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Optimization of Production Cost and Distribution Network of Nigerian Bottling Company Plc

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ABSTRACT

This research on optimization of production cost and distribution network was carried out in the Nigerian Bottling Company (NBC) which has many production facilities and multi-products systems. Three plants and twenty two warehouses within the South-South and South-East region of Nigeria were selected for this study. Production operations of the three plants were monitored and data obtained were analyzed using operations research technique. A mathematical model that captured supply chain network problems of the company was developed using mixed-integer programming approach. The model consists of one hundred and ninety six (196) variables and one hundred and twenty six (126) constraints. A programming software known as Lingo Model (15.0 Version) was used. The results obtained showed that production without the optimization techniques gave a total cost of fourteen billion, three hundred and nine million, six hundred and eighty nine thousand, one hundred and two naira, eighty kobo (₦14,309,689,102.80) while the application of this proposed model gave eleven billion, one hundred and sixty one million, five hundred and fifty seven, five hundred naira (₦11,161,557,500.00). This showed that an annual cost saving of five hundred and twenty four million, six hundred and eighty eight thousand, six hundred naira, thirty kobo (₦524,688,600.30) was realized. In addition, the existing situation of the company was improved and an annual demand increase of 2,799,820 cases was recorded, which amounted to sixty million, eight hundred and seventeen thousand, forty naira, fifty kobo (₦60,817,040 .50). The study recommended the application of this research outcome to other similar companies that intend emulating the benefits in Supply Chain (SC) network.

KEY WORDS: *Supply chain, Optimization, model, Production, Inventory, Distribution, mixed-integral*

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I. INTRODUCTION

Manufacturing companies are organized into networks of production and distribution sites that procure raw materials, process them into finished products and distribute the products to customers. The aim is to deliver the right product to the right place at the right period of time for the right price. The primary cost factors within a supply chain can be put into the categories of production, transportation and inventory. The supply chain management is therefore an integration of these activities (i.e. Production, transportation and inventory) (Chandra and Fisher, 2000).

Supply chain management (SCM) is the term used to described the management of the flow of materials, information and funds across the entire supply chain, from suppliers to component producers, final assembles, distribution (warehouses and retailers), and ultimately to the consumer. It therefore represents a set of approaches utilized to efficiently integrate suppliers, manufactures, 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 requirements. It arises out of a systematic analysis and decision-making within the different business functions of an organization resulting in smooth and cost effective flows of resources material, information, and money. In other words, it is the coordination and synchronization of the flow of resources in the network of suppliers, manufacturing facilities, distribution centers and customers. These network elements form the different echelons in the supply chain. The supply chain is the network that sources raw materials from suppliers, transforms them into finished products through the process facilities, and distributes the finished products to the final customers through the distribution centers. These activities constitute the individual business functions of the company's supply chain network. In general, decisions are made across the supply chain on three levels; strategic, tactical and operational. Strategic decisions are long term decisions where the time horizon may be anything from one year to several years involving multiple planning horizons. These decisions could be made on an organizational level or at the supply chain level with the aim for global optimization. Tactical decisions are taken over a shorter period of time, maybe a few months. These are more localized decisions taken to keep the organization on the track set at the strategic level. Operational decisions are similar to day-to-day decisions for planning a few days-worth of operations. These take into consideration the most profitable way to carry out daily activities for satisfying immediate needs.

Supply chain management uses an increasing set of tools and techniques to effectively coordinate the decision making process. Quantitative models have been developed to analyze the various dimensions of a company's supply chain. These models are targeted to effectively portray the governing factors and their interactions in deciding the overall performance of the supply chain. Attempts have also been made to model the qualitative aspects taking into consideration the ensuring subjectivity in the analysis. These efforts were aimed at gaining a better understanding of the overall nature of the problem and to model it in the most accurate manner. A tool such as operations research, statistical analysis, quality control, location science, inventory control, theory of constrains, and soon has been used for modeling purposes, (Cohen and Lee, 2008).

From the definition of supply chain management, it is obvious that optimization plays a key role in supply chain management. Optimization will involve the development of a mathematical model that defines the problems and its parameters. Each business issue is represented as a "variable," while the relationships between business issues are formulated as "constrains" and the desired "objectives" (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 approached to find an optimized solution. This "modeling" process is necessary for virtually every optimization problem (Canel and khumawala, 2001)

In general, 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 (Jayaraman, 2003). 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. Effective supply chain members invariably integrate the wishes and concerns of their downstream members into their operations while simultaneously ensuring integration with their upstream members. This work however concentrates on developing optimization tools to enable companies take advantage of opportunities to improve their supply chain (Abott and Mckinney, 2013).

Optimization of production-distribution plans concerns the minimization of the total costs, while dealing with a number of constraints, demand uncertainties, production capacity, warehouse capacity, transport routings and facilities' location among others. To do so, in recent studies either analytic or simulation approaches (with their own merits and demerits) have been used.

Total cost in a production-distribution network generally consists of two major cost components: 1). Production costs: sum of fixed costs of operating and opening different manufacturing plants and the variable costs associated with production of multiple products at different plans. These variable costs may include regular-time production, overtime production, outsourcing, inventory holding costs and storage costs; 2). Distribution costs: sum of fixed costs of opening and operating the distribution centers and variable costs of transporting finished goods from the plants to the end users through the warehouses. The variable costs may include storage costs at warehouses, transportation costs from plants to warehouses and from warehouses to end-users as well as shortage costs of not meeting demand forecasts (Arntzen et al, 2005).

1.1 The need to integrate

Supply chains have been more or less integrated to some extent-albeit on a low scale as a whole, or in parts. Integration, if done at all, has been mostly done in patches throughout the supply chain. In many cases, this has been driven more by the need to survive and improvise than by the willingness to improve and advance further. For example, suppliers have been cooperating with manufacturers to implement quality assurance programs in order to meet the ever increasing stringent quality requirements. These quality standards are mostly driven by market conditions which would not allow the manufacturer to accept material from the supplier if it does not meet those standards, thus risking the suppliers business.

Traditionally the different echelons of the supply chain as well as the different decisions have been considered separately for planning purposes. They have been dealt with on an individual basis rather than collectively. In order words, problems in these domains have been solved separately and/or sequentially which, although makes them a lot easier to solve, may not necessarily consider their interrelationship. However, the manufacturing environment has changed a lot with respect to the ideological changes and technological advancements. As a result, this isolation of decision components and the individual handling of the different business functions may often lead to local optimization of the supply chain instead of global optimization. There are a lot of disadvantages associated with the traditional way of handling un-integrated supply chain operations (Gong, et al, 2008**).**

Integration can be carried out for different aspect of a company's supply chain.

There are numerous benefits of integration that can help the company to improve its performance by way of collaborative planning and execution. According to Chen (2010) one of the most visible and obvious benefits for a manufacturing company is in the area of inventory control. Due to combined optimization of the various functions in a manufacturing environment, such as location, production, and distribution, inventory can be controlled at optimum levels leading to lower holding costs, reduction of required warehouse space, reduce materials handling activities, and timely deliveries. Another benefit is the reduction in transaction costs due to high level of information sharing in an integrated environment. Real-time updates, reduced paperwork due to e-transactions, and reduced execution times, lead to lower transaction costs for each entity in the supply chain. Additional benefits include:

- Reduced bottlenecks
- Decrease in level of redundant activities
- Cheaper cost of manufacturing operations
- Reduction in investment levels due to elimination of redundant manufacturing capacity.
- Increase competitiveness

1.2 Statement of the problem

Companies deliver products to their customers using logistics distributions network such networks consist of product flows from the plant to the customers through distribution centers (warehouse) and retailers. These companies generally need to make decisions on production planning, inventory levels and transportation at each level of the logistics distribution network in such a way that customers demand is satisfied at minimum cost. For many years companies and researchers failed to take an integrated view of the entire supply chain. They considered only one piece of the overall problem. There is need to develop new optimization tool that can integrate production, inventory and transportation costs using mixed-integer programming techniques. This will enable companies to take advantage of opportunities to improve on their supply chain.

1.3 Significance of the study

The study would be a significant model that can be used by other players to enhance performance through the exposure of processes that would need face-lift or better management.

This research would also shed light on the need for firms to enhance their decision making and supply chain process management. It might also become a reference point for future reference in the field of supply chain management. As said earlier this study might have an impact in the designing of the management strategy for supply chain of the firm.

1.4 Optimization model development

Economic benefits can be achieved by integrating the production and inventory functions with distribution. Certain production schedules need to be planned to fulfill each customers demand. Products must be shipped out as required by the customer. During this process, it might not always be necessary to produce the exact amount as the customers ordered because of the variability in demand, lead times and transportation times. Also it may not always be possible to produce goods according to incoming orders due to production capacity. But with DCs, it is possible to meet peak season demand by accumulating inventory. There are three levels of planning in decision making, strategic, tactical and operational. This study, focus on a tactical planning problem in a 12-month time period to synchronize the distribution, production and inventory functions in a supply chain (Lee and Moore, 2003).

The logistics system (figure 1.0) considered in this study consists of several manufacturing plants producing different types of items using a set of resources. When an order is placed by an end customer, the production schedule is planned to ensure fulfillment of the demand. Following production, the products are first shipped to several intermediate warehouses or DCs based on the location of the customers. Then the products are shipped out to the customers based on their seasonal demand and shipping requirement (such as package size). The inbound and outbound transportation could be carried in-house or outsourced from a number of third party trucking companies that own a fleet of homogenous or non-homogenous vehicles with limited capacity. Each trucking company has a limited number of drivers and truckload, which can vary over time. The shipping cost varies based on transported quantities, traveled distance, product type, carrier used and time consumed. For each product type, it is necessary to consider a fixed setup cost, not depending on the quantity produced. In each manufacturing plant and DC, a particular level (not beyond the maximum capacity) of inventory needs to be kept in case of peak season or emergency shipment. To manage inventory successfully, plants and DCs must balance the risks of obsolescence against those of stock-outs.

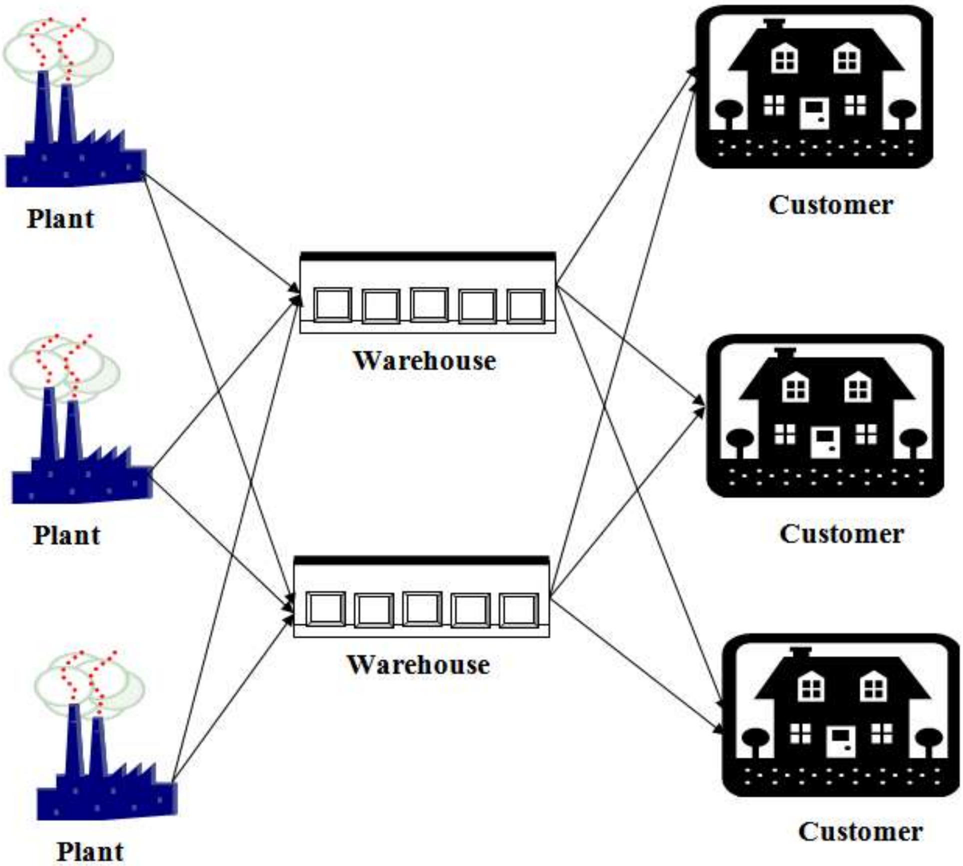

Figure 1.0: A logistic network including manufacturing plants, warehouses/DCs and end customers.

A number of new developments have had an impact on manufacturing companies. For example, increased market responsiveness has intensified the inter-dependencies within the supply chain (Erenguc, et al, 2009) technological innovations have shortened the life span of manufacturing equipment, which in turn increases the cost of manufacturing capacity; internet has offered high speed communication (Geunes, et al, 2002, Gue and Meller, 2009). These developments combined with increased product variety and decreased product volumes prompted companies to explore new ways of running their business.

Experience has shown that a firm's ability to manage its supply chain is a major source of competitive advantage. This realization became the single most important reason for the recent emphasis on supply chain management in industry and academia. To exploit these new opportunities to improve their profitability, companies needed decision support tools that could provide evaluation of alternatives using optimization models.

Chandra and Fisher (2000) investigated the effect of coordinating production and distribution on a single-plant, multi-commodity, multi-period scenario. In this scenario, the plant produces and stores the products until they are delivered to the customers using a fleet of trucks.

They proposed two solution approaches. The first approach solved the production scheduling and routing problems separately while the second part considered both, production and routing decisions to be incorporated into the model. Their computational study showed that the coordinated approach could yield up to 20% in costs savings. Anily and Federgruen (2003) considered integrating inventory control and transportation planning decisions motivated by the trade-off between the size and the frequency of delivery. Their model considered a single warehouse and multiple retailers with inventories held only at the retailers who face constant demand. Burns, et al (2005) investigated on the distribution strategies that minimized transportation and inventory costs. Successful applications of supply chain decision coordination were reported by Xerox (2004) and Hewlett (2005). As a result of coordinating the decisions on inventories throughout the supply chain, they were able to reduce their inventory levels by 25%.

II. METHODOLOGY

In order to achieve the stated objectives of the study, a thorough study of supply chain modelling was carried out using a manufacturing industry as a case study.

I. Data Collection: How essential information for the research will be collected through primary and secondary sources, the combinations include:
(i) Interview with some key personnel in the stores, purchasing, production, inventory and transportation departments of the company. (ii) Interview with the supply chain personnel (Supply chain manager).
(iii) Observation of the production process to observe the flow of goods in the conversion process. Materials handling and storage and also the patrol.
(iv) Relevant data from the company's annual report and journals.
(v) Library and internet services.

The research information includes:

i. Number of potential warehouses or distribution centers (depots)
ii. Number of plants
iii. Number of trucks
iv. Production capacity per plant
v. production cost per plant
vi. Transportation cost
vii. Capacity of the warehouse
viii. Number of product demand per distribution center (DC)
ix. Annual demand fin each product per DC
x. Order processing cost
xi. Warehousing cost, including labour, inventory holding cost and fixed operating cost etc.

2. Model development: 'this involves the abstraction of the system into mathematical logical relationship in accordance with the problem formulation. It is aimed at developing optimization models that will coordinate Production, transportation and Inventory decisions in a particular supply chain.

3. Model translation: This involves the generation of computer software in LINGO programming language for integrating and solving of production, inventory and transportation problems.

4. Optimization of production, inventory and transportation problems: This involves the execution of the mixed-integer programming model to obtain output value.

5. Analysis of results: This is the process of analyzing the outputs from the optimization process to draw inferences and make recommendations for the problem resolution.

6. Validation: Finally, the work ends at the stage of validating or testing the model for performance results.

2.1. Existing Supply Chain Network of Coca-Cola Bottling Company Limited

To clearly portray how mathematical model of supply chain network design works, it is important to thoroughly examine the existing supply chain structure of the company in tile south-south and south-east region of the country. The company has three plants which it directly supplies and 21 distribution centres within tile south-east and south-south regions of the country. A simplified schematic diagram of the supply chain of the company's existing operation within the said regions is given in figure 2.0 (see appendix 1)

2.2 Model Notation and Formulation

Consider a typical problem of configuring a production-inventory-distribution system, where a set of manufacturing plants need to be established to produce multiple items. The DCs act as intermediate facilities between plants and end customers and facilitate the shipment of products between the two echelons. A mathematical model to assist decision making in an integrated production, inventory and distribution system can be developed. The model formulated will attempt to minimize total cost by simultaneously considering facility location, production schedule, inventory decision, distribution batch size and so on. To model such as problem, the following notations were defined.

Indices:

i Index for plants, $i = 1, 2, \ldots\ldots, I$
j Index for DCs, $j = 1, 2, \ldots\ldots.. J$
k Index for customers, $k = 1, 2, \ldots\ldots.. K$
l Index for products, $l = 1, 2, \ldots\ldots.. L$
m Index for inbound-shipment carriers, of m = l, 2, ..., M.
n Index for outbound-shipment carriers, n = 1, 2, ..., N.
t Index for time periods, $t = 1, 2, ..., T$.

Parameters:

A_{ilt} Fixed production cost for product *l* at plant *i* in period *t*
B_{ilt} Variable cost for producing a unit of product *l* at plant i in period *t*
C_{ilt} Inventory cost for carrying a unit of product *l* at plant *i* in period *t*
D_{klt} Demand for product *l* by customer *k* in period *t*
E_{jlt}, Inventory cost for carrying a unit of product *l* in DC *j* in period *t*
F_{ijlmt} Transportation cost for shipping a unit of product *l* from plant *i* to DC *j* when using carrier m in period *t*
G_{jklnt} Transportation cost for shipping a unit of product *l* from DC *j* to customer k when using carrier n in period *t*.
H_{ilt} Production capacity for product *l* at plant *i* in period *t*
I_{ilt} Inventory capacity for product *l* at plant *i* in period *t*
J_{jlt} Inventory capacity for product *l* in DC *j* in period *t*.
K_{jt} Upper bound on throughput capacity in DC j in period t
L_{jt} Lower bound on throughput capacity in DC *j* in period t
M_{mt} Truckload capacity of inbound-shipments carrier *m* in period *t*
N_{nt} Truckload capacity of outbound-shipments carrier *n* in period t
O_{mt} Driver capacity of inbound-shipments carrier *m* in period *t*
Q_{nt} Driver capacity of outbound-shipments carrier n *in* period t
R_{lmt} Average truckload for a standard vehicle shipping product *l* for inbound shipments carrier in period *t*.
S_{lnt} Average truckload for a standard vehicle shipping product *l* for outbound shipments carries' n in period *t*
T_{lmt} Average trips a driver of inbound-shipments carrier m can make for product *l* in period t.
U_{lnt} Average trips a driver of outbound-shipments carrier n can make for product *l* in period *t*.
V_{oil} Starting inventory level for product *l* at plant *i*.
W_{olj} Starling inventory level for product *l* in DC *j*.
Z_{lkt} Shipping requirement (the degree of consolidation or break bulk) of customer k for product *l* in period *t*.

Decision Variables:

X_{ijlmt} Amount of product *l* shipped from plant *i* to DC *j* when using inbound shipment's carrier *m* in period *t*.
Y_{jklnt} Amount of product *l* shipped from DC *j* to customer *k* when using outbound shipments carrier n in period *t*.
$Z_{lit} = 1$ if product *l* is produced at plant *i* in period *t*; 0 otherwise.
P_{ilt} Amount of product *l* produced at plant *i* in period *t*.
V_{ilt} Inventory level of product *l* at plant *i* in period *t*.
W_{jlt} Inventory level of product *l* in DC *j* in period *t*.

The objective function is to minimize the total cost of the supply chain including fixed told variable production costs, inventory costs both at plants and in DCs, and inbound and outbound distribution costs:

$$Minimize\ \mathbb{Z} = \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t-1}^{T} A_{ilt}Z_{ilt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} B_{ilt}P_{ilt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} C_{ilt}V_{ilt}$$

$$+ \sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{t=1}^{T} E_{jlt}W_{jlt} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{m=1}^{M}\sum_{t=1}^{T} F_{ijlmt}X_{ijlmt}$$

$$+ \sum_{l=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{n=1}^{N}\sum_{t=1}^{T} G_{jklnt}Y_{jklnt}$$

All the constraints are listed as follows:

$$\sum_{j=1}^{J}\sum_{n=1}^{N} Y_{jKlnt} = D_{klt} \quad for\ all\ k,l,t \qquad (1)$$

$P_{ilt} \le H_{ilt}\ x\ Z_{ilt,}$ for all *i, l, t* (2)

$V_{ilt} \le I_{ilt}$, for all *i, l, t* (3)

$W_{jlt} \le J_{jlt}$, for all *j, l, t* (4)

$$I_{jl} \le \sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{n=1}^{N} Y_{jklnt} \le K_{jt} \quad for\ all\ j,t \qquad (5)$$

$$P_{ilt} + V_{ilt-1} - V_{ilt} = \sum_{j=1}^{J}\sum_{m=1}^{M} X_{ijlmt} \quad for\ all\ i,l,t \qquad (6)$$

$$\sum_{i=1}^{I}\sum_{m=1}^{M} X_{ijlmt} + W_{jlt} - \sum_{k=1}^{K}\sum_{n=1}^{N} Y_{jlnt}\beta_{klt} = W_{jlt} \quad for\ all\ j,i \qquad (7)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L} X_{ijlmt} \le M_{mt} \quad for\ m,t \qquad (8)$$

$$\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} Y_{jklnt} \le N_{nt} \quad for\ n,t \qquad (9)$$

$$\frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L} X_{ijlmt}}{\sum_{l=1}^{L} R_{lmt}} \le \sum_{l=1}^{L} T_{lmt}O_{mt} \quad for\ all\ m,t \qquad (10)$$

$$\frac{\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} Y_{jklnt}}{\sum_{l=1}^{L} S_{int}} \le \sum_{l=1}^{L} U_{lnt}Q_{nt} \quad for\ all\ n,t \qquad (11)$$

$X_{ijlmt} \ge 0$ for all *i, j, l, m, t* (12)

$Y_{jknmt} \ge 0$ for all *j, k, l, n, t* (13)

$P_{ilt} \ge 0$ for all *i, l, t* (14)

$V_{ilt} \ge 0$ for all *i, l, t* (15)

$W_{jlt} \ge 0$ for all *j, l, t* (16)

Zilt are 0, 1 variables (17)

In constraint (1), customers place an order containing single or multiple types of products at the beginning of each time period. One customer could receive its entire order from one, or snore than one, intermediate DCs. Shipments occurring Coin DCs to customers are solved by company-owned or third party carriers.

Constraint (2) shows that once a decision to produce product *l* al plant *i* in period I is made, the amount to produce must be within its production capacity.

In constraints (3) said (4), although both manufacturing plants and DCs arc allowed to carry inventory, in each plant and DC there is a predetermined maximum inventory level for each type of product in each planning period, which cannot be exceeded

The reason to include constraint (5) is because we are using both privately owned and third party DCs, we have to keep the throughput below the upper limit which may vary from one period to the next. On the other hand, it is also necessary to keep the monthly throughput above a lower limit to best utilize available resources.

In constraint (6), production and inventory plans arc determined in each plant and month after receiving customer orders. Counting any products left over from last month, each plant produces a particular amount of items to meet customer orders. The shipment is carried out by a number of trucking companies. Products that are not shipped are considered as initial inventory for the next month.

This production, inventory and distribution policy occurs in each DC in each time period. However, the inbound shipment and outbound shipment arc different in terms of requirement. It might be necessary to break or consolidate some types of products in the inbound shipments as required by different customers in different seasons in constraint (7). In constraints (8) and (9), the total shipments carried by cash inbound and outbound shipment carriers arc different from each other. We need to consider allocating truckloads to each carrier below its maximum capacity even if this carrier could offer the lowest shipping price among all the other carriers. In many trucking companies, a big issue in operations is that it becomes very difficult to find enough qualified drivers, especially in peak seasons. In constraints (10) and (11), we assume each driver is capable of making the same number of trips and each vehicle is capable of taking the same amount of workload. Constraints (12) to (17) arc the requirements for all the decision variables.

Assumptions

Some assumptions in the model development include:

- That the opening or closing of a production line happens simultaneously with the plan.
- That demand occurs at the beginning of a period. It is deterministic and known;
- That there are no defectives or losses during the process of production and transportation;
- That the initial inventory is permitted both in the manufacturing plants and DCs.
- That equipment is as good as new alter a preventive maintenance service
- That when a breakdown occurs, the equipment has to be repaired or replaced immediately

Constraints

Manufacturing plant

- Production cost of each plant
- Inventory cost of each plant
- Production capacity of each plant
- Inventory capacity of each plant

Warehouse

- Total cost from each plant to each warehouse
- Inventory cost of each warehouse
- Inventor\ capacity of each warehouse

Distribution

- Total cost from each warehouse to each customer
- Demand by each customer for one period

Taking into account the above said constraints, the following outputs are obtained

1. Total cost for all periods in order to satisfy the demand constraint.
2. Optimal production rate in each period for all plant
3. Optimal warehouse stock in each period for all warehouses.
4. Optimal Routing (from plain to warehouse to customers) for all periods.

2.3 Data Collection plan

To extract the needed data for easy analysis, 40 pages questionnaire was designed and the supply chain management team of the organization was given a time frame to respond to it tin- analysis. Five of these employees in the mid-level management that execute day to day activities were used for this purpose. The data obtained for this study were collected using self-administered questionnaire.

The survey was administered between October 20th 2015 and February 10th 2016. Participants were expected to use at least 30 minutes to complete the questionnaire.

The survey responses were then collected and manipulated with Microsoft Excel.

Raw material type and Source

The raw materials that are utilized for the production of the company's product mix include concentrate, sugar, bottle, crown, carbon dioxide (CO_2) and caustic soda (NBC, 2010). Table 2.0 depicts the sources of raw materials.

Table 2.0: Raw material type and sources

S/No	Raw Material	Source
1	Concentrate	USA
2	Sugar	Nigeria/USA
3	Bottle	Nigeria
4	Crown	Nigeria
5	CO2	In-house Production
6	Caustic Soda	Nigeria

Table 2.1: Maximum production capacity of the Company per year

Plant		2009	2010	2011	2012	2013	2014	Total
Owerri	Line 1	3191766	3562330	4677427	5691327	5706646	6720159	29549655
	Line2	3191566	3562266	4677266	5691166	5706474	671981	29548609
							Total	**59098264**
Enugu	Line1	3471624	3604513	4035328	4526458	4591368	4595369	24824660
	Line2	3474545	3605133	4040143	4521733	4586651	4595175	24823380
							Total	**49648040**
P/H	Line 1	9587650	9895670	11019700	12025610	12089990	13058700	67677350
	Line2	9587350	9895600	11019660	12025520	12089800	13057592	67675522
							Total	**135352872**
							Grand Total	**244099176**

Table 2.2: Annual demands at depots (warehouses)

	Demand (in Cases)						
Depot	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Owerri	1311500	1331550	1442500	1461000	1582500	1600000	8719050
Ekpoma	988400	998500:	1016520	1034500	1056500	1077800	6172220
Ugheli	967500	977600	998700	1016500	.1037530	1058700	6056530
Enugu	13011000	1310100	1430400	1455000	1576700	1597700	8669900
Warri	1 103500	1134500	1145300	1160000	1182500	1200000	6914800
Asaba	1220000	I241500	1263500	1280000	1307500	1326700	7639200
Agbor	1221500	1240000	1261700	1283,400	1300000	1330000	7636600
Ahoada	823450	893420	1116570	1013450	1002670	1010860	5860420
P/H	1314600	13301100	1357820	1370000	1390000	1412500	8174920
Calabar	1340000	1365500	1380000	1·100000	1425000	1440000	8350500
Wukari	924500	965000	987500	1000000	103500	1040000	5940500
IkotIkpeme	997800	101000	1034500	1050000	1075)00	1090000.	6357800
Eket	135500	1350000	1375700	1390000	1412500	1430000	8293700
Uyo	1405200	1·12000	1440000	1467500	1480000	1502500.	8721700
Onitsha	1486700	1500000	1525200	15,17200	1560000	1581500	9200600
Aba	1490000	1513500	1530000	1558700	1575000	1590000	9257200
Umuahia	1252500	1273500	1290000	1300000	1325500	1340000,1	7781500
Orlu	1001000	102:2500	1040000	1067500	1085500	1100000	6116500
Nnewi	1362100	1380000	1401250	1432500	1440000	1460000.	8465850
Awka	1337200	1355200	1370000	1393500	1410000	1430000	8295900
Nsukka	1400000	1·120000	1442-500	1·100000	1485600	1500000	8708100
Abakaliki	1380000	1400000	1426500	1440000	1462500	1480000	8589000

Table 2.3: Warehouses (Depots) and their distances from the plants in Kilometers

	Plant		
W/House (Depot)	Owerri	Enugu	Port-Harcourt
Owerri	0.00	147.00	99.00
Ekpoma	213.50	238.40	304.70
Ugheli	178.00	269.90	172.90
Enugu	147.00	0.00	236.00
Warri	206.50	298.30	161.10
Asaba	100.70	125.60	191.90
Aghor	158.00	182.90	249.20
Ahoada	74.60	219.40	69.50
P/H	99.00	236.00	0.00
Calabar	208.00	258.00	14730
Wukari	513.90	369.30	633.00
Ikot-Ikpeme	97.90	175.90	128.00
Eket	170.10	248.00	114.40
Uyo	125.90	203.9(	123.60
Onitsha	87.00	107.70	155.60
Aba	63.00	184.00	61.00
Umuahia	62.20	126.80	108.30
Orlu	37.70	124.80	81.70
Nnewi	71.70	105.30	162.80
Awka	94.00	66.80	186.10
Nsukka	201.80	60.90	284.70
Abakaliki	214.70	70.10	247.80

Table 2.4: Types of trucks and their capacity

	Number of trucks				Capacity in cases		
Type	Enugu	Owerri	P/H	Total	Enugu	Owerri	P/H
4 Pallet truck	15	15	15	45	4500	4500	4500
6 Pallet truck	8	8	8	24	3600	3600	3600
8 Pellet truck	6	6	6	18	3600	3600	3600
10 Pallet truck	5	6	6	17	3750	4500	4500
Hauler Trailer (22 Pallet)	15	16	16	47	24750	26400	26400
				Total 1	40200 1	42600	42600

The company uses vender managed inventory and agents must fulfill minimum criteria to qualify for it. Agents owned trucks and their capacity are given in Table 2.5.

Table 2.5: Types of third party trucks and their capacity

	Type of Truck			
Depot	**4 Pallet**	**6 Pallet**	**8 Pallet**	**Capacity**
Owerri	4	2	3	3900
Ekpoma	3	2 _	-	1800
Ugheli	2	3	-	1950
Enugu	4	2		3300
Warri	2	2	1	2100
Asaba	4	2	1	2700
Agbor	3	2	1	2400
Ahoada	3	2	-	1800
P/H	5	2	3	4200
Calabar	4	2	1	2750
Wukari	3	2	1	2400
IkotIkpeme	3	2	1	2400
Eket	2	4	1	3000
Uyo	4	2	2	3300
Onitsha	5	3	1	3450
Aba	5	2	1	3600
Umuahia	3	2	1	2400
Orlu	3	1	1	1950
Nnewi	4	2	2	3300
Awka	3	2	1	2850
Nsukka	4	3	2	3750
Abakaliki	3	2	2	3000

Table 2.6: Average Annual plant fixed costs

Plant	Fixed Cost (N)					
	2009	*2010*	*2011*	2012	2013	2014
Owerri	1698132	17988132	1898132	1898132	1898132	1908133
Enugu	1415110	1515110	1615110)	161511	1615110	1665100
Port-Harcourt	1698132	1798132	1898132	189813	1898132	1908132

Table 2.7: Average unit cost of producing 35cl and 50cl per plant

Plant	Unit Cost (N)					
	2009	2010	2011	2012	2013	2014
Owerri	*17.01*	17.00	17.75	18.42	18.75	18.75
Enugu	17.02	17.10	17.65	18.42	18.75	18.75
Port-Harcourt	17.02	17.10	17.85	18.42	18.75	18.75

Table 2.8: Average transportation cost in Naira/case between plants and W/H Locations

	Plant		
Depot (W/H)	**Owerri**	**Enugu**	**Port-Harcourt**
Owerri	0.00	124.95	84.15
Ekpoma	181.48	202.64	259.00
Ugheli	151.30	229.42	146.97
Enugu	124.95	0.00	200.60
Warri	175.53	253.56	136.94
Asaba	85.60	106.76	163.12
Agbor	134.30	155.47	211.82
Ahoada	63.41	186.49	59.08
P/H	84.15	200.60	0.00
Calabar	176.80	219.30	125.21
Wukari	436.82	313.91	538.05
IkotIkpeme	83.22	149.52	108.80
Eket	144.59	210.80	97.24
Uyo	107.02	173.31	105.06
Onitsha	73.95	91.55	132.26
Aba	53.55	156.40	51.85
Umuahia	52.87	107.78	92.06
Orlu	32.05	106.08	69.45
Nnewi	60.95	89.51	138.38
Awka	79.90	56.78	158.19
NSukka	171.53	51.77	242.00
Abakaliki	182.50	59.59	10.61

Table 2.9: Average transportation cost in Naira/case between Warehouses and Customer

Depot	Cost(N)	Customer's Demand
Owerri	50.20	8719050.00
Ekpoma	50.00	6172220.00
Ugheli	53.00	6056530.00
Enugu	54.00	8669900.00
Warri	56.00	6914800.00
Asaba	55.00	7639200.00
Agbor	53.20	7636600.00
Ahoada	52.70	5860420.00
P/H	52.00	8774920.00
Calabar	53.00	8350500.00
Wukari	55.00	5940500.00
Ikot-Ikpeme	53.00	6257800.00
Eket	56.00	8293700.00
Uyo	50.10	8721700.00
Onitsha	52.50	9200600.00
Aba	57.20	9257200.00
Umuahia	53.15	7781500.00
Orlu	50.40	6316500.00
Nnewi	51.10	8465850.00
Awka	51.00	8295900.00
Nsukka	55.00	8708100.00
Abakaliki	56.60	8589000.00

Based on the available data the total production cost for existing network was calculated first analytically and then compared with the optimization solution techniques. Finally Optimization with the renewed setting was made.

2.4 Analysis of the data

(a) Analytical approach

Analytically, the total production cost warehouses using equation 1 results N14,309,689,102.80. The actual total production cost obtained from plants is almost equal to this value.

(b) Using solution techniques to optimize production and distribution problem

Substituting all the parameters above into the general from of the mathematical model for the production and distraction problem developed in this chapter:

Objective function to optimize:

Minimize $\mathbb{Z} = 1698132Z_{11} + 1798132Z_{12} + 1898132Z_{13} + 1898132_{14} + 1898132Z_{15} + 1908132Z_{16} + 1415110Z_{21} + 1515110Z_{22} + 1615110Z_{23} + 1615110Z_{24} + 1615110Z_{25} + 1665110Z_{26} + 1689132Z_{31} + 1798132Z_{32} + 1898132Z_{33} + 1898132_{35} + 1908132Z_{36} + 17.01P_{11} + 17.06P_{12} + 17.75P_{13} + 18.42P_{14} + 18.75P_{15} + 18.75P_{16} + 17.02P_{21} + 17.10P_{22}\ 17.65P_{23} + 18.42P_{24} + 18.75P_{25} + 18.75P_{26} + 17.02P_{31} + 17.10P_{32} + 17.85P_{33} + 18.42P_{34} + 18.75P_{35} + 18.75P_{36} + 11.50V_{11} + 11.50V_{12} + 12.50V_{13} + 12.50V_{14} + 15.50V_{15} + 15.50V_{16} + 11.50V_{21} + 11.50V_{22} + 12.50V_{23} + 12.50V_{24} + 15.50V_{25} + 15.50V_{26} + 11.50V_{31} + 11.50V_{32} + 12.50V_{33} + 12.50V_{34} + 15.50V_{35} + 15.50V_{36} + 0.00X_{11} + 181.48X_{12} + 151.30X_{13} + 124.95X_{14} + 175.53X_{15} + 86.60X_{16} + 134.30X_{17} + 63.41X_{18} + 84.15X_{19} + 176.80X_{110} + 436.82X_{111} + 83.22\ X_{112} + 144.59X_{113} + 107.02X_{114} + 73.95X_{115} + 53.55X_{116} + 52.87X_{117} + 32.05X_{118} + 60.95X_{119} + 79.90X_{120} + 171.53X_{121} + 182.50X_{122} + 124.95X_{21} + 202.64X_{22} + 229.42X_{23} + 0.00X_{21} + 253.56X_{25} + 106.76X_{212} + 210.80X_{213} + 173.31X_{214} + 91.55X_{215} + 156.40X_{216} + 107.78X_{217} + 106.08X_{218} + 89.51X_{219} + 56.78X_{220} + 51.77_{221} + 59.59X_{222} + 84.15X_{31} + 259.00X_{32} + 149.97X_{33} + 200.00X_{34} + 136.94X_{35} + 163.12X_{36} + 211.82X_{37} + 59.08X_{38} + 0.00X_{39} + 125.21X_{310} + 538.05X_{311} + 108.80X_{312}\ 97.24X_{313} + 105.06X_{314} + 132.20X_{315} + 51.85X_{316} + 92.06X_{317} + 69.45X_{318} + 138.38X_{319} + 158.19X_{321} + 210.63x_{322} + 13.5W_1 + 13.00W_2 + 13.20W_3 + 14.02W_4 + 14.00W_5 + 14.00W_6 + 13.02W_7 + 13.20W_8 + 15.50W_9 + 14.50W_{10} + 13.20W_{11} + 13.40W_{12} + 12.50W_{13} + 14.60W_{14} + 15.20W_{15} + 14.50W_{16} + 13.60W_{17} + 13.00W_{18} + 14.50W_{19} + 14.30W_{20} + 15.20W_{21} + 13.40v22 + 50.20Y_{1K} + 50.00Y_{2K} + 53.00Y_{3K} + 54.00Y_{5K} + 55.00Y_{6K} + 53.20Y_{7K} + 52.70Y_{8K} + 52.00Y_{9K} + 53.00Y_{10K} + 55.00Y_{11K} + 52.00Y_{12K} + 56.00Y_{13K} + 50.00Y_{14K} + 52.00Y_{15K} + 57.20Y_{16K} + 53.10_{17K} + 50.40Y_{18K} + 51.10Y_{19K} + 51.00Y_{20K} + 50.00Y_{21K} + 56.60Y_{22K}$ ………………………………………………………… 1

Subject to:

$P_{11} + p_{12} + p_{13} + P_{14} + P_{15} + P_{16} \leq 59098264$ ……………………………………….2a

$P_{21}+ p_{22}+ p_{23}+ P_{24} + P_{25}+ P_{26} \leq 49648040$ ……………………………………..…2b

$P_{31}+ p_{32}+ p_{33}+ P_{34} + P_{35}+ P_{36} \leq 135352872$ ………………………………….......2c

$V_{11}+ V_{12}+ V_{13} + V_{14} + V_{15}\ V_{16} + \leq 220000$ ……………………………………..3a

$V_{21}+ V_{22}+ V_{23} + V_{24} + V_{25}\ V_{26} + \leq 200000$……………………………………….3b

$V_{31}+ V_{32}+ V_{33} + V_{34} + V_{35}\ V_{36} + \leq 220000$ …………………………………….3c

$X_{11}+ X_{12} + X_{13} + X_{14} + X_{15} + X_{16} +X_{17} + X_{18} + X_{19} + X_{110} + X_{111} + X_{112} +X_{113} + X_{114}+ X_{115} + X_{116} + X_{117} + X_{118} + X_{119} +X_{120} + X_{121} + X_{122} + X_{21} + X_{22} + X_{23} +X_{24} + +X_{25} + X_{26} + X_{27} + X_{28} + X_{29} +X_{210} + X_{211}+X_{212} + X_{213}+ X_{214} + X_{215}+X_{216} + X_{217} + X_{218}+X_{219}+ X_{220} +X_{221} +X_{222}+ X_{31}+X_{32}+ X_{33}+ X_{34}+ X_{35}+ X_{37}+ + X + X_{218}+X_{219}+ X_{220} +X_{221} +X_{222}+ X_{31}+X_{32}+ X_{33}+ X_{34}+ X_{35}+ X_{37}+ + X_{38}+ X_{39}+X_{310}+ X_{311} +X_{312} +X_{313}+ X_{314}+X_{315}+ X_{316}+ X_{317}+ X_{318}+ X_{319}+ + X_{320} + X_{321}+X_{322}+ \leq 125400$ ………………………………………………………………..4

$Y_{1K} +Y_{2k} + Y_{3k}+ Y_{4k}+ Y_{5k} +Y_{6k}+ Y_{7k}+ Y_{8K}+Y_{9K} +Y_{10K}+ Y_{11K} +Y_{12K} + Y_{13K} + Y_{14K} +Y_{15k} + Y_{16k}+ Y_{17k}+ Y_{18k} +Y_{19k}+ Y_{20k}+ Y_{21K}+Y_{22K} \leq 170022490$………………………....5

$W_1 \leq 100000$ …………………………………………………………………...6a

$W_2 \leq 100000$ …………………………………………………………..….6b

$W_3 \leq 100000$ ………………………………………………………….…..6c

$W_4 \leq 100000$ ………………………………………………………………..6d

$W_5 \leq 120000$ ………………………………………………………………..6e

$W_6 \leq 120000$ ………………………………………………………………..6f

$W_7 \leq 120000$ ………………………………………………………………..6h

$W_8 \leq 120000$ ………………………………………………………………..6h

$W_9 \leq 100000$ ………………………………………………………………..6i

$W_{10} \leq 100000$ ………………………………………………………………..6j

$W_{11} \leq 120000$ ………………………………………………………………..6k

$W_{12} \leq 120000$ ………………………………………………………………..6l

$W_{13} \leq 120000$ ………………………………………………………………..6m

$W_{14} \leq 120000$ ………………………………………………………………..6n

$W_{15} \leq 120000$ ………………………………………………………………..6o

$W_{16} \leq 100000$ ………………………………………………………………..6p

$W_{17} \leq 120000$ ………………………………………………………………..6q

$W_{18} \leq 120000$ ………………………………………………………………..6r

$W_{19} \leq 100000$ …………………………………………………………………6s

$W_{20} \leq 100000$ …………………………………………………………………6t

$W_{21} \leq 120000$ …………………………………………………………………6u

$W_{22} \leq 120000$ …………………………………………………………………6v

$Y_{1k} \leq 100000$ …………………………………………………………………7a

$Y_{2k} \leq 120000$ …………………………………………………………………7b

$Y_{3k} \leq 120000$ …………………………………………………………………7c

$Y_{4k} \leq 120000$ …………………………………………………………………7d

$Y_{5k} \leq 120000$ …………………………………………………………………7e

$Y_{6k} \leq 120000$ …………………………………………………………………7f

$Y_{7k} \leq 120000$ …………………………………………………………………7g

$Y_{8k} \leq 120000$ …………………………………………………………………7h

$Y_{9k} \leq 120000$ …………………………………………………………………7i

$Y_{10k} \leq 120000$ …………………………………………………………………7j

$Y_{11k} \leq 120000$ ………………………………………………………………7k
$Y_{12k} \leq 120000$ ………………………………………………………………7l
$Y_{13k} \leq 120000$ ……………………………………………………………7m
$Y_{14k} \leq 120000$ ………………………………………………………………7n
$Y_{15k} \leq 120000$ ………………………………………………………………7o
$Y_{16k} \leq 120000$ ………………………………………………………………7p
$W_{17} \leq 120000$ ………………………………………………………………7q
$W_{18} \leq 120000$ ………………………………………………………………7r
$W_{19} \leq 120000$ ………………………………………………………………7s
$W_{20} \leq 120000$ ………………………………………………………………7t
$W_{21} \leq 120000$ ………………………………………………………………7u
$W_{22} \leq 120000$ ………………………………………………………………7v
$Y_{1K} + Y_{2K} + Y_{3K} + Y_{4K} + Y_{5K} + Y_{6K} + Y_{7K} + Y_{8K} + Y_{9K} + Y_{10K} + Y_{11K} + Y_{12K} + Y_{13K} +$
$Y_{14K} + Y_{15K} + Y_{16K} + Y_{17K} + Y_{18K} + Y_{19K} + Y_{20K} + Y_{22K} \leq 125000$ ………………8
$0.5Y_{1K} \leq 100000$ ……………………………………………………………9a
$0.5Y_{2K} \leq 120000$ …………………………………………………………...9b
$0.5Y_{3K} \leq 120000$ …………………………………………………………...9c
$0.5Y_{4K} \leq 120000$ …………………………………………………………...9d
$0.5Y_{5K} \leq 120000$ …………………………………………………………...9e
$0.5Y_{6K} \leq 120000$ …………………………………………………………...9f
$0.5Y_{7K} \leq 120000$ …………………………………………………………...9g
$0.5Y_{8K} \leq 120000$ …………………………………………………………...9h
$0.5Y_{9K} \leq 120000$ …………………………………………………………...9i
$0.5Y_{10K} \leq 120000$ …………………………………………………………...9j
$0.5Y_{11K} \leq 120000$ …………………………………………………………...9k
$0.5Y_{12K} \leq 120000$ …………………………………………………………...9l
$0.5Y_{13K} \leq 120000$ …………………………………………………………..9m
$0.5Y_{14K} \leq 120000$ …………………………………………………………...9n
$0.5Y_{15K} \leq 120000$ …………………………………………………………...9o
$0.5Y_{16K} \leq 120000$ …………………………………………………………...9p
$0.5Y_{17K} \leq 120000$ …………………………………………………………...9q
$0.5Y_{18K} \leq 120000$ …………………………………………………………...9r
$0.5Y_{19K} \leq 120000$ …………………………………………………………...9s
$0.5Y_{20K} \leq 120000$ …………………………………………………………...9t
$0.5Y_{21K} \leq 120000$ …………………………………………………………...9u
$0.5Y_{22K} \leq 120000$ …………………………………………………………...9v
$0.05X_{11} + 0.05X_{12} + 0.05X_{13} + 0.05X_{14} + 0.05X_{15} + 0.05X_{16} + 0.05X_{17} + 0.05X_{18} + 0.05X_{19} + 0.05X_{110} +$
$0.05X_{111} + 0.05X_{112} + 0.05X_{113} + 0.05X_{114} + 0.05X_{115} + 0.05X_{116} + 0.05X_{117} + 0.05X_{118} + 0.05X_{120} +$
$0.05X_{121} + 0.05X_{122} + \leq 85680$……………………………………………10a
$0.05X_{21} + 0.05X_{22} + 0.05X_{23} + 0.05X_{24} + 0.05X_{25} + 0.05X_{26} + 0.05X_{27} + 0.05X_{28} + 0.05X_{29} + 0.05X_{210} +$
$0.05X_{211} + 0.05X_{212} + 0.05X_{213} + 0.05X_{214} + 0.05X_{215} + 0.05X_{216} + 0.05X_{217} + 0.05X_{218} + 0.05X_{219} +$
$0.05X_{220} + 0.05X_{221} + 0.05X_{222} + \leq 82320$……………………….....10b
$0.05X_{31} + 0.05X_{32} + 0.05X_{33} + 0.05X_{44} + 0.05X_{35} + 0.05X_{36} + 0.05X_{37} + 0.05X_{38} + 0.05X_{39} + 0.05X_{310} +$
$0.05X_{311} + 0.05X_{312} + 0.05X_{313} + 0.05X_{314} + 0.05X_{315} + 0.05X_{316} + 0.05X_{317} + 0.05X_{318} + 0.05X_{319} +$
$0.05X_{320} + 0.05X_{321} + 0.05X_{322} + \leq 85680$ …………………………10c
And X_{11}, X_{12} ……………………...X_{322} , ≥ 0
Y_{1k} …………………………………$Y_{22k} \geq 0$
P_{11} …………………….…………$P_{36} \geq 0$
V_{11} …………………………………$V_{36} \geq 0$

W_1 ………………………………….$W_{22} \geq 0$

The mixed integer linear programming model was completely formulated and implemented using LINGO programming software.

To see the benefit of supply chain network for the company: two set of optimization are considered:

1. Optimization based on existing set of operation of the company: in this case, the existing plant and warehouse location are fixed.
2. Optimization with renewed setting: in this option, all warehouse location are set to change and optimization techniques are used to arrive at a minimum cost scenario.

III. RESULT AND DISCUSSION

Optimization Based on Existing set of Operation

Based on the existing network structures, the plant at Owerri plant supplies five warehouse within the South-south and almost all the warehouse location within the south-east except Abakaliki, and Nsukka. Enugu plant supplies ten warehouses within south-east. In the optimization approach, a built-in programming tool called LINGO is utilized. In this scenario, the total annual cost is found to be N11,161,557,500,000.00 within the minimum inventory holding cost of N309,500 per year. Thus, it resulted in N524,688,600.30 annual saving from the actual cost investigated with the analytical method which is N14,309,689, 102.80. All the demand is met and all warehouse supply demands within their proximity. The excess transportation capacities to transport 109544 cases from Owerri plant, 224040 cases from Enugu plant and 6,056,592 cases from P/H plant re used to serve third party distributors or agents directly take shipments from plant.

Optimization with Renewed Setting

The basic problem with agents is that, they are not likely to travel longer distance to collect shipment. For instance, it is difficult to find distribution and MDCs in towns located far from plants. The total cost they incur coupled with their capacity to satisfy market largely hampers their performance. Besides, the opportunity the company loses is taken up by competitors right away.

Therefore, it is better for the company to outreach as much markets as possible.

Accordingly, warehouse at Mbaise, Eleme and Agbani towns are identified as potential sites in addition to the already existing ones. Other places in the country have relatively level topography and nearby to Owerri, Enugu and P/H plant hence, agents can easily be found.

After potential places in the country are proposed, the optimal solution taking into consideration all potential market locations is formulated in the mixed integer linear programming model.

In the renewed network optimization, the Owerri plant which was used to supply five warehouse (south-south) and its area is now utilized to supply four warehouse (south-south) (Ekpoma, Asaba, Agbor, and Ikot Ikpeme). Also its supplies six warehouse (south-south) (Owerri, Mbaise, Onitsha, Umuahia, Orlu and Nnewi). Enugu plant which was used to supply two warehouse (south-south) and its area is now utilized to supply one warehouse (south-south) (Wukari) only. Also its supplies five warehouse (south-south) (Enugu, Agbani, Awka, Nsukka, and Abakaliki). Port Harcourt (P/H) plant which was used to supply twelve warehouse (south-south) and its area is now utilized to supply eight warehouses (south-south) (Ughecli, Warri, Eleme, Ahoada, P/H, Calabar, Eket, and Uyo). Also its supplies one warehouse (south-south) (Aba) only.

In doing so, the company can increase its responsiveness by fully utilizing its whole capacity to supply itself. In this scenario a total of 2799820 market demands in cases which is equivalent to N60817040.50 are achieved, and at the sometime all the demands are met. The final SC network design is therefore, as given in fig. 3.0 (see appendix 2)

To simplify the Supply Chain operation, Warehouses should be established away from the plant. This is a based issue for the company with the objective to relieve the queue at the plants, to respond faster to demands with higher customer services level, to simplify information processing between distribution centres (DCs) and the company, and to use different set of trucks for different purpose purposes.

There are excess numbers of trailers at the plants (Owerri, P/H and Enugu). By proper scheduling of the shipments, cost saving and resources utilization will be assured.

Table: 3.0 shown the proposed schedule for the shipment from plant to warehouse. For distributors outside the city only 18 trailers are required, the remaining can be used for distribution within the city.

Table 3.0: vehicles scheduling for shipment out of P/H plant

	Days of the week								
Warehouse	Distance	Mon	Tue	Wed	Thurs	Fri	Sat	Sun	Max. NO of trucks required
P/H	0.00	X		X		X			2.00
Eleme	26.00		X		X		X		2.00
Ugheli	172.90			X			X		2.00
Warri	161.10	X					X		2.00
Ahoada	69.50		X		X				2.00
Calabar	147.30	X				X			2.00
Eket	114.40		X		X				2.00
Uyo	123.60	X				X			2.00
Aba	61.00		X		X		X		2.00

Number of Warehouses to be Established

To determine the number of warehouses to be established and find the right locations, waiting time to load shipment from plant to DCs and lost market demand have to be considered. To respond to demand at any DC, a vehicle spends an average of one hour in the queue, another one hour to get empty bottles to inspect and load. Moreover, to arrive at the destination an average of one hour is lost. Therefore, a total of two and a half hours are spent on average. An average of (8719050/365) or 23888 cases have to leave the plants per day. As the company uses trucks of capacity 300 cases for P/H shipments, a total of 22 trucks have to wait to get their shipment done. The means 22hrs are wasted per day only in the queue, which is equivalent to 8030 hrs per year. If assumed that cost of one hour of a vehicle is N800 (average) a total of N6,424,000.00 is lost in queuing. This cost is enough to open a warehouse in another place within the city. In addition to the existing plant warehouse in P/H, it would be advisable to establish one warehouse in Eleme with a capacity of 999970 cases. Initial shipment is made directly from plant to the warehouse at Eleme by a truck of capacity 2976 cases per day and then the shipment can further be distributed by trucks of capacity 300 cases. After utilizing 18 Hauler Trailers with a capacity of 1650 cases outside the city, the company remains with other trucks with a combined capacity of carrying 3690 cases per day.

IV. CONCLUSION AND RECOMMENDATIONS

The production, inventory and distribution systems of the Nigerian Bottling Company (NBC) [south – south and south-east of Nigeria] have been studied in this thesis and the potential for using mixed integer linear programming (MILP) model in managing a large scale production, inventory and distribution problems subsequently identified. Three plants and twenty two distribution centres of the company were considered and data were obtained with respect to their operations. The decision variables, parameters and constraints for formulating a model of the company's production, inventory and distribution operations so identified have been solved using Lingo 15.00 version.

A MILP model which consists of 196 variables and 126 constraints has been fitted and subsequently formulated. The optimal production, Inventory and distribution of NBC products, has been analysed and the model improved the overall production cost of the company under study by 22% and also enhanced the production, inventory and distribution strategy used by the company. The model developed resulted to significant cost reduction of 25.5% with optimization principle. The result of the network has shown that optimization of different NBC products can be achieved using MILPS software (Lingo) and is highly sensitive to changes putting into consideration the constraints that limit what is achievable.

Thus, Supply Chain network design in this thesis has a high economic benefit for manufacturing company. Therefore, the following recommendations were made:

1. Three new warehouses should be established at Mbaise, Agbani and Eleme.
2. The mixed integer linear programming (MILP) developed and optimization techniques employed here will be good grounds for any similar bottling companies with a need to design appropriate SC network thereby reducing their costs.
3. This model could be easily adapted to another manufacturing plant based on their existing operating situations.

REFERENCE

[1]. Abott, S. & Mckinney, P. (2013), Application of planning models in the agri-food supply chain: a review // European Journal of Operational Research. 196 (1). pp. 1 20.

[2]. Anily, S. & Federgruen, A. (2003). One warehouse multiple retailer system with vehicle routing costs. Management Science, 36, pp. 93 – 114.

[3]. Arntzen, B.C., Brown, C. G., Harrison, T. P. & Trafton, L.L. (2005), Global supply chain management at digital equipment corporation", Interfaces, 25, pp.69-93.

[4]. Burns L.D., Hall R. W., Blumenfeld D. E., & Daganzo C. F., (2005). Distribution strategies that minimize transportation and inventory costs, Operations Research, 33(3), pp. 469-490.

[5]. Canel C., Khumawala B. M., (2001) International facilicities location: a heuristic procedure for the dynamic uncapacitated problem, International Journal of Production Research, 39(17), pp. 3975-4000.

[6]. Chandra P., & Fisher M.L., (2000). Coordination of production and distribution planning, European Journal of Operational Research, 72(3), pp. 503-517.

[7]. Chen, Z.-L., (2010), "Integrated production and outbound distribution scheduling: review and extensions," Operational Research, 58(1), pp. 130-148.

[8]. Cohen M. A., & Lee H. L., (2008). Strategic analysis of integrated production –distribution systems: Models and methods, Operations research, 36(2), pp. 216-228.

[9]. Erenguc, S. S., Simpson, N. C. & Vakharia, A.J., (2009). Integrated production /Distribution planning in supply chains: An invited review. European Journal of Operational Research, 115, pp. 219-236.

[10]. Geunes, J., Pardalos, P. M. & Romeijn, H.E., (2002). 3rd ed. Supply chain Management: Models, applications, and research directions. Kluwer Academic Publisher, Dordrecht, Netherlands.

[11]. Glover, F., Jones, G., Karney, D., Klingman, D. & Mote, J. (2009), An integrated production, distribution, and inventory planning system, Interfaces, 9(5), pp. 21 -35.

[12]. Gong, Q., Lai, K.K., & Wang, S. (2008), Supply chain networks: Closed Jackson network models and properties//International Journal of Production Economics. 113. pp.567-574.

[13]. Gue, K. R. & Meller, R. D., (2009) "Aisle Configurations for Unit-Load Warehouse," HE Transactions, 41(3), pp. 171-182.

[14]. Hewlett, P. (2005), Inventory and supply chain management with forecast updates. International series in operations research & management science. New York: Springer.

[15]. Jayaraman, V. & Ross, A. (2003), A simulated annealing methodology to distribution network design and management. European Journal of Operational Research, 144(3), pp. 629-645.

[16]. Lee, S.M & Moore, L.J., (2003). Optimizing transportation problems with multiple conflicting objectives, AHE transaction, 5(4). pp.120-129.

[17]. The Nigerian bottling Company balance sheet, Management and Assessment records (2012: The assessment and analysis of sales deficit, sales volume, profit and losses of the NBC account book, Vol. 4, No. 3, pp. 4-8.

[18]. The Nigerian bottling Company Journal of Operations Research and Management Technique (2010): Mathematical technique for Modeling, analysis and Solutions to Management and Production Problems of the NBC, Vol. 8, No. 2, pp. 7-13.

[19]. The Nigerian bottling Company Production System evaluation (2013): Production Capacity Utilization and volume of output produced per period, Vol. 2, No. 2, pp. 29-35.

[20]. The Production System flexibility and On-time delivery of the Nigerian bottling Company (2011): Frequency of Production System failure and quality Service Reliability of the NBC products, Vol. 12, No 3, pp. 10-15.

[21]. Xerox, H. (2004), 2nd Ed, Supply Chain Management and Advanced Planning, Springer.

Appendix 1

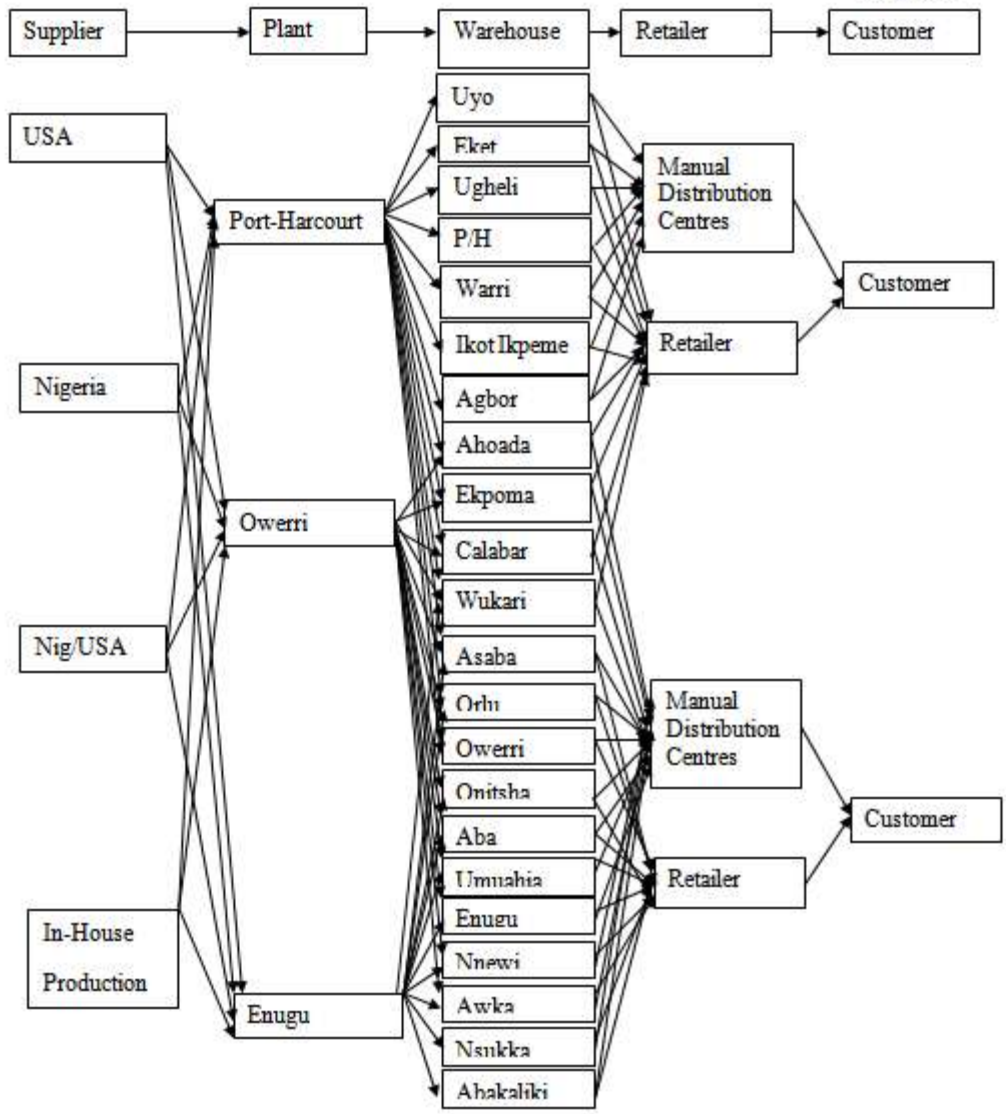

Figure 2.0 Existing supply chain network of the study area (NBC, 2011 and 2013)

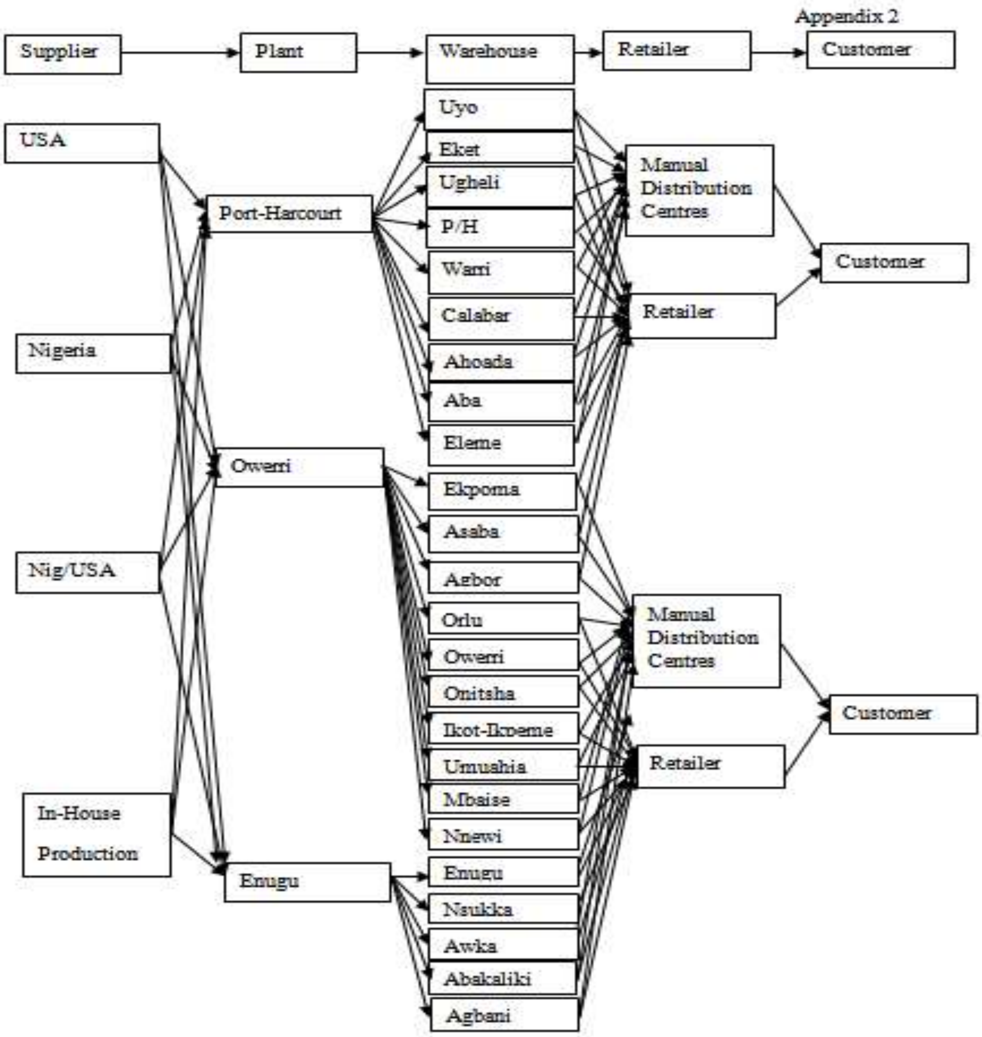

Figure 3.0: Renewed Supply Chain network design of the case company

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