Mixed Product Optimization for Supply Chain Network in Brewery Industry

Nwangwu Uchechukwu[1], Akpan Francis Anietie[2]

[1]Department of Mechanical Engineering, Federal University of Technology Owerri, P.M.B 460114, Imo State, Nigeria
[2]Department of Mechanical Engineering, Faculty of Engineering, University of Uyo, P.M.B 1017, Uyo, Akwa-Ibom State, Nigeria

---

***ABSTRACT** - This paper seek to integrate product mix formulation optimization and supply chain to optimize the product and transportation cost to help the organizations reduce cost and remain competitive, the cost of transportation as a function of distance from the plant to different distribution centres per month is approximately ₦5007.8556 in million by analytical method and this call for optimization. Transportation Method, Simplex Method, and Integer Linear Programming Method was employed in solving the transportation problem with Micro soft Excel solver which resulted in an optimal cost of ₦2879,506.8 and ₦2634,972.84 respectively, the integer linear programming, and the simplest method gave the same result, the transportation network was optimization to minimize the cost of transportation per truckload per month in all the plants and depots. The result obtained from the values minimum cost transportation schedule and the decision variables show the optimal quantities to transport over each route and a reduce cost in millions of ₦2.85474. The optimized cost for the new supply chain transportation schedule was ₦2879.5068 in million lower than the actual cost of ₦5007.8556 from the analytical result. The product mix problem revealed that more of Fanta Orange 50cl and Coke 50cl contribute mostly to the profit earned and their production quantities should be at least 462,547 and 415,593 crates respectively in order to remain in business and meet the unpredictable and constant change in customer's demand at a given price and time.*

***KEY WORDS*: Optimization, Supply Chain, Cost, Transportation, Mixed Product, Plant, Depots.**

1. INTRODUCTION

To stay competitive in business, organization need to provide quality services and make product available at lower price, at the door steps of final consumers. For this to be feasible, improvement of operational performance, optimization of distribution channels and product mix, and lean tools application in production process is necessary. Industries and organizations are continually in search of methodology that will optimized their production processes and also supply chain for effective reduction in production cost to meet customers' expectation, and maintain good market share among others competitors. The approach employed for the management of supply and distribution network is supply chains management (SC) [27]. As the need for customers' satisfaction, and cost minimization arises, several attempt to optimized SC performance with mathematical programming methods have proven to be effective as it integrates both the centralized and the decentralize model activities [22]. Optimization takes into cognizance the company's SC which consist of the plants, numbers and nature of filling lines, the numbers of distribution centers that are available and their respective warehouses. Again, building of a borderless supply chain that will supply territories at lowest cost with capability to imbed innovative technologies has been the quest of many companies. This has necessitated research into the SC and product mix (PM) formation of the Nigeria bottling company (Coca Cola) within the south-south plants and south-east plants. The drive of this section is to review the work of early and recent scholars in the subject area under deliberation the benefits and limitation of effort by earlier researchers are presented with knowledge gaps.

In the study carried out by [21] proposed mathematical model of the extended enterprise and a general network model for use in the investigation of strategic network issues were proposed. This model was design for the optimization of supply chain structure under some specific assumptions in the nature of production cost and value functions in typical production and distribution companies [13]. Also, [28] used a sensitivity analysis (SA) and an algorithm with two objectives functions to optimized location, and Cross Docks distribution centers. The first strategic model minimized fixed costs, and transport costs. While the second model minimized supply and transportation cost of products. Simulation annealing and Tabu search approach, with re-scaling approach were compared. The result got revealed that Tabu search approach make better quality solutions. [1] recommended a solution technique established on genetic algorithm to decipher Supply Chain Network Design problem. Three objective functions were formulated as a multi-objective mixed-integer non-linear programming model to optimize total cost by minimization, service level by maximization and capacity utilization balance by maximization. The proposed algorithm was coded in C++ programming language subject to the succeeding parameters: population size, crossover rate, mutation rate, and number of generations.

[17] compared flexible supply chains and traditional supply chains with a hybrid genetic algorithm and came out with benefit on the flexible supply chain. Also, numerous studies have been established on the optimization of supply chain network design using generic algorithm by different researchers. [8] suggested a supply chain network design that minimized costs and total delivery time and used genetic algorithm to solve the multi-objective problem. [16] collaboratively proposed a novel algorithmic framework for supply chain optimization planning and scheduling problem. The problem solved comprises of integration of inventory management problem, and vehicle routing problem with time windows, both of which are known to be NP-hard (nondeterministic polynomial time). [15] synthesized key challenges and opportunities associated with supply chain models of past researchers various guidelines for successful execution and development of new models were proposed. [14] considered total cost as an objective function in the design of supply chain network. The problem formulated was solved from genetic algorithm. [30] try to find procedures to address traditional distribution requirement planning (DRP) weaknesses and improve on the performances of the systems. [24] established a multi objective stochastic method, with an objective function to minimize safety stock costs, and distribution centers location of two level supply chain network with genetic algorithms proposed as a solution method. [23] presented a technique for integrated supply chain network design in a stochastic environment with different constraints in the network and discussion on the combination of network modeling, stochastic linear programming, and separate event simulation. [18] Suggested a logistics system design problem that comprised of potential suppliers, and manufacturing facilities, distribution centers, multiple conformations, and customers' demands that limit production and distribution system, and transfer prices between different firms configuration. [10] Model an uncertain market demand as a number of discrete scenarios with known probabilities. Fuzzy sets were used to describe sellers' and buyers' incompatible preference on product prices. Multi-product, multi-stage, and multi-period schedule model, was considered for multiple goals of the multi-echelon supply chain. Mixed-integer nonlinear programming was formulated for the supply chain subject to some useful objective setup in the supply chain. The findings obtained showed that the robustness measures inclusion as an objectives in the supply chain can significantly reduce the variability.

[32] Considered the interactions amid Green Supply Chain Management practices and performance among early adopters within Chinese enterprises. Automobile, power plants and electronic industries in Chinese were compared. The results obtained showed that the industries differ in Green Supply Chain Management practice adoption. The study identify four Green Supply Chain Management. [5] Developed supply chain network model that allowed transaction in both physical and electronic transactions means with the inclusion of supply and demand side risk. The model was made up of the manufacturers, distributors, and the retailers with random retail outlets. Equilibrium conditions was reached and a finite-dimensional vibrational inequality formulation was established. Conditions for computational procedure to guarantee illustration of on the supply chain network model was established. [2] Developed a model that solved minimum cost network flow optimizations problems, multi-period planning, country-wide network, customized transportation relations, fleeting and de-fleeting with partial substitutability were the essential practical needs considered.

[11] In their work they presented a generic methodological design of a production and distribution network for a divergent process industry. The industry manufacturing processes mapped out into a potential production and distribution facility locations and capacity options using a mathematical model. [3] presented Global supply chain model (GSCM) for the design of a manufacturing network, distribution, and sales. Mixed-Integer linear programming model was developed subject to decrease and balanced of cost and aggregated respectively in the production and distribution times with consideration. Demand and capacity limitations were also considered. [26] Developed a frame for the design of supply chain network with data envelopment analysis (DEA) and multi-scale decision. [25] Use mixed-integer programming and DEA in a multi-stage model to the solved the problem of skilled supply chain programming. [31] Inferred that the supply chain is operated in a fuzzy environment. Further, different game structures of the supply chain were considered, to determine each inventory in the supply chain (SC) in the presence of uncertainties. The result obtained showed an acceptable service level at reasonable total cost. It was then concluded that the fuzziness of the supply is associated with the customer's demand and the manufacturing cost. [19] Proposed an optimized procedure for a reverse logistics network design using SA. The SA algorithm was evaluated under different parameters. [12] Studied supply chain problem with concern on the environment. The objective captures trade-off between total cost, and environmental influence. The result found showed efficiency and managerial insight for firms. [4] used case the studies of five Portuguese automotive companies to test the relations of green supply chain and supply chain performances. Four categories of GSCM practices were identified. [7] Used sensitivity analysis to solve a combinatorial

optimization problem in supply chain design that incorporated cost and quality. The developed model was aimed to choose the entities of SC that maximize the profit and determine product quality error rate, at inspection and defective ratio in manufacturing. [6] Optimize supply chain network, for cost reduction. Four echelon system comprises of suppliers, plants, distribution centers and retailers were considered. The results showed the success of GA in providing optimal solution. [20] engaged GA technique to augment a multiple products and multiple suppliers supply chain model. The objective function was to maximize the total profit of the entire supply chain. The results obtained from both the Lindo and GA were compared and the GA method gave better solutions with high level information.

[7] Used sensitivity analysis to solve a combinatorial optimization problem in supply chain design that incorporated cost and quality. The developed model was aimed to choose the entities of SC that maximize the profit and determine product quality error rate, at inspection and defective ratio in manufacturing. [29] Developed supply chain optimization problems, formulated as linear programming (LP) problems, optimized, costs of transportation in several real-life applications. This include cost-related problems associated with transportation costs with reference to trucks and manpower. the result obtained reveal that 39.20% expenses in the company transportation sector for six years was on maintenance alone with 20.50%, 8.79% and 5.05% on fuel, drivers welfare, and loading and offloading respectively. Recommends from the research encourage top management to specify units of products to be transported from plant to each depot.

[9] Considered the approach to optimized supply chain and market demand analysis of a petroleum industry. Qualitative research technique was implemented in the research. The result obtained showed that achievement of a progressive success in the global competitive market are got from the supply chain management optimization approach. The above assessment reveals success and failure of previous and current work with a knowledge gap extended to product and process supply chains design consideration. This showed that limited work on supply chain and facility allocation and work on the impact of the town plan adopted in specific areas of the selected depots, as a contributing factor.

2. Data Collection

The data used for numerical illustration were gotten from Nigeria Bottling Company. Coca Cola Company is the area of interest. Globally, the Coca Cola Company are yet to standardized procedure to manage transportation and also better understanding of freight costs that would support its Coca Cola Vision 2020 goals, to reduced inventory and increase sales volume. The company has four major plants and five major depots in south-south and south-east Nigeria. The average numbers of truck load in each of the plant are presented in Table 1 this is taken to be uniform since it entails supply and Table 2 presents the average number of trucks demanded by each depot per month this also varies as a result of the difference in the warehouse capacities of the depots.

Table 1: Average number of Truckloads from each plant per month

S/N	Plant	Truckloads per month
1	Aba	16
2	Owerri	16
3	Port Harcourt	16
4	Enugu	16

(Source: NBC Port Harcourt)

Table 2: Average number of Truckloads demanded from each depot per month

S/N	Plant	Average number of Truckloads/month demanded/deport
1	Mbaise	4
2	Orlu	7
3	Umuahia	16
4	Calabar	18
5	Uyo	18
	Total	63

(Sourced data)

The distribution network showing the distance in kilometres from the plants to the depots are shown in Table 3. The distance was calculated using google map from the location of the plant to the location of the depots. The distance were further used to estimate the cost per trip of a truckload.

Table 3 Distance from plants to depots in kilometres

	Plant			
Depots	Aba	Owerii	Port Harcourt	Enugu
Mbaise	56.36	37.20	110.54	127.27
Orlu	109.47	64.02	160.65	126.33
Umuahi	63.47	83.64	114.93	257.88
Calabar	144.66	208.42	200.34	257.88
Uyo	74.24	138.00	129.92	208.30

(Google map)

Table 4 is a data gotten from these plants which are quantity of raw materials available in stock, cost and selling prices and the profit in crate of each product. The profit constitutes the objective function while raw materials available in stock are used as constraints. Also demand which must be met in order to optimise the supply chain is included in the constraints.

Table 4 Quantity of raw materials available in stock

Raw materials	Quantity available
Concentrates	4332 (units)
Sugar	467012 (kg)
Water (H_20)	16376630 (litres)
Carbon(iv) oxide(C_2O)	8796 (vol.per pressure)

Table 5 Quantity of raw materials needed to produce a crate of each product listed

Flavour	Concentrate	Sugar	Water	Carbon (iv)oxide
Coke 35cl	0.00359	0.54	6.822	0.0135
Fanta orange 35cl	0.00419	1.12	7.552	0.007
Fanta orange 50cl	0.00217	0.803	4.824	0.005
Fanta lemon 35cl	0.0042	1.044	7.671	0.0126
Schweppes 35cl	0.00359	0.86	6.539	0.0125
Sprite 35cl	0.00359	0.73	7.602	7.602
Fanta tonic 35cl	0.00359	0.63	6.12	0.0133

Krest soda 35cl	0.0036	0.89	7.055	0.0146
Coke 50cl	0.00438	0.23	7.508	0.0156

Table 6 Average cost and selling price of each product

Product	Average cost price	Average selling price	Profit
Coke 35cl	358.51	690	331.49
Fanta orange 35cl	370.91	690	319.09
Fanta orange 50cl	489.98	790	300.02
Fanta lemon 35cl	36.67	690	321.33
Schweppes 35cl	341.85	690	348.15
Sprite 35cl	486.04	790	303.96
Fanta tonic 35cl	322.09	690	367.91
Krest soda 35cl	266.72	690	423.28
Coke 50cl	489.89	790	300.11

3. Methodology

The general form of linear programming standard form formulation is presented in equation (1)

$$\min \mathrm{Z} = \sum_{i=1}^{n} C_i X_i \,(objective\ function) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

Subject to

$a\_i\ x\_i \leq b\ (constraints)$

$x\_i \geq 0\ (non-negative\ condition)$

The linear systems of the equation is presented in equation (2)

$$\min Z = \sum_{i=1}^{n} c_{11}\, x_1 + c_{12}x_2 + \cdots \cdots c_{1n}x_n \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .\ldots \ldots .(2)$$

Subject to

$$\begin{matrix} a_{11}x_1 + a_{12}x_2 + & \cdots & a_{1n}x_n \leq b_1 \\ a_{21}x_1 + a_{22}x_2 + & \cdots & a_{2n}x_n \leq b_2 \\ \vdots & \vdots & \vdots \\ a_{m1}x_1 + a_{m2}x_2 & \cdots & a_{mn}x_n \leq b_n \end{matrix} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

where

$x_1, x_2, \cdots\cdots\cdots, x_n$ are decision variables,

$c_1, c_2, \cdots\cdots\cdots, c_n$ are cost of variable considered.

And

$Ax \geq b, Bx \geq d, b_1, b_2, \cdots\cdots\cdots, b_m$ are the quantity of materials used.

Application of the following methods; integer and simplex method will be employed in solving the product mix problem of the Nigeria bottling company, while the transportation method will be used for the supply chain optimization of the Nigeria bottling company south-south which include Enugu, Owerri and Portharcourt.

3.1 Integer Programming Method

Equation (4) presents the general integer programming problem with the objective in equation (5). Integer programming is a valuable tool in operations research, having potential for applications in business and industry. All assignment and transportation problems are Integer Programming Problem (IPP), the decision variables are either zero or one that is $x_{ij} = 0 \text{ or } 1$

$$\min CX \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Subject to

$$Ax \geq b, Bx \geq d \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (5)$$

$x_j \geq 0$ and integer, $j \in I$

where

b, c and d are vectors

A and B are matrices of conformable dimensions, and the index set

I denotes variables required to be integer.

The reason for distinguishing two types of constraints is that the second of these, , $Bx \geq d$, is supposed to have special structure.

3.2 Simplex Method

The simplex method is a step by step arithmetic method of solving linear programming problem (LPP) ranging from several number of variables and constraints. It is design to simultaneously solve a system of linear equations where there are more unknowns than there are equations. It is an iterative procedure that is amendable to use on computers.

3.3 Formulation of Transportation Model

The transportation model is a special type of LPPs in which the objective is to transport a homogeneous commodity from various sources to different destination at minimum total cost or maximum total benefit.

$$\min Z = \sum\sum C_{ij} X_{ij} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (6)$$

Such that

$$\sum_{i=1}^{m} X_{ij} \leq a_i \; i = 1,2.\cdots\cdots, m \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots..(7)$$

And

$$\sum_{i=1}^{n} X_{ij} \leq b_j \; j = 1,2.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots..(8)$$

With the assumption that

$$\sum_{i}^{m} a_i = \sum_{j}^{n} b_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots.(9)$$

Shown in equations 10 to 12 are the step for the derivation of the roundtrip transportation cost per kilometre, average numbers of truck load per month per depot, and the average number of truck load per month per depot demanded. The summary of the cost, supply and demand are optimized

$$RTTC = 2D \times (12 \times NY) \times PP(KM) \ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (10)$$

where

$RTTC = Round\ trip\ transportation$

$cost\ per\ truckload$

$D = Ddistance$

$PP(KM) = price\ per\ kilometer$

$NY = Numbers\ of\ Years$

$$Supply = (12 \times NY)(ATLPD) \ldots.(11)$$

$ATLD = Average\ number\ of\ Truckloads/month\ per\ deport$

$NY = Numbers\ of\ Years$

$$Demand = (12 \times NY)(DPD) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(12)$$

$ADPD = Average\ number\ of\ Truckloads/month\ demanded\ per\ deport$

$NY = Numbers\ of\ Years$

3.4. Transportation cost per kilometres

The result for the analysis of the data are presented as follows; the average transportation cost per kilometres for both loaded and empty trucks from all the plants to the various depots is charge at N50.00 per kilometres (Uzorh and others, 2014). Table 7 present the round trip transportation cost based on the kilometres covered by the trucks in million as shown figure5.

Table 7 Cost of transportation in million per kilometres

	Depots				
Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo
Aba	₦0.35616	₦0.65682	₦0.38082	₦0.86796	₦0.44544

Owerri	₦0.2232	₦0.27612	₦0.49584	₦1.25052	₦0.828
Enugu	₦0.66324	₦0.9639	₦0.68958	₦1.20204	₦0.77952
Port Harcourt	₦0.76362	₦0.75798	₦1.54728	₦1.54728	₦1.2498

=(2*C28*12*C32*C33)/1000000

Distance from plants to depots in kilometres

Plant	Depots				
	Mbaise	Orlu	Umuahia	Calabar	Uyo
Aba	59.36	109.47	63.47	144.66	74.24
Owerri	37.2	46.02	82.64	208.42	138
Port Harcourt	110.54	160.65	114.93	200.34	129.92
Enugu	127.27	126.33	257.88	257.88	208.3
Year	5				
Price/Km	50				

Cost of transportation in million per kilometres

	depot				
Plant	Mbaise	Orlu	Umuahia	Calabar	Uyo
Aba	=(2*C28*12*C32*C33)/1000000				0.44544
Owerri	0.2232	0.27612	0.49584	1.25052	0.828
Enugu	0.66324	0.9639	0.68958	1.20204	0.77952
Port Harcourt	0.76362	0.75798	1.54728	1.54728	1.2498

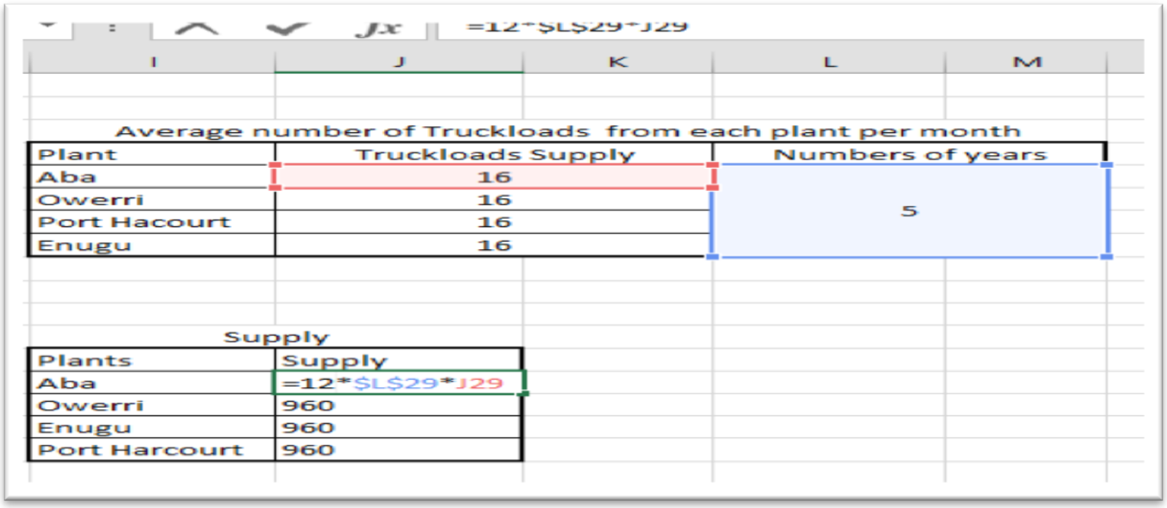
Figure5 Cost of transportation per kilometre

3.5 Supply From Plants to Depots

Shown in table 8 is the average monthly supply from the plants to the various depots, the result is gotten from the application of Equation 11, and figure2a and 2b . the result showed that all the plant supply exactly the same quantity of product to the various depots attached to them.

Table 8 Average monthly supply

Plants	Supply
Aba	960
Owerri	960
Enugu	960
Port Harcourt	960


=12*L29*J29

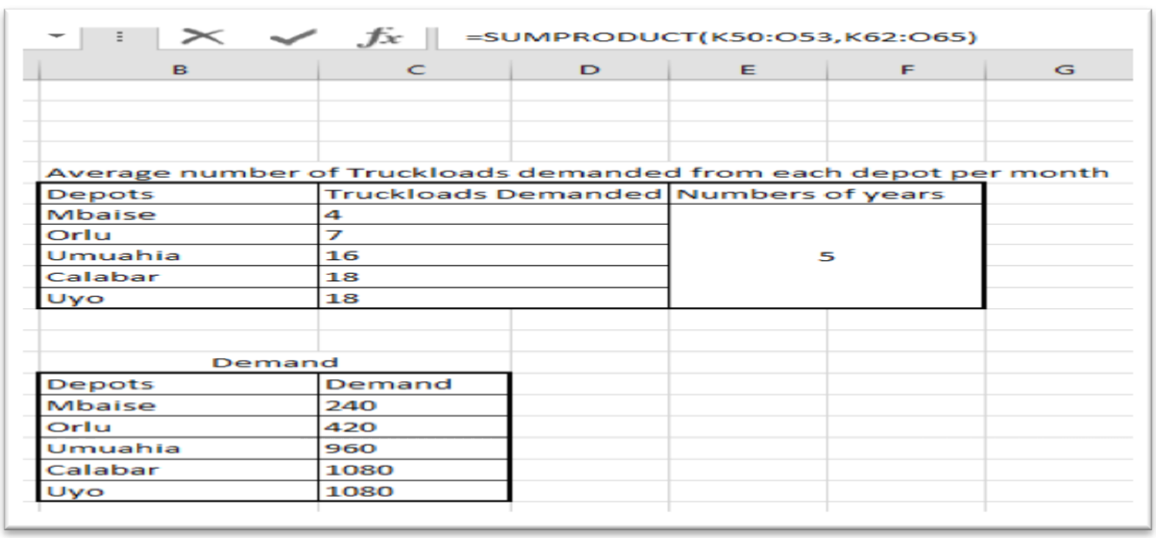
Average number of Truckloads from each plant per month

Plant	Truckloads Supply	Numbers of years
Aba	16	5
Owerri	16	
Port Hacourt	16	
Enugu	16	

Supply

Plants	Supply
Aba	=12*L29*J29
Owerri	960
Enugu	960
Port Harcourt	960

Figure 2a. Quantity supplied from the plant


=SUMPRODUCT(K50:O53,K62:O65)

Average number of Truckloads demanded from each depot per month

Depots	Truckloads Demanded	Numbers of years
Mbaise	4	5
Orlu	7	
Umuahia	16	
Calabar	18	
Uyo	18	

Demand

Depots	Demand
Mbaise	240
Orlu	420
Umuahia	960
Calabar	1080
Uyo	1080

Figure 2b. Quantity demanded from the plant

Also, the average monthly truckload demand from the various depots are presented in Table 9. The result show that Calabar and Uyo have the highest demand of truckload. Follow by Umuahia, Orlu and Mbaise.

Table 9 Average monthly truckload demand

Depots	Demand
Mbaise	240
Orlu	420
Umuahia	960
Calabar	1080
Uyo	1080

The transportation table showing the demand from each of the depot, supply from the various plant and the cost of transport in million for truckloads, from the plant to the different depots is shown in Table 10. The cost of transport per month is approximately ₦5007.8556 in million this demands for optimization. Coca Cola has started tracking carrier performance including on-time deliveries and pick-ups to enable the company to make more informed decisions regarding consolidation to improve efficiency and reduce freight costs supporting vision 2020 goals.

Table 10 Transportation

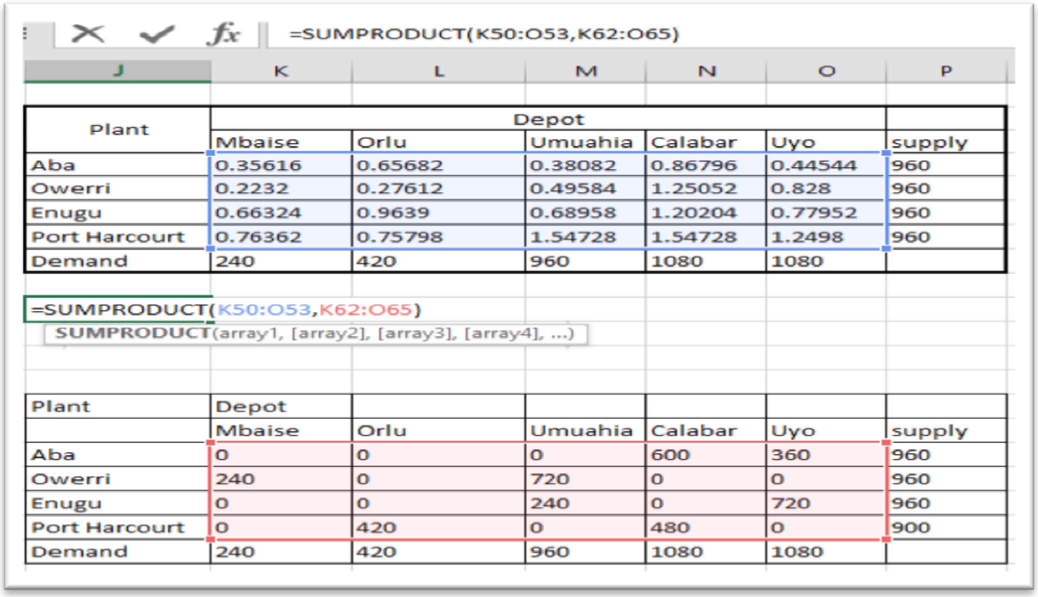
Plant	Depots					
	Mbaise	Orlu	Umuahia	Calabar	Uyo	Supply
Aba	₦0.35616	₦0.65682	₦0.38082	₦0.86796	₦0.44544	960
Owerri	₦0.2232	₦0.27612	₦0.49584	₦1.25052	₦0.828	960
Enugu	₦0.66324	₦0.9639	₦0.68958	₦1.20204	₦0.77952	960
Port Harcourt	₦0.76362	₦0.75798	₦1.54728	₦1.54728	₦1.2498	960
Demand	240	420	960	1080	1080	

3.5 Optimization Results

Microsoft Excel Solver was use for the optimization of the transportation network, to minimize the cost of transportation per truckload per month in all the plants and depots. The result obtained is shown in Table 11 the values for the decision variables show the optimal quantities to transport over each route and a reduce cost in millions of ₦2.85474. The optimized cost for the new supply chain transportation schedule was ₦2879.5068 in million lower than the actual cost of ₦5007.8556 from the analytical result got by using the company supply chain. The steps involve in the optimization problem also the sensitivity analysis and the optimization constraints are shown in Figure 4 blow.

Table 11 minimum cost transportation schedule.

Plants to Depots	**Quantity supply**	**Reduced Cost in million**
Aba - Mbaise	0	₦0.2733
Aba - Orlu	0	₦0.57816
Aba - Umuahia	0	₦0.02532
Aba - Calabar	600	0
Aba - Uyo	360	0
Owerri - Mbaise	240	0
Owerri- Orlu	0	₦0.05712
Owerri - Umuahia	720	0
Owerri - Calabar	0	₦0.24222
Owerri - Uyo	0	₦0.24222
Enugu - Mbaise	0	₦0.2463
Enugu - Orlu	0	₦0.55116
Enugu - Umuahia	240	0
Enugu - Calabar	0	₦4.44089E-16
Enugu - Uyo	720	0
PortHarcourt - Mbaise	0	₦0.00144
Port Harcourt - Orlu	420	0
PortHarcourt -Umuahia	0	₦0.51246
PortHarcourt -Calabar	480	0
Port Harcourt - Uyo	0	₦0.12504



=SUMPRODUCT(K50:O53,K62:O65)

Plant	Depot					
	Mbaise	Orlu	Umuahia	Calabar	Uyo	supply
Aba	0.35616	0.65682	0.38082	0.86796	0.44544	960
Owerri	0.2232	0.27612	0.49584	1.25052	0.828	960
Enugu	0.66324	0.9639	0.68958	1.20204	0.77952	960
Port Harcourt	0.76362	0.75798	1.54728	1.54728	1.2498	960
Demand	240	420	960	1080	1080	

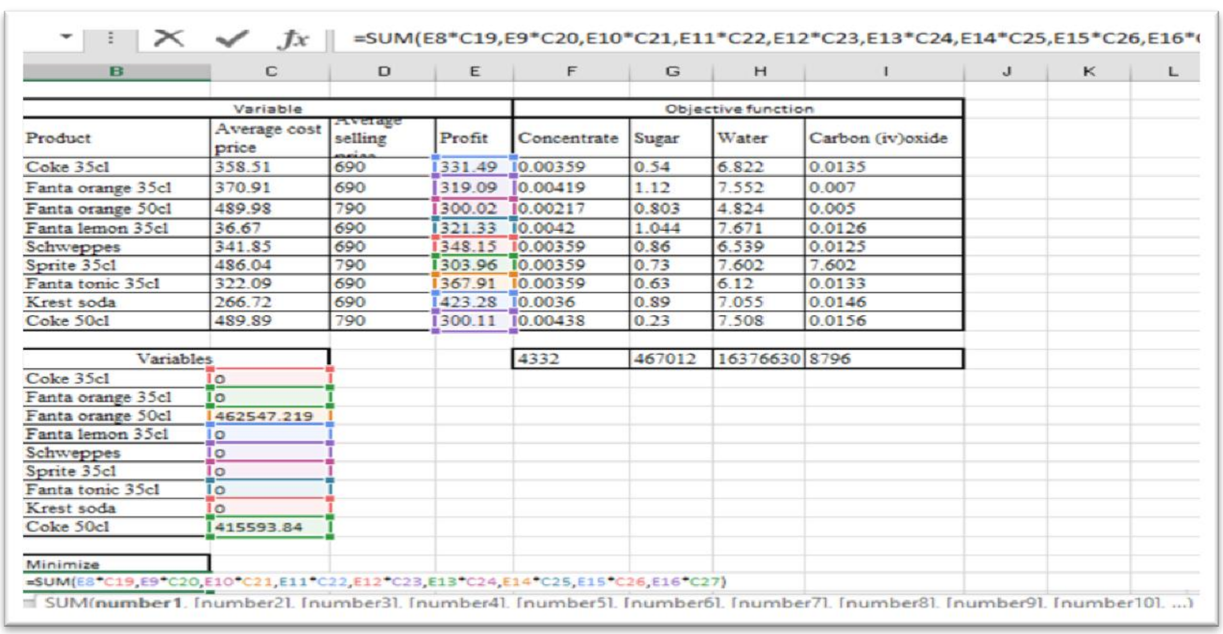
=SUMPRODUCT(K50:O53,K62:O65)
SUMPRODUCT(array1, [array2], [array3], [array4], ...)

Plant	Depot					
	Mbaise	Orlu	Umuahia	Calabar	Uyo	supply
Aba	0	0	0	600	360	960
Owerri	240	0	720	0	0	960
Enugu	0	0	240	0	720	960
Port Harcourt	0	420	0	480	0	900
Demand	240	420	960	1080	1080	

Figure 4. Optimization Procedure

3.6 Result of the Product Mix Formulation

Application of the integer linear programming and the simplest method gave the same result when Ms Excel solver was applied for the analysis of the product mix model. The result obtained from the model indicated that to achieve a maximum profit of ₦263,497,283, as indicated in Figure 3 blow, more of two products should be produced 50cl Fanta Orange and 50cl Coke, and their production quantities should be 462,547 and 415,593 crates respectively as show in Table 12. This is in agreement with the work of Oluwafemi and others, (2012).



=SUM(E8*C19,E9*C20,E10*C21,E11*C22,E12*C23,E13*C24,E14*C25,E15*C26,E16*(

Variable				Objective function			
Product	Average cost price	Average selling price	Profit	Concentrate	Sugar	Water	Carbon (iv)oxide
Coke 35cl	358.51	690	331.49	0.00359	0.54	6.822	0.0135
Fanta orange 35cl	370.91	690	319.09	0.00419	1.12	7.552	0.007
Fanta orange 50cl	489.98	790	300.02	0.00217	0.803	4.824	0.005
Fanta lemon 35cl	36.67	690	321.33	0.0042	1.044	7.671	0.0126
Schweppes	341.85	690	348.15	0.00359	0.86	6.539	0.0125
Sprite 35cl	486.04	790	303.96	0.00359	0.73	7.602	7.602
Fanta tonic 35cl	322.09	690	367.91	0.00359	0.63	6.12	0.0133
Krest soda	266.72	690	423.28	0.0036	0.89	7.055	0.0146
Coke 50cl	489.89	790	300.11	0.00438	0.23	7.508	0.0156
				4332	467012	16376630	8796

Variables	
Coke 35cl	0
Fanta orange 35cl	0
Fanta orange 50cl	462547.219
Fanta lemon 35cl	0
Schweppes	0
Sprite 35cl	0
Fanta tonic 35cl	0
Krest soda	0
Coke 50cl	415593.84

Minimize
=SUM(E8*C19,E9*C20,E10*C21,E11*C22,E12*C23,E13*C24,E14*C25,E15*C26,E16*C27)
SUM(number1, [number2], [number3], [number4], [number5], [number6], [number7], [number8], [number9], [number10], ...)

Figure 3. Ms excel solver of the linear programming solution of the mixed product.

Table 12 Variables

Name	Final values
Coke 35cl Average cost price	0
Fanta orange 35cl Average cost price	0
Fanta orange 50cl Average cost price	462547.2189
Fanta lemon 35cl Average cost price	0
Schweppes Average cost price	0
Sprite 35cl Average cost price	0
Fanta tonic 35cl Average cost price	0
Krest soda Average cost price	0
Coke 50cl Average cost price	415593.8401

4. CONCLUSION AND RECOMMENDATION FOR FURTHER RESEARCH

The outcome of this research showed that whenever there is a physical movement of goods from the point of manufacturer to the final consumers through a variety of channels of distribution, it is pertinent to minimize the cost of transportation so as to increase profit on sales. Further application of the Ms Excel solver for the analysis of the three methods. Transportation Method, Simplex Method, and Integer Linear Programming Method in solving the transportation problem and product mix problem resulted in an optimal cost of ₦2879.5068 and ₦263497284 respectively. Which is an indication that any of the three methods could be used to give optimal cost which would minimizes the total shipping cost and satisfy both demand and supply and also product mix limits.

More so, the result of the product mix problem revealed that for Nigeria Bottling Company to satisfy their customers, Fanta Orange 50cl and 35cl, Coke 50cl and 35cl, Fanta lemon 35cl, Sprite 50cl, Schweppes, Krest soda 35cl should be produced. While more of Fanta Orange 50cl Coke 50cl in order to remain in business and meet the unpredictable and constant change in customer's demand at a given price and time, because they contribute mostly to the profit earned. We recommend that future research should see to the scheduling nature of customer's arrival as well as the lead-times and associated cost charges for urgent demands with respect to number of workers. Also, a more detailed approach like Integration of machine learning, Assignment and inventory control method should be adopted for further research on cost minimization process.

REFERENCE

[1]. Altiparmak, F.; Gen, M.; Lin, L. and Paksoy, T. (2006). A Genetic Algorithm Approach for Multi-Objective

Optimization of Supply Chain Networks. Computers & Industrial Engineering, 51, 196-215.

[2]Andrews, B. and Torsten, U. (2006). Malaysian graduates employability UNITAR E- Journal 4(1), 15-45.

[3]. Arntzen, B.C.; Brown, G.G.; Harrison, T.P. and Trafton, L.L. (1995): Global supply chain management at Digital Equipment Corporation. Interfaces. 25, 69-93.

[4]. Azevedo, L. and Wisner, J.D. (2011). A structural equation model of supply chain management strategies and firm performance Journal of Business Logistics 24(1), 1-26

[5]. Anna, N. and Jose, Cruz. (2005). Supply Chain Networks, Electronic Commerce, and Supply Side and Demand Side Risk, Department of Finance and Operations Management, Isenberg School of Management.

[6]. Castillo-Villar, K.K.; Smith, N.R. and Herbert-Acero, J.F. (2014). Design and Optimization of Capacitated Supply Chain Networks Including Quality Measures. Mathematical Problems in Engineering, Article ID: 218913.

[7]. Castillo-Villar, K.K.; Smith, N.R. and Simonton, J.L. (2012). The Impact of the Cost of Quality on Serial Supply-Chain Network Design. International Journal of Production Research, 50, 5544-5566

[8]. Chan, C. and Chung, W (2004). Just in Time Total Quality Management and Supply Chain Management, Understanding their linkages and impact on business performance OMEGA: International journal of management science 33, 2.

[9]. Chandan KumarJha (2016). Supply Chain Optimization approaches and Market Demand Analysis of Petroleum Industry: A Case Study of ONGC'' International Journal of scientific research and management (IJSRM) 4(7), 4461 -4475

[10]. Cheng, F. and Wen, C. (2004). The nature of inter firm partnering in supply chain management Journal of logistics management 9(2), 1-19.

[11]. Didiuer, C.; Lin, C.; and Madu, C.N. (2006). The relationship between supply chain quality management practices and organizational performance International Journal of Quality and reliability Management, 18 (8), 864-872.

[12]. Fan, k.; Liu, C.K. and Wong, W. (2010). Relationships for quality improvement in Hong Kong- China supply chain The International Journal of Quality and Reliability Management, 16(1), 24-4.

[13]. Farahani, R.Z. and Elahipanah, M. (2008). A Genetic Algorithm to Optimize the Total Cost and Service Level for Just-in-Time Distribution in a Supply Chain. International Journal of Production Economics, 111, 229-243

[14]. Gen, M.; Yun, Y.S. and Syarif, A. (2002). Study on Multi-Stage Logistics Chain Network: A Spanning Tree-Based Genetic Algorithm Approach. Computers & Industrial Engineering, 43, 299-314.

[15]. Hokey, M. and Genqui, P. (2002). Supply Chain management: a strategic perspective International journal of operations and production management, 22(6), 614-31.

[16]. Hoong Chuin Lau and Qi Zhang Liu (2000). Solving a Supply Chain Optimization Problem Collaboratively, School of Computing, National University of Singapore, 3 Science Drive 2, Singapore 117543

[17]. Lin, L.; Gen, M. and Wang, X. (2007). A Hybrid Genetic Algorithm for Logistics Network Design with Flexible Multistage, Model. International Journal of Information Systems for Logistics and Management, 3, 1-12.

[18]. Marc, W. and Srensson, G. (2002). The theoretical foundation of supply chain management: a functionalist theory of marketing," International Journal of physical distribution and logistics management 32(9), 734-54.

[19]. Pishvaee, M.S.; Farahani, R.Z. and Dullaert, W. (2010). A Memetic Algorithm for Bi-Objective Integrated Forward/Reverse Logistics Network Design. Computers & Operations Research 37, 1100-1112.

[20]. Rezaci, G.; Nathan, T.R. and Nathan, B.R. (2013). Development and validation of a measurement instrument for studying supply chain management practises," Journal of Operations Management, 23(6), 618-41.

[21]. Salem, L.; Alain M.; Ossama, K. and Muhittin, O. (2000). Theory and Methodology on the Optimization of supply chain networking decisions, Network Organization Technology Research Center, Faculty des Sciences de I' Administration, University Laval, Cite Universitaire, Ste-Foy, QC. Canada GIK 7P4

[22]. Shashi, S. and Reino, P. (2013). Supply Chain Network Optimization of the Canadian Forest Products Industry: A Critical Review, Faculty of Natural Resources Management, Lakehead University, Thunder Bay, Canada.

[23]. Sirivongpascal, G. and Rogers, H. (2000). Management Suppliers when fewer can mean more International journal of physical distribution and logistics management, 27(7), 422-36.

[24]. Sourirajan, K.; Ozsen, L. and Uzsoy, R. (2009). A Genetic Algorithm for a Single Product Network Design Model with Lead Time and Safety Stock Considerations. European Journal of Operational Research, 197, 599-608.

[25]. Tailor, S. and Baker, T. (2002). Up-to-date communications, a must for keeping pace in the service business," Air-condition Heating and Refrigeration News, 205(16), 5-6.

[26]. Talluri, S.; Baker, R.C. and Ozkarahan, I.(2008). A Multi-Phase Mathematical Programmig Approach for Effective Supply Chain Design. European Journal of Operational Research, 141(3), 544-558

[27]. Thomas, R and Raph, T. (2006). Buyer Supplier Relationship derived value over two decades. The journal of Supply Chain Management, 44(2), 28 – 55.

[28]. Tsai, W.H. (1998): Quality Cost Measurement under Activity-Based Costing. International Journal of Quality and Reliability Management, 15, 719-752.

[29]. Uzorh, A.C. and Nnanna, I.(2014). Supply Chain Management Optimization Problem : The International Journal Of Engineering and Science (IJES) 3(6), 1-9.

[30]. Wang, J.L. (2009). A Supply Chain Application of Fuzzy Set Theory to Inventory Control Models-DRP System Analysis. Expert Systems with Applications: An International Journal, 36, 9229-9239.

[31]. Zhou, C.; Zhao, R. and Tang. W. (2008). Supply Chain Games in a Fuzzy Environment. Computers and Industrial Engineering: An International Journal, 55, 390-405.

[32]. Zhu, K. and Sarkis, P. (2004). The Importance of new Technology and innovation in SCM in enhancing production performance and product-quality performance: an investigation on Mediating effect," Global Review of Business and Economic Research, 6(2), 19-38.