IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 4 Ver. IV (Jul. - Aug. 2018), PP 28-41
www.iosrjournals.org

Optimization of Distribution Network of Nigerian Bottling Company PLC Using LINGO

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Abstract: *This research on Optimization of Distribution Network using LINGO was carried out in the Nigerian Bottling Company (NBC) which has many distribution centres all over the country. Three plants and twenty two warehouses within the South-South and South-East region of Nigeria were selected for this study. Model for the distribution problem of the company were developed using linear programming approach. The data collected was analyzed using LINGO programming. The analytical result obtained was thirty billion, nine hundred and three million, nine hundred and fifteen thousand, twenty nine naira, eleven kobo (N30, 903,915,029.11). The actual distribution cost obtained from the company's annual report is almost equal to this value. The optimization result obtained was (N6, 798,861,306.36) which is the annual distribution cost for the period of six years. When compared with the analytical method N24, 105,053,722.75 (about N4,017508953 per annual) was saved and all the demand was met and all warehouses supplied with demands within their proximity. This showed that about 22% reduction in distribution cost was achieved by optimizing all the distribution cost elements. In addition, the existing situation of the company was improved and a new network system for the company designed. The study recommended the application of this research outcome to other similar companies that intend emulating the benefits in the designed distribution network.*

Key words: *Supply chain, Optimization, model, Warehouse, Distribution, LINGO*

Date of Submission: 05-08-2018 Date of acceptance: 22-08-2018

I. Introduction

The characteristics of today's competitive environment, such as the speed with which products are designed, manufactured and distributed, as well as the need for higher efficiency and lower operational costs, are forcing companies to continuously search for ways to improve their operations.

Optimization models and algorithms, decision support systems and computerized analysis tools are examples of approaches taken by companies in an attempt to improve their operational performance and remain competitive under the threat of increasing competition.

The objective of this paper is to optimize distribution function of the company using LINGO programming. We wish to focus on models that consider the transportation system since our main interest is to concentrate on the following points: (i) How have logistics aspects been included in the analysis? and (ii) What competitive advantages have been obtained from the optimization of the distribution function to other production functions within a company and among different companies?

Chandra and Fisher in (Chandra and Fisher, 2000) are very close to the study problem. The main differences in their paper are the production of several products, an unlimited fleet and storage capacity at the plant, the absence of inventory holding cost at the plant, and split deliveries (multiple deliveries can be made by different vehicles to the same customer). Compared to study case, the multi-product option seems more complicated, but in fact the unlimited fleet and split deliveries make the problem easier because the hard bin-packing sub-problems consisting of assigning the demands to a limited number of vehicles are avoided. These authors proposed a first approach that computes separately one production plan and then a distribution plan, and a so-called coupled approach. In fact, the letter consists in searching cost-reducing changes in the two plans returned by the first approach. Saving between 3% and 20% are reported for the second method on instances with up to 10 products, 50 customers and 10 periods. It should be noted that the instances are weakly constrained, one third of them have a total demand per day limited to 85% of production capacity, one other third 60%, while the last third considers an unlimited production capacity. Chandra and Fisher (2000) tackled a problem of preparation of orders in a regional warehouse to satisfy the demands of customers in the same region. If an order cannot be satisfied, the warehouse may transmit it to a higher echelon (e.g., a factory) but this induces a fixed cost. The tests conducted on different data sets show a cost reduction ranging from 5% to 14% when distribution and order preparation are coordinated. Fumero and Vercellis, (2010) dealt with a problem closely related with the one studies by Chandra and Fisher. Their solution method, based on lagrangean relaxation, is evaluated on smaller instances with up to 12 customers, 10 products and 8 periods. Here again, the algorithm is compared with an uncoupled approach and significant savings are obtained. Erenguc, et al. (2009) handled the same kind of problem. Like Chandra and Fisher, they start with a decomposition of the global problem into a production planning problem and a distribution problem. However, they relax some constraints in this first phase and reintroduce them progressively to ensure coordination and make the results of the first phase feasible for the global problem. Metter's (1996) investigated the coordination between a sorting center and mail distribution. The objective includes the total cost, the reduction of routing delays. Bramel, et al. (2000) and Melachrinoudis, et al, (2000) solved a problem of cooperation among several factories that can make components or sub-assemblies for each other. However, the routing aspects are very simplified, since truckload transportation is assumed between factories. A review of the different problems raised by the coordination between production and distribution is presented in Sarmiento and Nagi, (1999) and Min and Melachrinoudis, (1999).

II. Research Methodology

Jha (2008) and Kothari (2004), points out that researches can be identified either by quantitative or qualitative based on the questions being investigated or researched and data to be collected. Since this is about optimizing the supply chain network, a quantitative research method approach would be used. Quantitative data collected through the questionnaires would be used to assign levels of the three cost factors in the supply chain. Jha (2008), also points out that if quantification of data cannot be done, then the research is a qualitative one. 'Thus the main difference between quantitative and qualitative research lies in the data collection and analysis procedure used in the research.

The main objective of this research work is to minimize the total cost of the supply chain network, in this reason a descriptive research methods would be applied. Sachdeva (2009), points out the goal of descriptive research is to describe things, data and characteristics about a population or activity being investigated. Descriptive research also involves the use of frequencies, averages and other forms of statistical analysis and manipulations. Since the facts to be extracted can be quantified and statistical manipulations can be applied to it then, it can be termed descriptive.

2.1 Tools

Bell (2010), defines a research instrument as a tool used to collate data. According to Boulton (2012), it is important to use a good tool to run a survey to help in collection of data and analysis. Kelly, et al. (2003), also points out that, the areas of interest in any research work should be well demarcated and related to research question under investigation. As the tool used to gather the data would be an important factor that can affect the reliability and validity of the results generated, the tool generated would be given serious attention in the development stage to make sure it satisfies the intended goals of the study.

In order to design a good tool that can extract the needed information for analysis, Operations Research techniques were comprehensively looked at with focus on best model that fit the areas of interest of the thesis. Since the target is to measure how activities and cost implications of the three factors are being carried out within the chain, mixed integer linear programming model would be the criteria used in the assessment. The questionnaire would tackle some selected processes used in managing activities in the supply chain from the planning to final delivery to the customer.

2.2 Research Materials

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

2.3 Data Collection

Essential information for the research will be collected through primary and secondary sources, which include:

(i) Interview with some key personnel in the production and transportation departments of the company. The interview questions include:

General questions

1. For how long have you been working in this company?
2. Do you usually go for training, workshop or conferences?

Production section

3. How do you evaluate cost of a product?
4. How many production lines do your company have?

Transportation section

5. How do you evaluate the cost of transporting from different plants to different distribution centres?
6. What type of transporting trucks do your company have?

(ii) Interview with the supply chain personnel (Supply chain manager). The interview questions include:

1. How many trucks are available for outbound business?
2. What is the number of drivers deployed for outbound business? Any driver's support?
3. What is the standard size of truck for outbound business?

(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.

2.4 Description of the study area

The study company is the Coca-Cola bottling company, the leading soft drinks producers and distributors in Nigeria. Coca-Cola's range of products in Nigeria includes the following beverages: Coca-Cola, Fanta in orange, Lemon and black currant flavors, Sprite and Schweppes in bitter Lemon, Club soda and tonic water, Eva bottled water and five Alive fruit juice brand. The company became operational in Nigeria through the Nigerian Bottling Company (NBC) Plc, which was established in 1951. Production in Nigeria began in 1953 at a bottling facility in Ebute-Metta Lagos and new plants at Kano, Port Harcourt and Ibadan were opened shortly afterwards. Over the years production capacity has grown and it presently operates 13 facilities, 60 distribution centres (depots) and over 400,000 dealers nationwide. Since production started, Coca-Cola bottling company has remained the largest bottler of non-alcoholic beverages in the country in terms of sales volume, with about 1.8billion bottles sold per year, making it the second largest market in Africa. In this study however, the Coca-Cola plants and distribution centres in the South-East and South-South geopolitical regions of the country will be used. Coca-Cola bottling company Ltd operates 3 plants and 21 distribution centres in the South-Fast and South-South regions of Nigeria. In an effort to improve on the company's plant distribution needs, an investment of over ₦1billion was made by NBC to purchase more than 100 sales trucks, tractors, semi-trailers and forklifts in April 2012 (NBC, 2012).

In the current business operations however, some segments of the markets for the company's product are experiencing shortage. This may be due to shortage of supply from the plant/depot, or lack of supply to specific market segment while excess supply is experienced in others. This means that the company is losing its sale because the customer may cancel the order or shift to some other brand. However, the company does not have well established means to monitor the shortage in the market and mechanisms on how to supply the market accordingly. 'This underscores the need to develop a new supply chain network design for the company.

2.5 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 22 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 1.0 (appendix 1)

2.6 The Modeling Framework

Consider a typical problem of configuring a 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 optimized distribution system can be developed. The model formulated will attempt to minimize distribution cost by simultaneously considering facility location, production capacity, distribution batch size and so on. To model such as problem, the following notations were defined.

Z Total distribution cost

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

D_{klt} Demand for product l by customer k in period t

F_{ijlmt} Transportation cost for transporting a unit of product l from plant i to DC j when using carrier m in period t

G_{jklnt} Transportation cost for transporting 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*
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-loads carrier *m* in period *t*
N_{nt} Truckload capacity of outbound-loads carrier *n* in period t
O_{mt} Driver capacity of inbound-loads carrier *m* in period *t*
Q_{nt} Driver capacity of outbound-loads carrier n *in* period t
R_{lmt} Average truckload for a standard vehicle transporting product *l* for inbound loads carrier in period *t*.
S_{lnt} Average truckload for a standard vehicle transporting product *l* for outbound loads carries' n in period *t*
T_{lmt} Average trips a driver of inbound-loads carrier m can make for product *l* in period t.
U_{lnt} Average trips a driver of outbound-loads 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} Transporting requirement (the degree of consolidation or break bulk) of customer k for product *l* in period *t*.
X_{ijlmt} Amount of product *l* transported from plant *i* to DC *j* when using inbound loads carrier *m* in period *t*.
Y_{jklnt} Amount of product *l* transported from DC *j* to customer *k* when using outbound loads 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*.

The main objective is to allocate the demand from different DCs and from various customers at minimize total cost of facilities, and transportation.

The problem is formulated as the following linear program:

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

$$+ \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{m=1}^{M}\sum_{t=1}^{T} F_{ijlmt}X_{ijlmt} + \sum_{l=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{n=1}^{N}\sum_{t=1}^{T} G_{jklnt}Y_{jklnt} \quad (1)$$

Subject to:

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

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L} X_{ijlmt} \le M_{mt} \quad for\ m,t \quad (3)$$

$$\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} Y_{jklnt} \le N_{nt} \quad for\ n,t \quad (4)$$

$$\frac{\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L} X_{ijlmt}}{\sum_{l=1}^{L} R_{lmt}} \le \sum_{l=1}^{L} T_{lmt}O_{mt} \quad for\ all\ m,t \quad (5)$$

$$\frac{\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} Y_{jklnt}}{\sum_{l=1}^{L} S_{int}} \le \sum_{l=1}^{L} U_{lnt}Q_{nt} \quad for\ all\ n,t \quad (6)$$

$X_{ijlmt} \ge 0$ for all *i, j, l, m, t* (7)
$Y_{jknmt} \ge 0$ for all *j, k, l, n, t* (8)
$P_{ilt} \ge 0$ for all *i, l, t* (9)
Zilt are 0, 1 variables (10)

III. Data Collection

(i) Based on Production capacity of the company

The three plants of the company, located in Owerri, Enugu and Port-Harcourt are operating at about 80 percent of maximum production capacity as may be observed in tables 1.0 mid 1.1. Therefore, for all practical purposes production capacity of 80 percent will be used. Table 1.0 shows the maximum capacities of the three plants.

Plant		2009	2010	2011	2012	2013	2014	Total
Owerri	Line 1	3191766	3562330	4677427	5691327	5706646	6720159	29549655
	Line2	3191566	3562266	4677266	5691166	5706474	6719810	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 1.0: Maximum production capacity of the Company per year (Source: Survey data from NBC)

Table 1.1: Average Annual plant fixed costs (Source: Survey data from NBC)

Plant	Fixed Cost (N)					
	2009	2010	2011	2012	2013	2014
Owerri	1698132	17988132	1898132	1898132	1898132	1908133
Enugu	1415110	1515110	1615110	1615110	1615110	1665100
Port-Harcourt /arroar9	1698132	1798132	1898132	1898132	1898132	1908132

(ii) Annual demand at warehouses

In Uyo, each retailer is supplied by manual distribution centers (MDCs) nearby. It can be assumed that demand is concentrated at the point of MDC location. The MDCs can further be aggregated based on the total distance to serve a specific market segment. This is determined by the customer service level set by the company, which is 12 hrs a day.

In areas where there are warehouses, demand is taken to be fixed at the warehouse location. In fact there are places which can have supply from multiple warehouses. For example if there is no warehouse in Owerri, the company directly distributes and sells its products to agents at MDCS. In such cases, multiple of MDCS are grouped based on their geographic proximity to represent demand at a specific location. Therefore, all MDCs at Owerri are summed together to represent a single warehouse.

As a result there are demand locations at twenty two towns. The amount of cases shipped to these destinations annually (average) is given in table 1.2.

Table 1.2: Annual demands at depots (warehouses) (Source: Survey data from NBC)

	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

(iii) Transportation Rates

The cost of transporting products from a specific source to a specific destination is a function of the distance between these two points. The warehouses at Owerri, Enugu and P/H are integrated with the plant. Considering the relevant carrier and operational costs, the average transportation cost per case per kilometer is found to be 0.85 Naira in a round trip.

A 4 pallet truck has a capacity of transporting 300 cases. A single pallet means 300/4 which is equal to 75 cases. Therefore, capacities of other trucks can be calculated by multiplying their pallet capacity by 75. The summary for all eases are presented in table 1.3

Table 1.3: Warehouses (Depots) and their distances from the plants in Kilometers (Source: Survey data from NBC)

W/House (Depot)	Plant		
	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(1	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 1.4: Types of trucks and their capacity (Source: Survey data from NBC)

	Number of trucks				Capacity in cases		
Type	Enugu	Owerri	P/H	Total	Enugu	Owerri	P/H
4 Pallet Truck	1 5	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)	1 5	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 1.5.

Table 1.5: Types of third party trucks and their capacity (Source: Survey data from NBC)

	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 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 1.6: Average transportation cost in Naira/case between plants and W/H Locations (Source: Survey data from NBC)

	Plant		
Depot (W/H)	**Owerri**	**Enugu**	**Port-Harcourt IarcOUrt**
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	210.61

The optimization model was formulation based on the existing network structure of the company. Hence, to validate the model, existing production, inventory and distribution costs are calculated using analytical method and compared against the Lingo optimization model result. The cost of' transport/km/case is N0.85, and the distances between the plants and warehouses are represented in table 3.6. Accordingly, the transportation costs/case is as shown in table 1.6.

3.1 Analysis of the data

Two approaches were used to ensure a better result: **(**a) Analytical approach (b) Use of solution techniques to optimize distribution network problem

Objective function is to optimize distribution cost:

$Minimize\ \mathbb{Z}$ = $0.00X_{11} + 181.48X_{12} + 151.30X_{13} + 124.95X_{14} + 175.53X_{15} + 86.60X_{16} + 134.30X_{17} + 63.41X_{18} + 84.15X_{19} + 176.80X_{110} + 436.82X_{111} + 83.22\ X_{112} + 144.59X_{113} + 107.02X_{114} + 73.95X_{115} + 53.55X_{116} + 52.87X_{117} + 32.05X_{118} + 60.95X_{119} + 79.90X_{120} + 171.53X_{121} + 182.50X_{122} + 124.95X_{21} + 202.64X_{22} + 229.42X_{23} + 0.00X_{24} + 253.56X_{25} + 106.76X_{26} + 155.47X_{27} + 186.49X_{28} + 200.60X_{29} + 219.30X_{210} + 313.91X_{211} + 149.52X_{212} + 210.80X_{213} + 173.31X_{214} + 91.55X_{215} + 156.40X_{216} + 107.78X_{217} + 106.08X_{218} + 89.51X_{219} + 56.78X_{220} + 51.77_{221} + 59.59X_{222} + 84.15X_{31} + 259.00X_{32} + 149.97X_{33} + 200.00X_{34} + 136.94X_{35} + 163.12X_{36} + 211.82X_{37} + 59.08X_{38} + 0.00X_{39} + 125.21X_{310} + 538.05X_{311} + 108.80X_{312}\ 97.24X_{313} + 105.06X_{314} + 132.20X_{315} + 51.85X_{316} + 92.06X_{317} + 69.45X_{318} + 138.38X_{319} + 158.19X_{320} + 242.00X_{321} + 210.63X_{322} + 50.20Y_{1K} + 50.00Y_{2K} + 53.00Y_{3K} + 54.00Y_{4K} + 56.00Y_{5k} + 55.00Y_{6K} + 53.20Y_{7K} + 52.70Y_{8K} + 52.00Y_{9K} + 53.00Y_{10K} + 55.00Y_{11K} + 52.00Y_{12K} + 56.00Y_{13K} + 50.00Y_{14K} + 52.00Y_{15K} + 57.20Y_{16K} + 53.10_{17K} + 50.40Y_{18K} + 51.10Y_{19K} + 51.00Y_{20K} + 50.00Y_{21K} + 56.60Y_{22K}$ ………………………………………………… 2

Subject to:

Plant to Distribution centre constraints

$X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{110} + X_{111} + X_{112} + X_{113} + X_{114} + X_{115} + X_{116} + X_{117} + X_{118} + X_{119} + X_{120} + X_{121} + X_{122} \leq 59098264$ (Owerri Plant production capacity) ……………………………………………..2a

$X_{21} + X_{22} + X_{23} + X_{24} + + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{210} + X_{211} + X_{212} + X_{213} + X_{214} + X_{215} + X_{216} + X_{217} + X_{218} + X_{219} + X_{220} + X_{221} + X_{222} \leq 49648040$ (Enugu Plant production capacity) …………………………………………………..2b

$X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} + + X_{37} + X_{38} + X_{39} + X_{310} + X_{311} + X_{312} + X_{313} + X_{314} + X_{315} + X_{316} + X_{317} + + X_{318} + X_{319} + X_{320} + X_{321} + X_{322} + \leq 135352872$ (P/H Plant production capacity) ……………………………………………………2c

$X_{11}+ X_{12} + X_{13} + X_{14} + X_{15} + X_{16} +X_{17} + X_{18} + X_{19} + X_{110} + X_{111} + X_{112} +X_{113} +$
$X_{114}+ X_{115} + X_{116} + X_{117} + X_{118} + X_{119} +X_{120} + X_{121} + X_{122} + X_{21} + X_{22} + X_{23} +X_{24} +$
$+X_{25} + X_{26} + X_{27} + X_{28} + X_{29} +X_{210} + X_{211}+X_{212} + X_{213}+ X_{214} + X_{215}+X_{216}$
$+ X_{217} + X_{218}+X_{219}+ X_{220} +X_{221} +X_{222}+ X_{31}+X_{32}+ X_{33}+ X_{34}+ X_{35}+ X_{36}+$
$+ X_{37}+X_{38}+ X_{39} +X_{310} +X_{311}+ X_{312} + X_{313}+ X_{314}+ X_{315} + X_{316} + X_{317} +$
$+ X_{318}+ X_{319}+ X_{320} + X_{321}+X_{322}+ \leq 125400$ (total truck capacity) ………………2d

$0.05X_{11} + 0.05X_{12} + 0.05X_{13} + 0.05X_{14} + 0.05X_{15} + 0.05X_{16} + 0.05X_{17} + 0.05X_{18} +$
$0.05X_{19} + 0.05X_{110} + 0.05X_{111} + 0.05X_{112} + 0.05X_{113} + 0.05X_{114} + 0.05X_{115} +$
$0.05X_{116} + 0.05X_{117} + 0.05X_{118} +0.05X_{120} + 0.05X_{121} + 0.05X_{122}+ \leq 85680$…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 (inbound load and number of trip per driver) ………………………………………………………..2e

Distribution centre to Customer constraints

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

$Y_{1K} +Y_{2K} + Y_{3K}+ Y_{4K} + Y_{5K} + Y_{6K} + Y_{7K} + Y_{8K} + Y_{9K} + Y_{10K}+ Y_{11K} +Y_{12K} +Y_{13K} +$
$Y_{14K} +Y_{15K} + Y_{16K}+ Y_{17K} + Y_{18K} + Y_{19K} + Y_{20K} + Y_{22K} \leq 125000$ (outbound load and number of trip per driver)……………………2g

3.2 Lingo Model for the Problem

```
MODEL:
! A 3 Plant 22 Distribution Centre 22 Customer Supply Chain Network Problem;
SET:
! Three plants and each has an associated fixed cost, A and "open" indicator Z;
            PLANTS/OWE ENU PH/: F, Z;
! 22 Distribution centres;
           DISTCTR/DC1 DC2 DC3 DC4 DC5 DC6 DC7 DC8 DC9 DC10 DC11 DC12 DC13 DC14 DC15
DC16 DC17 DC18 DC19 DC20 DC21 DC22/;
! 22 CUSTOMERS;
           CUSTOMERS/K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12 K13 K14 K15 K16 K17 K18 K19 K20
K21 K22/;
! P = Amount of a product produce at a plant;
! B = Production cost of a product at a plant;
           BLINK(PLANT): B, P;
! H = Capacity for a product at a plant;
           HLINK(PLANT): H;
! D = Demand for a product by a customer;
           DEMLINK: D;
! G = Cost/case of a product shipped from a DC to customer;
! Y = Cases of a product shipped from a DC to customer;
           GLINK: G, Y;
!F = Cost/case of a product shipped from a plant to a DC;
           FLINKS(PLANT DISTCTR): F,X;
! X = Cases of a product shipped from a plant to a DC;
           ! E = Inventory carrying cost of a product at a DC;
! M = Truckload capacity of shipping a product at a plant;
! O = Driver capacity at a plant;
           MLINK: M, O;
! N = Truckload capacity of shipping a product at a DC;
! Q = Driver capacity at a DC;
           NLINK: N, Q;
ENDSETS:
DATA:
! Plant Fixed Cost;
```

```
        A = 20288792;
! Average production Costs at a plant;
        B = 436.80 442.08 444.20;
! Plant Capacity;
        H = 59098264 49648040 62322972;
! Truckload capacity at a plant;
        M = 42600 40200 42600;
! Driver capacity at a plant;
        O = 12 11 12,
! Customer demands;
        D = 8719050 617220 6056530 8669900 6914800 7639200 7636600 5860420 8774920 8350500
59405006257800 8293700 8721700 9200600 9257200 7781500 6316500 84658500 8295900 8708100
8589000;
! Shipping Cost from a DC to a Customer;
        G = 50.20 50.00 53.00 54.00 56.00 55.00 53.20 52.70 52.00 53.00 55.00 52.00 56.00 50.10 52.50 57.20
53.15 50.40 51.10 51.00 55.00 56.60;
! Shipping cost;
        F = 0.00 181.48 151.30 124.95 175.53 85.60 134.30 63.41 84.15 176.80 436.82 83.22 144.59 107.02
73.95 53.55 52.87 32.05 60.95 79.90 171.53 182.50
          124.95 202.64 229.42 0.00 253.56 106.76 155.47 186.49 200.60 219.30 313.91 149.52 210.80
173.31 91.55 156.40 107.78 106.08 89.51 56.78 51.77 59.59
      84.15 259.00 149.97 200.00 136.94 163.12 211.82 59.08 0.00 125.21 538.05 108.80 97.24 105.06 132.20
51.85 92.06 69.45 138.38 158.19 242.00 210.63;
! Truckload capacity at a DC;
        N = 3900 1800 1950 3300 2100 2700 2400 1800 4200 2750 2400 2400 3000 3300 3450 3600 2400
1950 3300 2850 3750 3000;
! Driver capacity at a DC;
        Q = 7 5 5 6 5 5 5 5 5 6 5 5 5 6 7 6 5 5 6 5 5 5;
ENDDATA
! ----------------------------------------------------------------------------------------------------;
! Objective function minimize supply chain costs;

        [OBJ] MIN = FXCOST + PCOST + SHIPDC + SHIPDCCUST;
        FXCOST = @SUM(PLANT: A*Z);
        PCOST = @SUM(BLINK(j i):
                        B(j i)*P(j i));
        SHIPDC = @SUM(FLINK(i j):
                        F(i j)*X(i j));
        SHIDCCUST = @SUM(GLINK(i j k):
                        G(i j k)*Y(i j k));
! Plant constraints;
        @FOR(PRODUCT(i): [H_ROW]
                @SUM(PLANTS(i): P(j i) <= H(j i));
! Distribution constraints;
        @FOR(PRODUCT(i): [D_ROW]
          @FOR(DISTCTR(j):
            @SUM(CUSTOMER(k): Y(j k) = D(j k)));
        @FOR(PRODUCT(i): [N_ROW]
          @FOR(DISTCTR(j):
                @SUM(CUSTOMER(k): Y(j k) <= N(i j)));
! Warehouse constraints;
        @FOR(PRODUCT(i): [M_ROW]
        @FOR(PLANTS(i):
          @SUM(DISTCTR(j): X(i j) <= M(i j));
! Make open binary(0/1);
        @FOR(PLANTS: @BIN(Z);
END
----------------------------------------------------------------------------------------------------
```

IV. Results And Discussion

4.1 Results

The total distribution cost obtained analytically using

$$Minimize\ Z = \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} A_{ilt}Z_{ilt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} B_{ilt}P_{ilt}$$
$$+ \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{m=1}^{M}\sum_{t=1}^{T} F_{ijlmt}X_{ijlmt}$$
$$+ \sum_{l=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{n=1}^{N}\sum_{t=1}^{T} G_{jklnt}Y_{jklnt}$$

was thirty billion, nine hundred and three million, nine hundred and fifteen thousand, twenty nine naira, eleven kobo (N30,903,915,029.11). The actual distribution cost obtained from the company's annual report is almost equal to this value.

Table 1.7 shows the summary of output result of optimization with the existing distribution structure of the company using LINGO programming application.

Table 1.7: The summary of output result of optimization with the existing distribution network of the company

Warehouse	Plant			Demand (cases)
	Owerri	Enugu	Port-Harcourt	
DC1	0.00			8719050
DC2	328047335.40			6172220
DC3		185379158.12		6056530
DC4		0.00		8669900
DC5			346688227.60	6914800
DC6	453915580.40			7639200
DC7	435820075.40			7636600
DC8			346233613.60	5860420
DC9			0.00	8174920
DC10			445441620.40	8350500
DC11		383533385.40		5940500
DC12	435890616.05			6357800
DC13			502479388.12	8293700
DC14			421711520.23	8721700
DC15	76484988.50			9200600
DC16			358051112.14	9257200
DC17	315427905.31			7781500
DC18	278103172.50			6116500
DC19	315975557.50			8465850
DC20		451041202.23		8295900
DC21		340818337.45		8708100
DC22		377818510.01		8589000
TOTAL COST		**₦6,798,861,306.36**		

*DC = Distribution Centre Owerri = DC1, Ekpoma = DC2, Ugheli = DC3, Enugu = DC4, Warri = DC5, Asaba = DC6, Agbor = DC7, Ahoada = DC8, P/H = DC9, Calabar = DC10, Wukari = DC11, IkotIkpeme = DC12, Eket = DC13, Uyo = DC14, Onitsha = DC15, Aba = DC16, Umuahia = DC17, Orlu = DC18, Nnewi = DC19, Awka = DC20, Nsukka = DC21, Abakaliki = DC22.

4.2 Discussion

4.2.1 Optimization Based on Existing set of Operation

Based on the existing network structures, the plant at Owerri 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 and two warehouses within the south-south. Port-Harcourt plant supplies twelve warehouses within south-east and two warehouses within the south-south (see appendix 1). Table 1.7 represents the result of optimization approach with LINGO programming tool based on existing distribution network, which showed that for optimal distribution cost of N6,798,861,306.36 to be achieved the plant at Owerri should made supplies to eight distribution centres (Ekpoma, Asaba, Agbor, IkotIkpeme, Onitsha, Umuahia, Orlu and Nnewi) outside the plant. Enugu plant to five distribution centres: Ugheli, Wukari, Awka, Nsukka and Abakaliki. Then Port-Harcourt plant to six distribution centres outside the plant: Warri, Ahoada, Calabar, Eket, Uyo and Aba. This result obtained (N6,798,861,306.36) was the annual distribution cost. When compared with the analytical method N24105053722.75 was saved and all the demand was met and all warehouse supplied with demands within their proximity. This showed that about 22% reduction in distribution cost can be achieved by optimizing the distribution cost elements such as:

- Fuel cost which is not always constant
- Poor maintenance culture
- Welfare of the drivers
- Poor road network
- Management decision

Table 1.7 actually reflected the stated objectives of this work. Table 1.7 also showed that in the renewed network optimization (see appendix 2), 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 five warehouse (south-east) (Owerri, 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 four warehouse (south-east) (Enugu, 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 seven warehouses (south-south) (Ughecli, Warri, Ahoada, P/H, Calabar, Eket, and Uyo). Also its supplies one warehouse (south-east) (Aba) only.

Table: 1.8 show the proposed schedule for transporting 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 1.8: vehicles scheduling for transporting products 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

However, the results obtained showed that the model improved the distribution network of the company by 22%. This showed that the model is a better approach when compared with one proposed by Ketzenberg, et al (2001) and Kleijen, J.P.C. (2005), which proposed 10.6% and 20% reduction cost respectively.

V. Conclusion

The distribution systems of the Nigerian Bottling Company (NBC) [south –south and south-east of Nigeria] have been studied and the potential for using mixed integer linear programming (MILP) model in managing a large distribution problems subsequently identified. The decision variables, parameters and constraints for formulating a model of the company's distribution operations so identified and also solved using Lingo 15.00 version.

The optimal distribution cost of NBC products, has been analysed and the model improved the distribution network of the company under study by 22%. 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. Therefore, the study recommends that three new warehouses should be established in order to reduce congestion at the plants. The mixed integer linear programming (MILP) developed and optimization techniques employed here should be applied in any similar bottling companies with a need to design appropriate SC network thereby reducing their distribution cost.

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Appendix 1

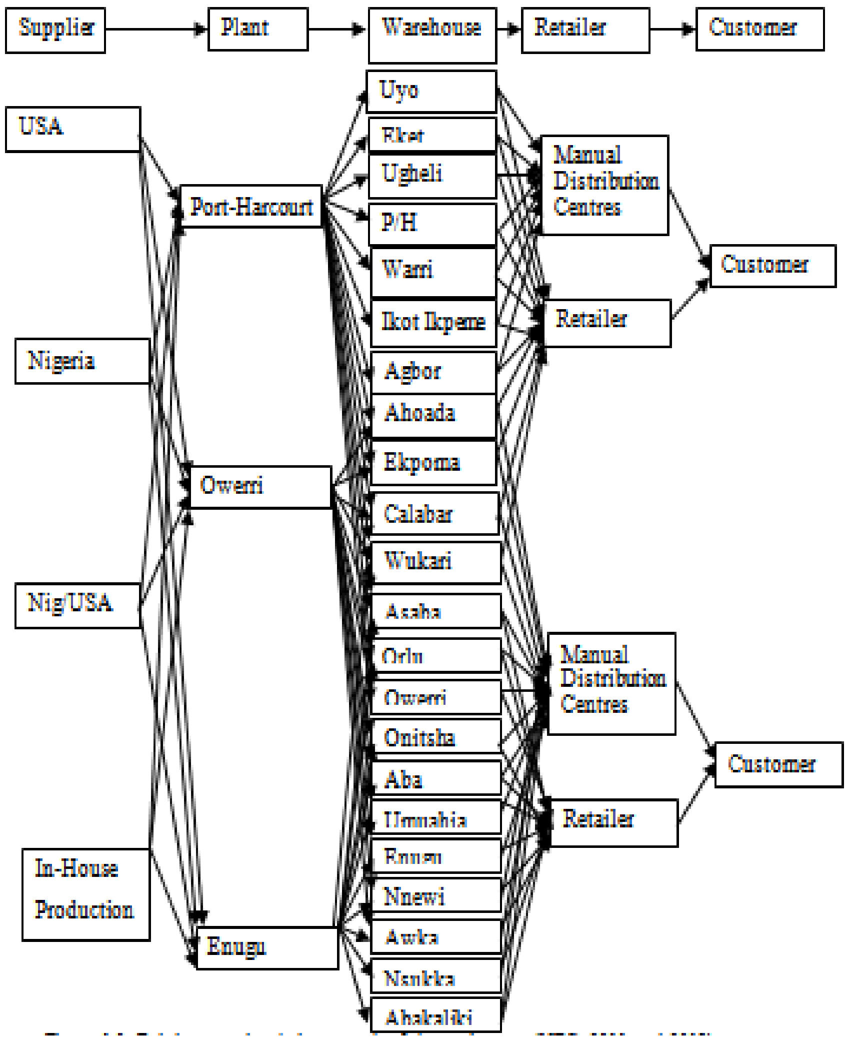

Figure 1.0. Existing supply chain network of the study area (NBC, 2011 and 2013)

Appendix 2

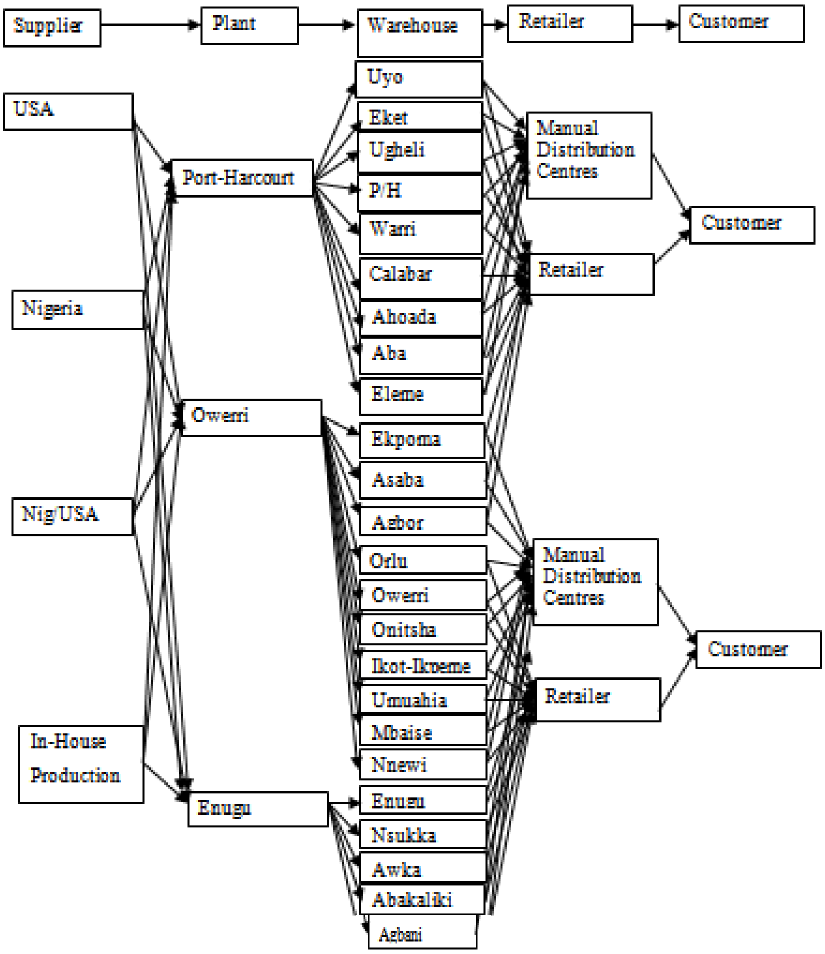

Figure 2.0: Renewed Supply Chain network design of the company

Engr. Dr. B. E. Okafor .” Optimization of Distribution Network of Nigerian Bottling Company PLC Using LINGO.” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 15, no. 4, 2018, pp. 28-41.