profit level should also capable of satisfying additional goals simultaneously. GP approach is especially appropriate for decision-maker centered cases.

Supply chain problems includes transportation and transshipment problems which is a modified version of the transportation problem, where goods and services are allowed to pass through intermediate points while going from original sources to final destinations.

2.1 TRANSPORTATION MODEL

In 1941 Hitchcock first developed the transportation model. Roy and Gelders (2005), solved a real life distribution of a liquid bottled product through a 3-stage logistic system; the stages of the system being plant-distributor and distributor-dealer. They modeled the customer allocation, depot location and transportation problem as a 0-1 integer programming model with the depot setup costs, and delivery costs subject to supply constraints, demand constrains, truck load capacity constrains, and driver hours constraints. The problem was solved optimally by branch and bound, and Langrangian relaxation.

Fisher and Jaikumar (2001), developed a generalized assignment for vehicle routing. They considered a problem where a multi-capacity vehicle fleet delivers products stored at a central depot to satisfy customer orders. The routing decision involves determining which of the demands will be satisfied by each vehicle and what route each vehicle will follow in servicing its assigned demand in order to minimize total delivery cost. They claim their heuristics will always find a feasible solution if one exists, something no other existing heuristics (until that time) can guarantee. Further, the heuristics can be easily adapted to accommodate many additional problem complexities.

Laporte et al. (2000), examined a class of asymmetrical multi-depot vehicle routing problems and location-routing problems, under capacity or maximum cost restrictions. The problem was formulated as a traveling salesman problem (TSP) in which it is required to visit all specific nodes exactly once and all non-specified nodes at most once. And, there exist capacity and maximum cost constraints on the vehicle routes; plus, all vehicles start and end their journey at a depot, visit a number of customers and return to the same depot. Leung et al. (2000), develop an optimization-based approach for a point-to-point route planning that arises in many large-scale delivery systems, such as communication, rail, mail, and package delivery. In these settings, a firm, which must ship goods between many origin and destination pairs on a network, needs to specify a route for each origin destination pair so as to minimize transportation costs. They developed a mixed multi-commodity flow formulation of the route planning problem, which contains sixteen million 0-1 variables, which is beyond the capacity of general IP code. The problem was decomposed into two smaller sub-problems, each amenable to solution by a combination of optimization and heuristic techniques. They adopted solution methods based on Langrangian relaxation for each sub-problem.

Saumis et al. (2001), considered a problem of preparing a minimum cost transportation plan by simultaneously solving the following two sub-problems: first the assignment of units available at a series of origins to satisfy demand at a series of destinations and second, the design of vehicle tours to transport these units, when the vehicles have to be brought back to their departure point. The original cost minimization mathematical model was constructed, which is converted into a relaxed total distance minimization, then finally decomposed into network problem, a full vehicle problem, and an empty vehicle problem. The problems were solved by tour construction and improvement procedures. This approach allows large problems to be solved quickly, and solutions to large test problem have been shown to be 1% or 2% from the optimum.

Achuthan et al. (2004), wrote an Integer programming model to solve a vehicle routing problem (VRP) with the objective of distance minimization for the delivery of a single commodity from a centralized depot to a number of specified customer locations with known demands using a fleet of vehicles that a have common capacity and maximum relaxed total distance restrictions. They introduced a new sub-tour elimination constraint and solved the problem optimally using the branch and bound method and used the CPLEX software to solve the relaxed sub-problems. Tzeng et al. (2005), solved the problem of how to distribute and transport the imported coal to each of the power on time in the required amounts and at the required under conditions of stable and supply with least delay. They formulated a LP that minimizes the cost of transportation subject to supply constraints demand constraints vessel constraints and handling constraints of the ports. The model was solved to yield optimum results, which is then used as input to a decision support system that help manage the used as input to a decision support system that help manage the coal allocation, voyage scheduling, and dynamic fleet assignment. Fisher et al. (2005), worked on a problem in which a fleet of homogeneous vehicles stationed at a central depot must be scheduled and routed to pickup and deliver a set of orders in truckload quantities. They defined schedule as a sequential list of the truckload orders to be carried by each vehicle, that is, where the bulk pickups and the delivery points are. They solved the problem by a network flow based heuristic, and claimed their algorithm consistently produces solutions 1% of optimality.

A major oil company in the United Sates has dispatchers that are responsible for assigning itineraries to drivers to pickup crude products, using homogeneous capacity tank trucks, at designated locations for delivery to pipeline entry points.

Brandao and Mercer (2006), used the tableau search heuristic to solve the multi-trip vehicle routing and scheduling in a distribution problem, taking into account into only the constraints delivery time windows, multi capacity vehicles, access to some customers is restricted to some vehicles, and drivers have maximum driving time with breaks.

Equi et al. (2001), modeled a combined transportation and scheduling in one problem where a product such as sugar cane, timber or mineral ore is transported from multi origin supply points to multi destination demand points or transshipment points using carriers that can be ships, trains or trucks. They defined a trip as a full-loaded vehicle travel from one origin to one destination. They solved the model optimally using langrangean decomposition.

Jayamaran (2000), formulated a mixed integer programming model that looked into the relationship between inventory, location of facilities and transportation issues in a distribution network design. The formulation involves minimizing t he cost of warehouse and plants location, inventory related costs and transportation costs of products from open plants to open warehouses and costs to deliver t he products from warehouses to customer outlets. Kim and Pardalos (2000), considered the fixed charge network flow problem, which has many practical applications including transportation, network design, communication, and product scheduling. They transformed the original discontinuous piecewise linear formulation into a 0-1 mixed IP problem to solve very large problem of up to 202 nodes and 10,200 arcs using a heuristics called dynamic slope scaling procedure that generate solutions within 0% to 0.65% of optimality in all cases.

Wang and Regan (2000), describe a solution method for a multiple travel salesman problem with time window constraints to develop vehicle assignment for a local truckload pickup and delivery. The integer 0.1 model was developed with time objective to minimize total transportation cost with fleet size fixed, vehicle to pick up and leave each load at most once, vehicle departs from a load only if it serves the load first, and time window requirements. The model was run to optimality using CPLEX version 5.0.

Budenbender et al. (2000), worked on a network design problem for letter mail transportation in Germany with the following characteristics; freight has to be transported between large number of origins and destinations, to consolidate it is first shipped to a terminal where it is reloaded and then shipped to its destination. The task is to decide which terminals have to be used and how the freight is transported among terminals. They modeled the problem as capacitated warehouse location problem with side constraints using mixed IP and solved by a hybrid tableau search/ branch-and-bound algorithm.

Chao (2000), studied the truck and trailer routing problem, which is a variant of the vehicle routing problem. The problem looked into some real-life applications in which fleet of mk trucks and ml trailers (mk>ml) services a set of customers. There are three types of routes in a solution to the problems: (1) a pure truck route traveled by a truck alone, (2) a pure vehicle route without any sub-tours traveled by a complete vehicle and (3) a complete route consisting of a main tour traveled by a complete vehicle, and one or more sub-tours traveled by a truck alone. A sub-tour begins and finished at a customer on the main tour where the truck uncouples, parks, and re-couples its pulling trailer and continues to service the remaining customers on the sub-tour. The objective is to minimize the total distance traveled, or total cost incurred by the fleet. He solved the problem tabular search and deterministic annealing.

Irnich (2000), introduced a special kind of pickup and delivery problem, called 'multidepot pickup and delivery problem with a single hub and heterogeneous vehicle'. All request have to be pickup at or delivered to one central location which has the function of a hub or consolidation point. In hub transportation network routes between customers and the hub are often shortly involve only one or very few customers. The problem primarily considers the assignment of transportation request to routes. The author concludes that many problems in transportation logistics can be modeled and solved similarly whenever routes can be enumerated and the temporal aspects of transportation requests are important.

Diaz and Perez (2000), applied the simulation optimization approach proposed by Vashi and Bienstock (1995) to solve the sugar cane transportation problem in Cuba that involved thousands of workers, dozens of cutting machines, hundreds of tractors and several hundreds of truck and trailers. Li and Shi (2000) formulated a dynamic transportation model with multiple criteria and multiple constraints (MC2) LP. An algorithm is developed to solve such DMC2 transportation problems. In this algorithm, dynamic programming ideology is adopted to find the optimal sub-policies and optimal policy for a given DMC2 locate the set of all potential solutions over possible changes of the objective coefficient parameter and the supply and demand parameter for the DMC2 transportation problem.

Cheung and Hang (2001), studied a routing problem for a land transportation of air-cargo freight forwarders in Hong Kong, which allows time windows, backhauls, heterogeneous vehicles, multiple trips per vehicle and penalty for early arrival at customer sites. They formulated an IP to minimize the traveling costs and waiting costs subject to demand constraints, and capacity constraints. They developed two optimization-based heuristics to solve the problem, and using real data they showed that the model produce quality solutions quickly and are flexible in incorporating complex constraints.

The classical vehicle routing problem (VRP) consists of a set of customers with known locations and demands, and a set of vehicles with a limited capacity, which is to service the customers from a central location referred to as depot. The routing problem is to service all the customers without overloading the truck, while minimizing the total distance traveled and using minimum number of trucks. Thangiah and Salhi (2001), studied a multi depot vehicle starting from different depots, which is an extension of the classical VRP. They solved the problem by a generalized clustering method based on a genetic algorithm, called genetic clustering.

Doerner et al. (2001), solved a problem for a logistics service provider to satisfy a set of transportation requests between distribution centers. Each order is characterized by its size, it fills a truck completely, and its time window for pickup and delivery. Since consolidation is not an option, each order is transported directly from its source to its destination. The available fleet is distributed over the distribution centers, and each vehicle is constrained by ant colony optimization.

Wu et al. (2002), proposed a decomposition-based method for solving the location routing problem (LRP) with multiple depot, multiple fleet types, and limited number of vehicles for each different vehicle type. Like in any LRP it is assumed that the number, location and demand of customers, the number, and location of all potential depots, as well as the fleet type and size are given. The distribution and routing plan must be designed so that; the demand of each customer can be satisfied, each customer is served by exactly one vehicle, the total demand on each route is less than or equal to the capacity of the vehicle assigned to that route, and each route begins and ends at the same depot. Decision must be made on the location for factories/warehouse/distribution centers DC, referred as depots. Also, the allocation of customers to each service area must be decided. Transportation must be planned to connect customers, raw materials, plants, warehouses, and channel members. They formulated the mathematical problem to solve the above decisions simultaneously with the objective function to minimize the depot setup cost, delivery cost and the dispatching cost for the vehicle assigned subject to the following constraints (1) each customer assigned on a single route (2) vehicle capacity (3) sub-tour not allowed (4) flow conservation (5) each route served at most once (6) capacity for DC (distribution center) (7) customer assigned to DC if there is a route from that DC through that customer. This problem was solved using simulated annealing.

Gronalt et al. (2002), studied pickup and delivery of truckloads under time window constraints. A logistic service provider studied, accepts orders from customers requiring shipments two locations, and serves the orders from a number of distribution centers. Thus, shipments occur between the pickup location of an order and the closest distribution center, between distribution centers and between a distribution center and the delivery location of an order. The problem was formulated as a mix integer program with the objective of minimizing empty vehicle movement, and solved using a heuristic known as saving algorithm proposed by Clark and Wright (1963).

Glgler et al. (2002), applied dynamic programming (DP) in the supply chain of agricultural commodities, or what they called as agric chains. They applied DP methodology specifically in a case of the supply chain of willow biomass fuel to an energy plant. Included in the DP approach not only transportation but also various stages of handling (harvesting) and processing (natural drying) of the biomass fuel.

The most commonly used techniques for solving transportation problem are linear programming (LP) and generalized minimum cost network flow approach. These are single objective optimization techniques used for cost minimization. Dinesh et al (2003), developed a GP model with penalty functions for management decision-making in oil refineries in the context of transshipment problems.

In this thesis linear programming technique was used and the model was run to optimality using TORA software package.

CHAPTER THREE:

3.0 RESEARCH METHODOLOGY

STEP ONE:

A comprehensive literature review of the available work done on Supply Chain Management (SCM). The review include recent literature on the subject that addresses

- Concept of SCM
- SCM methodology
- Transportation model

Besides discussing other SCM related issues.

STEP TWO:

Design of a questionnaire related to SCM optimization in the Coca Cola Company, to identify views of Supply Chain Mangers about the transportation cost problem in Supply Chain Management.

STEP THREE:

Questionnaire submitted to the Supply Chain Manger, Coca Cola plant at Oweri, Aba, Port Harcourt, and Enugu.

STEP FOUR:

Data was collected

STEP FIVE:

Collected data was analyzed

STEP SIX:

Results from the analyzed data were summarized and presented in chats

STEP SEVEN:

Conclusion of the research and recommendation

3.1 DESIGN OF QUESTIONNAIRE

The questionnaire sought the opinion of the Supply Chain Manager on vital of supply chain operational records. Four copies questionnaire, accompanied by a covering letter (refer to Appendix C) was sent to the supply chain manager of each plant. The questionnaire was designed in such a way that it can be completed in 30 minutes considering the busy schedule of the Supply Chain Manager.

It includes the following for the period (2003 – 2008)

- Fueling cost per truckload per plant
- Maintenance cost per truckload per plant
- Loading/Off loading cost per truckload per plant
- Personnel cost per truckload per plant
- Quantity demanded by the depots per truckload
- Quantity supplied from the Plants to the depot centers per truck load

- Number of depots or Warehouses/Location
- Number of truckload/month/plant (Supply)
- Total Quantity demanded per month
- Total Quantity supplied per month
- Distance from plants to depots in mileage
- Average transportation cost per kilometer (km) for loaded and empty trucks.

3.2 SAMPLE SURVEY/DATA COLLECTION

Selection of the sample for the survey from the list of manufacturing companies in Nigeria plays a major role in making the research more effective and representative. By carefully considering the research theme from different angles and by avoiding any possible conflict and discrepancies in the collected data, only Coca Cola Plant was selected. The sample reflected the following transportation problem variations: mileage, maintenance, fuel, driver's welfare loading and offloading rates, quantity demanded and quantity supplied.

Table 3.1 shows the average number of truckloads/month per Plant.

Table 3.1: Average number of truckloads/month per Plant (2003-2008)

Plant	Ave. number of truckloads/month per plant (Supply)
Aba	15
Owerri	15
Port Harcourt	15
Enugu	15

Table 3.2 shows the five depots and average number of truckloads/month (demand) per depot.

Table 3.2: The five depots and average number of truckloads/month (demand) per depot (2003-2008)

Depot	Average truckloads/month per depot (Demand)
Mbaise	4
Orlu	7
Umuahia	16
Calabar	18
Uyo	18

Table 3.3 shows the average distance from each plant to each depot.

Table 3.3: Average distance from Plants to Depots

	Distance to depot (km)				
Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo
Aba	77.1	92.1	58.0	156	73.4
Owerri	15	30	58.3	201	135.5
Enugu	161	176	127	292	210
Port Harcourt	111.6	126.6	114	196	134

Table 3.4 shows the transportation costs per truckload per annum.

Table 3.4: Transportation costs (₦m) per annum (2003 – 2008)

	YEAR					
COST ELEMENT	2003	2004	2005	2006	2007	2008
Maintenance	0.9315	0.9410	0.9511	0.8424	0.9910	0.8910
Personnel	0.3910	0.3910	0.4010	0.4010	0.4110	0.4110
Fuel	0.4460	0.4540	0.4580	0.4650	0.4670	0.4903
Loading/Off loading	0.3421	0.3531	0.3532	0.3650	0.3410	0.3610

Table 3.5 shows the four transportation costs constraints per truckload per plant of the company.

Table 3.5: The transportation costs constraints per truckload per plant (2003-2008)

	Costs constraints (₦m) per truckload per plant			
Plant	Maintenance	Fuel	Personnel	Loading/off loading
Aba	1.173	0.5867	0.5433	0.4167
Owerri	1.227	0.6133	0.5567	0.5233
Enugu	1.867	0.9333	0.7167	0.6433
Port Harcourt	1.280	0.6400	0.5893	0.5321

Tables 3.3 and 3.5, were used to determine the average transportation cost as ₦54.31 per kilometer (km) for both loaded and empty trucks. The Plant Supply chain Managers estimated the number of truckloads of the products coming off each plant monthly based on the number of trucks available. The depots Managers have estimated the number of truckloads of the products their depot need each month. Table 3.6 shows round trip transportation costs per truckload.

Table 3.6: Round-trip transportation costs per truckload (2003-2008)

	Transportation cost (₦m) per truckload per depot				
Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo
Aba	0.6030	0.7203	0.4536	1.2200	0.5740
Owerri	0.1173	0.2346	0.4559	1.5719	1.0597
Enugu	1.2591	1.3764	0.9932	2.2836	1.6423
Port Harcourt	0.8728	0.9901	0.8916	1.5328	1.0480

*(77.1km x 2) x (12months x 6years) x (₦54.31 per km) = ₦602971.344 = ₦0.6030million.

Table 3.7 shows the summary of the transportation problem

Table 3.7: Transporting costs, truckloads available and truckloads demanded (2003-2008)

	Transportation cost (₦m) per truckload per depot					
Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo	Ave. available truckloads/plant
Aba	0.6030	0.7230	0.4536	1.2200	0.5740	1080
Owerri	0.1173	0.2346	0.4559	1.5719	1.0597	1080
Enugu	1.2591	1.3764	0.9932	2.2836	1.6423	1080
Port Harcourt	0.8728	0.9901	0.8916	1.5328	1.0480	1080
Depot demand (truckloads)	288	504	1152	1296	1296	

*(12months x 15 x 6years) = 1080truckloads (supply)

*(12months x 4 x 6years) = 288truckloads (demand)

Table 3.7 shows that the company spent approximately a total of N21,412million, for transporting its products from the respective plants to its respective depots for six years.

As can be seen from tables 3.6 and 3.7, there are some differences in transportation costs because of difference in the number of truckloads per depot and distances from plants to depots. This suggests that the realized sample may be considered an acceptable representation of the transportation problem in Supply Chain Management.

Management would like to determine how many of its trucks should be used to transport its product from each plant to each depot based on the number of trucks available.

The next information of interest is the monthly demand and supply of the product from the plants to the depots. The details are summarized in tables 3.8and 3.9.

Table 3.8: Monthly demand and supply (million crates) of the product for 2003

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Qty Supply	0.015	0.013	0.012	0.011	0.01	0.01	0.008	0.007	0.010	0.009	0.01	0.016
Qty Demand	0.014	0.012	0.011	0.01	0.009	0.009	0.009	0.006	0.01	0.008	0.011	0.018

Table 3.9: Monthly demand and supply (million crates) of the product for 2008

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Qty Supply	0.05	0.044	0.040	0.034	0.026	0.024	0.020	0.018	0.016	0.035	0.040	0.056
Qty Demand	0.053	0.04	0.039	0.032	0.025	0.023	0.018	0.016	0.014	0.030	0.038	0.055

Figure 3.1 shows the network representation of the problem.

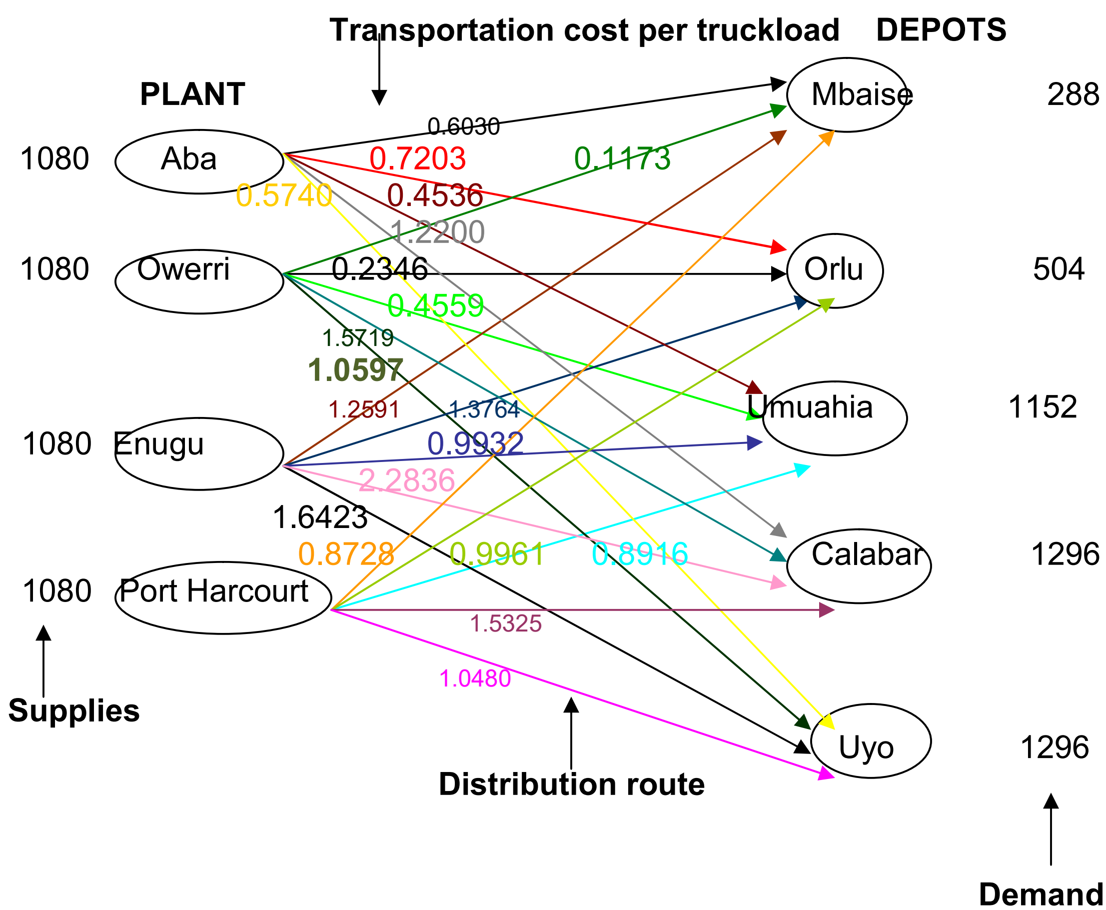

Figure 3.1: Network representation of the problem.

CHAPTER FOUR

4.0 ANALYSIS OF THE SURVEY DATA

4.1 METHOD OF ANALYSIS

The data obtained from the survey were analyzed using Operation Research (OR) technique. The OR approach involves the use of the tools of linear programming to model the problem. The model adopted for this study is transportation model which is very popular in literature. It allows getting the minimum cost of plan to transport a product from a number of plants to a number of depots.

4.2 TRANSPORTATION MODELS

Transportation models are primarily concerned with the optimal way in which a product produced at different plants can be transportation to a number of depots or warehouses. The objective in a transportation model is to fully satisfy the destination requirements within the operating environment, given some at capacity constraints at minimum possible cost. Whenever there is a physical movement of goods from the point of manufacture to the final consumers through a variety of channels of distribution (Wholesalers, retailers, distributor etc), there is need to minimize the cost of transportation so as to increase the profit on sales.

Transportation problems arise in all such cases. It aims at providing assistance to top management in ascertaining how many units of a particular product should be transported from the plant to each depot so that the total prevailing demand for the company's product is satisfied, while at the same time minimizing the total transportation costs are minimized.

Transportation model generally deal with obtaining the minimum cost plan to transport a product from a source (Plant) (m), to number of destination (Depot) (n) (Hamdy, 2008)

Using linear programming method to solve transporting problem, the value of objective function which minimize the cost for transporting a number of product from plant to depot was determined.

For this problem, the objective is to determine the number of truckload to be transported through each depot that provides the minimum total transportation cost. The cost for each truckload transported to each depot is given in table 3.7.

Solving this transportation problem with linear programming model, double-subscripted decision variables were used, with:

X_{11} = Number of truckload transported from plant 1 (Aba) to depot 1 (Mabise)

X_{12} = Number of truckload transported from plant 1 (Aba) to depot 2 (Orlu)

X_{13} = Number of truckload transported from plant 1 (Aba) to depot 3(Umuahia)

X_{14} = Number of truckload transported from plant 1 (Aba) to depot 4 (Calabar)

X_{15} = Number of truckload transported from plant 1 (Aba) to depot 5 (Uyo)

X_{21} = Number of truckload transported from plant 2 (Owerri Plant) to depot 1

X_{22} = Number of truckload transported from plant 2 (Owerri Plant) to depot 2

X_{23} = Number of truckload transported from plant 2 (Owerri Plant) to depot 3

X_{24} = Number of truckload transported from plant 2 (Owerri Plant) to depot 4

X_{25} = Number of truckload transported from plant 2 (Owerri Plant) to depot 5

X_{31} = Number of truckload transported from plant 3 (Enugu Plant) to depot 1

X_{32} = Number of truckload transported from plant 3 (Enugu Plant) to depot 2

X_{33} = Number of truckload transported from plant 3 (Enugu Plant) to depot 3

X_{34} = Number of truckload transported from plant 3 (Enugu Plant) to depot 4

X_{35} = Number of truckload transported from plant 3 (Enugu Plant) to depot 5

X_{41} = Number of truckload transported from plant 4 (Port Harcourt) to depot 1

X_{42} = Number of truckload transported from plant 4 (Port Harcourt) to depot 2

X_{43} = Number of truckload transported from plant 4 (Port Harcourt) to depot 3

X_{44} = Number of truckload transported from plant 4 (Port Harcourt) to depot 4

X_{45} = Number of truckload transported from plant 4 (Port Harcourt) to depot 5

4.2.1 GENERAL LP FORMULATION FOR TRANSPORTATION PROBLEM

The general problem of LP is the search for the optimal minimum of a linear function of variables constrained by linear relations (equations or inequalities).

The general transportation problem minimization model is:

Objective Function

$$\text{Minimize } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Subject to:

1. Constraints on total available truckloads at each plant

$$\sum_{j=1}^{n} X_{ij} = S_i \text{ for } i = 1, 2, \ldots m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

2. Constraints on total truckloads needed at each depot

$$\sum_{i=1}^{m} X_{ij} = D_j \text{ for } j = 1, 2, \ldots. n. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

And $X_{ij} \leq 0$ for all i and j.

$j = 1, 2, 3 \ldots. n; i = 1, 2\ldots m$

Where

Z= objective function that minimized transportation costs (Nm)

X_j = truckloads

C_j = coefficient measuring the contribution of the jth choice variable to the objective function.

S_i and D_j = constraint or restrictions placed upon the problem.

Constraints

1 Maintenance cost

2 Fuel cost

3 Personnel cost

4 Loading/Offloading cost

5 Distance

4.2.2 FORMULATION OF TRANSPORTATION PROBLEM AS A LINEAR PROGRAMMING MODEL

The LP model and analysis exploit the structural advantages that accompany deterministic data and avoid representing potentially costly errors. In reality, the decisions occur sequentially over time. From the Survey data table 3.7:

The objective function can be represented as

Minimize $Z = 0.6030X_{11} + 0.7203X_{12} + 0.4536X_{13} + 1.2200X_{14} + 0.5740X_{15} + 0.1173X_{21} + 0.2346X_{22} + 0.4559X_{23} + 1.5719X_{24} + 1.0597X_{25} + 1.2591X_{31} + 1.3764X_{32} + 0.9932X_{33} + 2.2836X_{34} + 1.5423X_{35} + 0.8728X_{41} + 0.9901X_{42} + 0.8916X_{43} + 1.5328X_{44} + 1.0480X_{45}$ {i.e. cost of transporting from coca cola plants to depots} ………………………………...4

Subject to:

$$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} \leq 1080$$

$$X_{21} + X_{22} + X_{23} + X_{24} + X_{25} \leq 1080$$

$$X_{31} + X_{32} + X_{33} + X_{24} + X_{35} \leq 1080$$

$$X_{41} + X_{42} + X_{43} + X_{44} + X_{45} \leq 1080$$

$$X_{11} + X_{21} + X_{31} + X_{41} \geq 288$$

$$X_{12} + X_{22} + X_{32} + X_{42} \geq 504$$

$$X_{13} + X_{23} + X_{33} + X_{43} \geq 1152$$

$$X_{14} + X_{24} + X_{34} + X_{44} \geq 1296$$

$$X_{15} + X_{25} + X_{35} + X_{45} \geq 1296$$

And X_{11}, X_{12}, ……X_{45} all such values are ≥ 0

4.3 SENSITIVITY ANALYSIS RULES

• For the objective function coefficients:

If $\sum_{j} \delta C_j/\Delta C_j \geq 1$, the optimal solution will not change

Where:

δC_j is the actual increase (decrease) in the coefficient,

ΔC_j is the minimum allowable increase (decrease) from the sensitivity analysis.

*For the RHS Constraints

If $\sum \delta b_j/\Delta b_j \geq 1$, the optimal basis and number of truckloads pre month will not change

Where:

δb_j is the actual increase (decrease) in the coefficient,

Δb_j is the minimum allowable increase (decrease) from the sensitivity analysis.

The linear programming model was completely formulated and implemented using TORA software package to generate various iterations and sensitivity analysis. As mentioned earlier, the objective is to minimize the transportation cost of the firm.

CHAPTER FOUR

5.0 RESULTS AND DISCUSSION

In this chapter, the results of the data obtained are discussion, summarized and present in simplex tableaus formats as well as in charts.

5.1 LINEAR PROGRAMMING (LP) RESULTS

The model was solved with TORA Software package, which provides the following LP information:

1. Information about the objective function:
   a. Objective function optimal value
   b. Coefficient ranges (ranges of optimality). The range of optimality for each coefficient provides the range of values over which the current solution will remain optimal. Managers should focus on those objective coefficients that have a narrow range of optimality and coefficients near the endpoints of the range.
2. Information about the decision variables:
   a. Their optimal values
   b. Their reduced costs
3. Information about the constraints:
   a. The amount of slack or surplus

b. The dual prices that represent the **improvement** in the value of the optimal solution per truck **increase** in the right-hand side.

c. Right-hand side ranges (ranges of feasibility) that represent the range over which the dual price is applicable. As the RHS increases, other constraints will become binding and limit the change in the value of the objective function.

Solving the above transportation problem using TORA software package will result:

Minimum transportation cost Z = ₦3945.69million. $X_4 = X_{14} = 216.00$, $X_5 = X_{15} = 1296.00$, $X_6 = X_{21} = 504.00$, $X_7 = X_{22} = 504.00$, $X_8 = X_{23} = 72.00$, $X_{13} = X_{33} = 1080$, $X_{19} = X_{44} = 1080$, while other variables has zero value (appendix B_1).

The amount (₦3945.68million) represents the minimum transportation costs for the company to transport its products from the four plants to the five depots (appendix B_1).

From the computer result sheet, variable $X_1 = X_{11}$, which is Aba Plant to Mbaise Depot, the value – Number of truckloads per month is zero, so no loads will be transported from Aba Plant to Mbaise Depot.

However, from the computer output summary (see appendix B_1) also shows that:

- no loads will be transported from Aba plant to Orlu depot
- no loads will be transported from Aba plant to umuahia depot
- no loads will be transported from Owerri plant to Calabar depot
- no loads will be transported from Owerri plant to Uyo depot
- no loads will be transported from Enugu plant to Mbaise depot
- no loads will be transported from Enugu plant to Orlu depot
- no loads will be transported from Enugu plant to Calabar depot
- no loads will be transported from Enugu plant to Uyo depot
- no loads will be transported from P.H plant to Mbaise depot
- no loads will be transported from P.H plant to Orlu depot
- no loads will be transported from P.H plant to Umuahia depot
- no loads will be transported from P.H plant to Uyo depot

For variable X_{14}, which is Aba Plant to Calabar Depot, the Value is a total of 216.00 truckloads per month.

For X_{15}, which Aba Plant to Uyo Depot the number of truckloads for the six years is 1296.00, and so on.

Looking at the **SLACK/SURPLUS** Column of the computer output sheet (appendix B_1), a value of 432.00 truckloads was for constraint 1 (Aba Plant). Since the constraint 1 is a greater-than-or-equal to constraint, 432.00 is surplus. This tells us that the truckloads in Plant 1, in the optimal solution (1080 trucks) exceeded demand for six years by 432 trucks.

Since the surplus value for constraints 2, 3, 4, 6, 7, 8 and 9 are zero, therefore, the optimal truckloads just meets the minimum number of trucks required at plants 2, 3, 4 and depots 2, 3, 4 and 5. Moreover, a slack value of zero in constraint 9 shows that the optimal solution provides total monthly truckloads of 1296 for six years.

5.2 SENSITIVITY ANALYSIS SA OF THE INPUT DATA

In linear programming input data of the model can change within certain limits without causing the optimal solution to change. This is referred to as sensitivity analysis, (Taha 2008).

However, exactness of our LP model was confirmed by running sensitivity analysis. Through this the impact of uncertainty on the quality of the optimal solution was ascertained.

In the **SENSITIVITY ANALYSIS** section of the computer output sheet (appendix B_1) , the **REDUCED COSTS** column shows how much each objective function coefficient would have to improve before the corresponding decision variable could assume a positive value in the optimal solution. As the computer output shows, the reduced costs for X_4, X_5, X_6, X_7, X_8, X_{13}, and X_{19} are zero, since the corresponding decision variables already have positive values in the optimal solution. The reduced cost of 0.60 for decision variable X_2 tells us that the cost minimized for transporting from Aba plant to Orlu depot would have decreased to at least 0.72 – 0.60 = #0.12m before X_2 could assume a positive value in the optimal solution.

The OBJECTIVE COFFICIENT RANGES (Min. Obj. Coeff. and Max. Obj Coeff.) Column shows the lower limit for the objective function coefficient of X_5 as 0.00. Thus, no matter how much the cost of transporting product from Aba plant to Uyo depot were to decrease, the optimal solution would not change.

However, any decrease in the per-unit cost of the truckloads would result in decrease in the total transportation cost for the optimal monthly transport.

The objective function coefficient values for X_1, X_2, and X_3 have no upper limit. Even if the cost of X_3 were to increase, from ₦0.45m to ₦10.45m per truckload, the optimal solution would not change because the value of X_3 in the Value column is zero.

The **DUAL PRICE** Column (appendix B_2), shows that the dual price for the plants 2, 3 and 4 are 0.12, 0.65 and 0.31 respectively and for the depots 2, 3, 4, and 5 are also 0.12, 0.34, 1.22, and 0.57 respectively. The dual price of 0.12 for constraint 2 (Owerri Plant) shows that a one-unit increase in the right-hand side of constraint 2 will reduce total transportation cost by ₦0.12m. Constraints 3, 4, 6 and 7 similarly express the same reduction in total transportation costs when there is one-unit increase in the right-hand side of them.

The **RIGHT-HAND SIDE RANGES** Column shows that this interpretation is correct for increases in the right-hand side up to maximum of 1512.00trucks. Thus, the effect of increasing the right-hand side of constrain 3 from 1080 to 1512trucks is a decrease in the total transportation cost of 2x0.65 0r #1.30m. Note if this change were made, the feasible region would change and we would obtain a new optimal solution.

However, through SA, it is possible to change the corresponding coefficient in the objective function and resolve the LP problem once more.

These observations give rise to the investigation of the SA.

Knowing that the structure of the problem does not change, it is possible to investigate how changes in individual data elements change the optimal solution as follows:

• If nothing else changes except the objective function value when slightly change, the number of truckloads, transportation cost and the nature of the solution changes considerably.

• On the other hand, if the transportation cost is kept fixed, and the number of truckloads needed increase or drop by e.g. 10% there would be no major impact on the solution, Firm would still transport their products and take the initial LP problem solution into consideration.

Note that the interpretations made in thesis using the sensitivity analysis information in the computer output are only appropriate if all other coefficients in the problem do not change. To consider simultaneous changes the 100% rule must be used or resolve the problem after making the changes.

From the computer output result sheet, values in the **VALUE** Column (appendix B_1) are assigning to our variables to determine the truck schedules for the company.

Table 5.1: Company truck schedule

Plant	Depot	Number of Truckload per month	Cost per truckload	Total cost
Aba	Mbaise	0.00	0.60	0.00
Aba	Orlu	0.00	0.72	0.00
Aba	Umuahia	0.00	0.45	0.00
Aba	Calabar	216.00	1.22	263.52
Aba	Uyo	1296.00	0.57	743.90
Owerri	Mbaise	504	0.12	59.12
Owerri	Orlu	504.00	0.23	118.24
Owerri	Umuahia	72.00	0.46	32.82
Owerri	Calabar	0.00	1.57	0.00
Owerri	Uyo	0.00	1.06	0.0000
Enugu	Mbaise	0.00	1.26	0.0000
Enugu	Orlu	0.00	1.38	0.0000
Enugu	Umuahia	1080.00	0.99	451.01

Enugu	Calabar	0.00	2.28	0.0000
Enugu	Uyo	0.00	1.67	0.0000
Port-Harcourt	Mbaise	0.00	0.87	0.0000
Port-Harcourt	Orlu	0.00	0.99	0.0000
Port-Harcourt	Umuahia	0.00	0.89	0.0000
Port-Harcourt	Calabar	1080.00	1.53	598.75
Port-Harcourt	Uyo	0.00	1.05	0.0000
Total monthly transportation costs for the company				N3945.69

Appendix A1 to A25 shows the procedures to obtain the optimal solution of the problem. This involves eleven (11) iterations and in each of the iteration different solutions were obtained. The optimal solution of the problem was obtained in 11th iteration (appendix A_{23}).

Appendix B_1 and B_2 are the output summary of Appendix A_1 to A_{25} and the sensitivity analysis of the problem

Figure 5.1 represents the four transportation costs constraints/month per plant for six years.

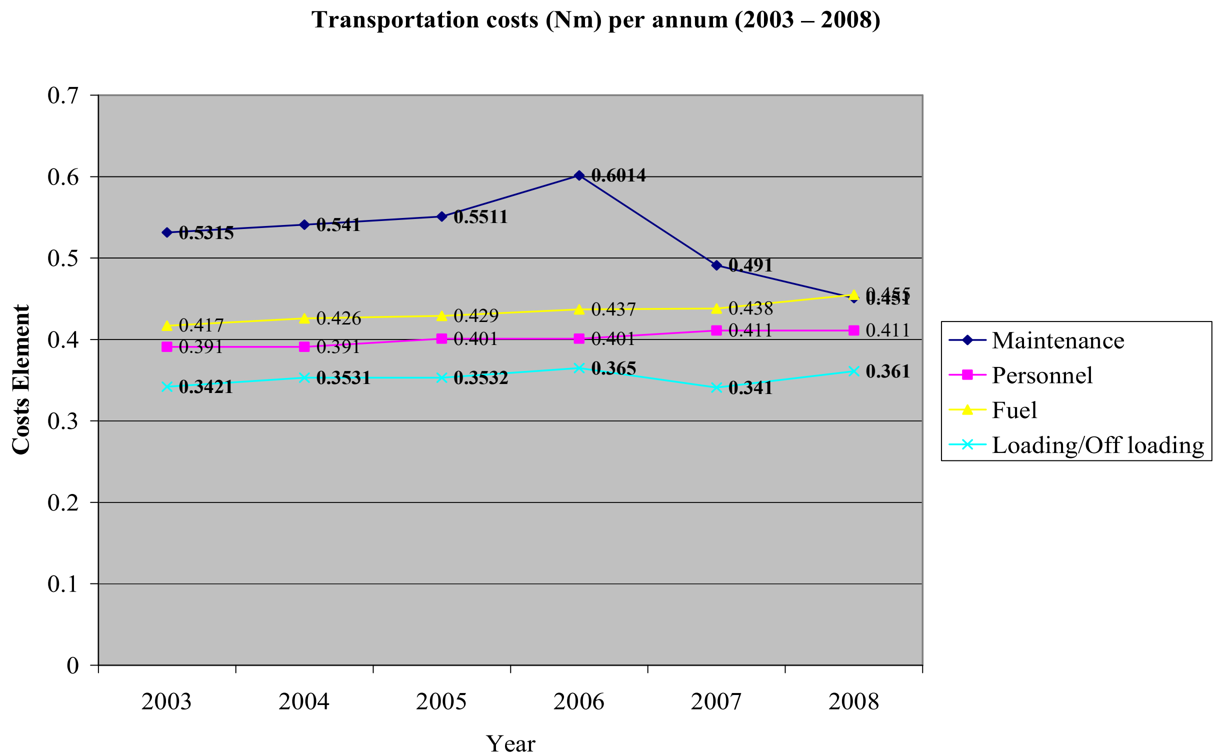

Figure 5.1: The four transportation costs constraints /month per plant for six years

Figure 5.1 shows that maintenance, fuel, driver's welfare, mileage, and loading/offloading costs have significant effect on transportation costs. Given these constrains due consideration, transportation costs will be minimize. It shows that the company spends more on maintenance than other factors that constitute transportation cost. That 39.20% of the Company total expenditure under transportation sector (Assume 100% budgetary allocation) for six years was on maintenance alone, because of the deterioration nature of some of the trucks and also the maintenance techniques adopted. While 20.50%, 879% and 5.05% was on fuel, driver's welfare and loading/offloading respectively. Loading/off loading cost is at the bottom of expenditure list every year.

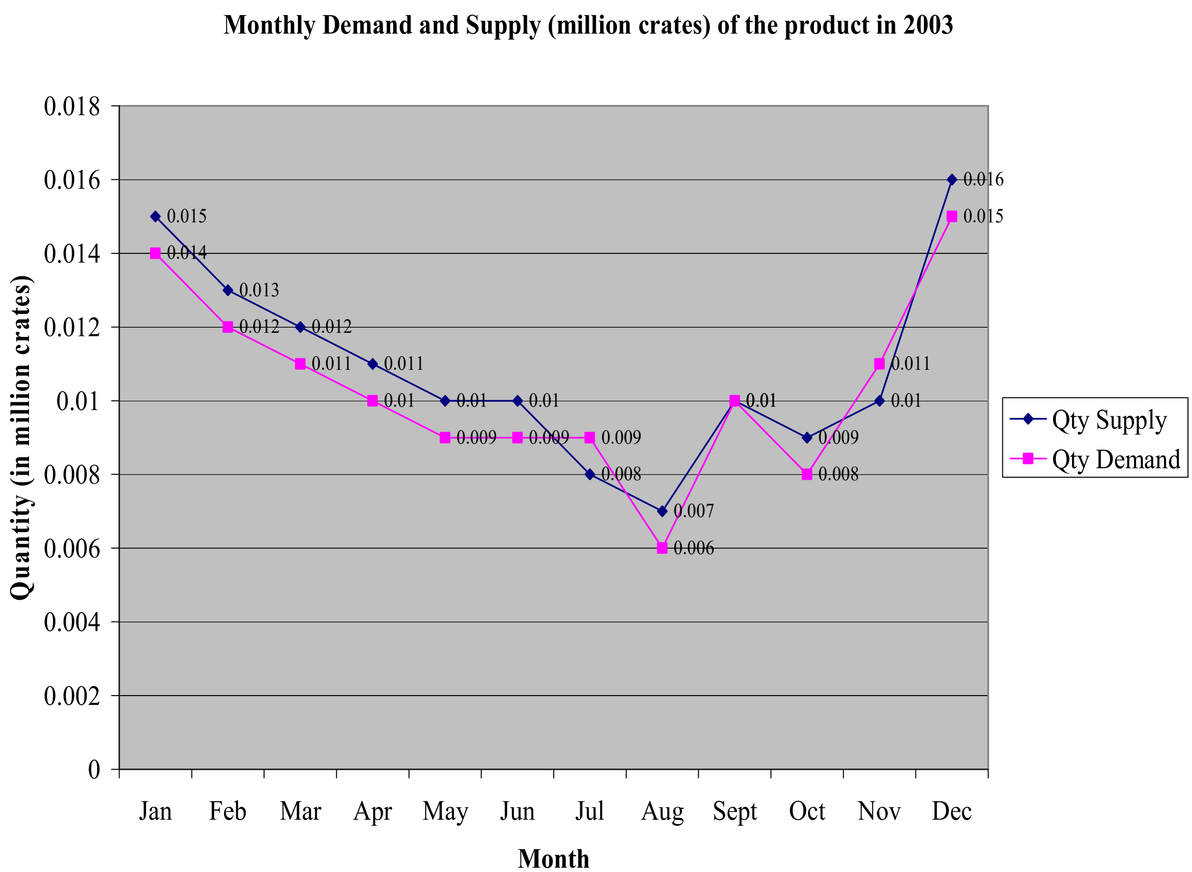

Figure 5.2: Monthly demand and supply of the product (2003)

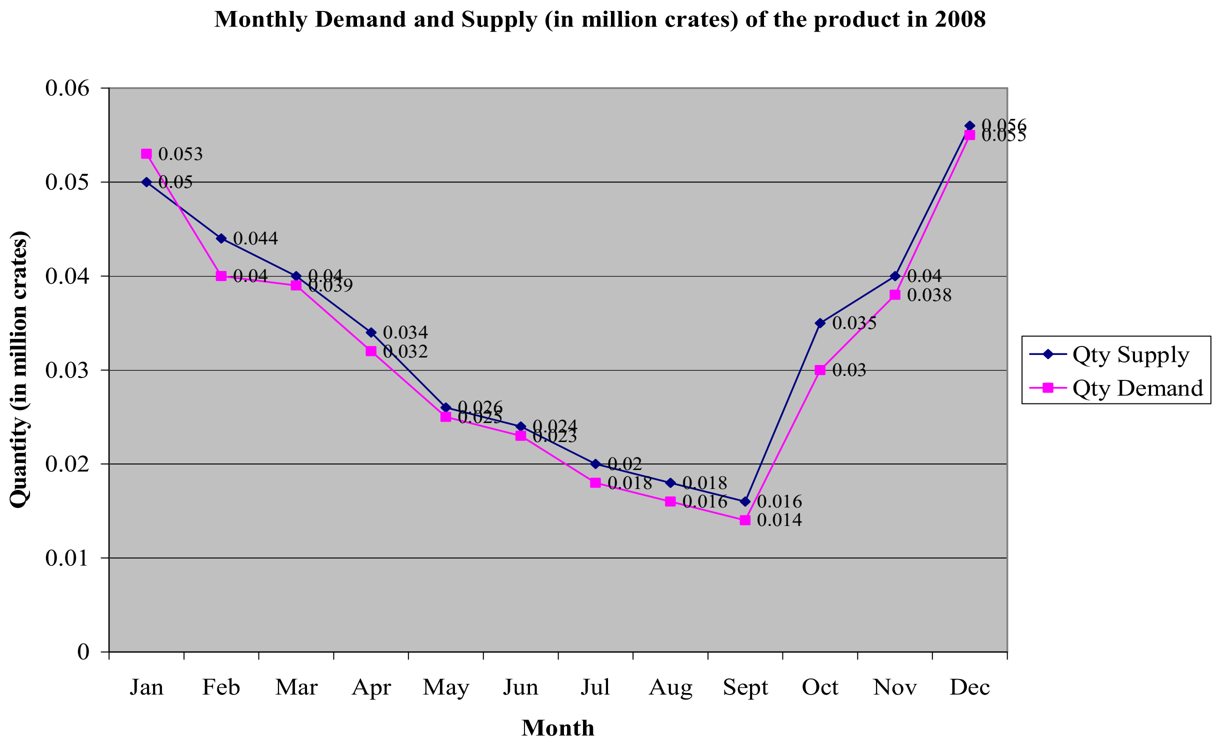

Figure 5.3: Monthly demand and supply of the product (2008)

Fig. 5.2 and 5.3, show that the demand for the product is always high in the month of December and January every year. This is because of the fact that the two months are the months of celebrations. However, weather also play an important role on product demand. Demand of the product will be low during rainy season as demonstrated in fig 5.2 and 5.3.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

In this thesis a class of optimization model has been studied that gives an insight to companies when looking for opportunities for improving the efficiency of transporting their products in a dynamic environment.

The scenario considered are as follows: There is a set of plants to deliver the demand to the depots and a set of depots. The production at the plants is constrained and the physical as well as the throughput capacities at the depots are restricted. The research goal is to find the most efficient way, i.e. with minimal total costs, to satisfy this demand. There is no room for transportation between plants. No room for transportation between depots.

A transportation problem was developed with respect to the operations of the Coca Cola Plant of Aba, Owerri, Port Harcourt and Enugu in its depots in Mbaise, Orlu, Umuahia, Calabar and Uyo and also the truckload movement between the cities. The data obtained in the study was used with respect to the cities; and a minimizing cost equation was developed. The problem was solved by using TORA software package. The minimum cost for the operation was obtained as approximately ₦3946million, which was smaller compared with the original cost (N21,412million).

Consequently, the LP and SA methods developed in this work yield an efficient compromise solution and overall decision maker satisfaction.

However, the results showed that 39.20% of the company total expenditure under transportation sector for six years was on maintenance, while 20.50%, 8.79% and 5.05% were on Fuel, driver's welfare and loading/offloading respectively. Therefore, the solution recommends the reduction in cost of maintenance per truck.

It recommends that the optimal decision is not to increase the number of truckloads per depot, but to reduce the cost of maintenance of trucks by adopting predictive and preventive maintenance rather than corrective maintenance.

It also recommends that the issue of conventional wisdom (i.e. if it is not broke, then don't fix it or that parts are expendable to some degree) should be eliminated.

6.1 CONTRIBUTIONS

This thesis proposes the following:

1. A new modeling methodology for supply chain optimization. This methodology provides an effective framework to analyze the performance of the transportation in a supply chain management.

2. A new mathematical model for transportation problem of a supply chain network design where the objective is to minimize the total transportation cost. Linear programming model was applied using TORA software package and present several solution procedures to determine the objective function. Computational results showed that the model behaves well in large-scale supply chain network design problems.

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