Development and Application of Multi-Commodity Multi-Location Integrated Model for Manufacturing Industry

Adedeji Kasali Aderinmoye, Zosu Segbenu Joseph, Duduyemi Oladejo Samuel and Oyetunji Elkanah Olaosebikan

Abstract: ***This paper presented the development and application of Linear Programming to the modeling of Multi-Commodity Multi-Location production-distribution model for manufacturing industry. The Manufacturing industry has two plants, three depots and twenty retailer's axis in Lagos. The products are based on how they are packaged; Product 1(P1), Product 2(P2), Product 3(P3) and Product 4(P4). TORA software is used in analyzing the data obtained from the company. Comparing the optimal Multi-Commodity Multi-Location transportation cost of One trillion, Five Hundred And Thirty Billion And Four Hundred And Ninety Million Naira to existing transportation cost of truckload Three Trillion, Five Hundred And Forty Four Billion Naira, the difference is Two Trillion, Thirteen Billion And Five Hundred And Ten Million Naira which is Four Hundred And Two Billion And Seven Hundred And Two Million Naira annually resulting to 56.82 percent gain in profit***

Keywords: Multi-Commodity Multi-Location Integrated Model, TORA Software, Transportation Cost, Transportation Model, Transportation Network.

I. INTRODUCTION

A. General Description of Area of Study

Transportation service is crucial for economic development as it enhances reaching world markets, global integration and foreign investment. The impact of efficient and effective transportation services cannot be underestimated in both developed and underdeveloped countries. For business and production to strive, the raw materials, work-in-progress and finished goods must be effectively transported from one point to the other at a minimum cost in order to reach the customers at the cheapest possible cost and of good quality. When this happens, it gives the manufacturer a competitive advantage, good image in the market and sustainability. Transportation model is a type of Linear Programming Model that is concerned with how best product(s) produced can be transported from different plants or manufacturing centres to warehouses or from warehouses to customers. The initial places is regarded as the source and the final place is known as destination. The function of transportation model is to satisfy the destination requirement within the operating capacity at the lowest possible cost. However, some of its applications are in production scheduling, product mix decision, resource allocation and optimal utilization of resources, capital budgeting and plant location. In decision-making, the use of transportation model cannot be underestimated, especially in supply chain management and logistics. However, despite series of problems encountered by the Manufacturing Industry in Lagos State, the tool will alleviate losses experienced so far by the company as it has never failed researchers who embarked on such project, saving huge sum of money for the companies. Conventional transport models replicate current levels of demand, movement patterns and system capacities, in order to form a detailed transport system representation for analysis and forecasting purposes. Where policies and strategies are developed without recourse to modeling, these are likely to be ineffective, short-lived, have unintended consequences and may even be counter-productive (Furnish & Wignall, 2009).The transportation model deals with a special class of Linear Programming (LP) problem in which the objective is to transport homogenous goods from various origins or factories to different destinations or market at a total minimum cost (Hillier and Lierberman, 2010). In general, as it is put by Galadinma et al (2015), a company produces products at location called supply points and transports the products to customer location called demand points. Modeling is only one component within policy and strategy development, but modeling is very important because of the need to forecast the individual effect of policy and strategy options and also to forecast the interactions between different policy and strategy components. Modeling often plays some part in the development of transport policies and strategies. The predominant use of models is to analyze operational issues such as travel speeds, network delays and the capacity for movement between areas by different models. Models can also be used to estimate other important impacts such as fuel use, emissions, air pollution and casualties. Yes, if models are used for the wrong purpose, especially if they are over relied on for answers to questions they were never designed to answer. For example, a road traffic may be very useful at describing operational conditions along a transport corridor and to develop road improvement proposal.

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However, such a model is unlikely to be able to adequately represent freight or public transport modes, either of which could materially affect the road based improvement being considered (Furnish & Wignall, 2009).

Nwekpa and Evans (2015) developed a transportation model from data collected to optimize cement distribution from selected firms to markets in Ebonyi State, Nigeria. The study is considered worthwhile as it minimizes costs, optimize transportation process and improves the profit of the company.

In the same vein, Edokpia and Amiolemhen (2016) utilizes genetic algorithm in solving the transportation problem of a beverage producing company in Nigeria with a view of minimizing the total transportation cost and obtaining an optimal schedule or schedules using transportation cost data from the peak periods. The obtained data were analyzed and formulated into transportation matrix to generate optimal schedule. Transportation model is an indispensable tool that improves the transportation flow of manufacturing firms in order to minimize the cost on transportation by finding an optimum solution routes from different sources to different warehouses (Nwekpa and Evans, 2015).

B. Statement of the Problem

The manufacturing industry plant 1 is the second largest plant in the world and largest in Africa situated in Lagos which is a populous and industrial heart of the country and plant 2 also situated in Lagos is the first plant in Nigeria. The state is faced with problem of congestion, pollution, bad roads which results in disruption of business activities due to the fact that, there is no free flow of goods and raw materials. Hence, in order to alleviate the problems aforementioned and redeem company's position in market, it is necessary to solve the problem through best transport networking which will enhance efficiency and effectiveness resulting to minimization of transport cost, increase in profits and productivity, this can be achieved through effective modeling and evaluation of the company's transportation problem.

C. Justification of the Study

This study is considered worthwhile as it plays a pertinent role in optimization of transportation process resulting to cost minimization, improvement in company's position in the market and increase in profitability of the organization. From the accomplishments, the companies would also be encouraged to pay back to the public by sponsoring sports, education, culture, entertainment and healthcare.

D. Scope of the Study

For effective research;

- The work will be limited to two plants in Lagos State, their depots and retailers.
- Only four products Product 1(P1), Product 2(P2), Product 3(P3) and Product 4(P4) will be considered.
- The model formulation will cover three sectors (plants – depots – retailers) and five periods, 1,2,3, 4 and 5 (2014 – 2018).

However, the model can extend to any length of time depending on the capacity of the software.

E. Specific Objectives

- To develop a multi-commodity multi-location model for solving transportation problem
- Evaluate the model using TORA software
- Determine optimal transportation network

II. LITERATURE REVIEW

Crainic et.al (1990). Presented a general modeling framework of freight by rail proposed for strategic analysis and planning of regional and national multimode system. The modeling framework is not detailed representation of an existing rail system but accommodates the construction of an adequate representation of the rail network components, operations, economies and it easily and accurately predicts freight flow. Lefeber and Rooda (1994) ascertained in their paper modeling and analysis of manufacturing systems that certain modeling techniques can be used to desire models that can be used for analysis and controls of manufacturing system. Among which a traffic flow model which describes the dynamic behavior of cars along the highway of macroscopic level and contains information about number of cars passing a certain point and about the time it takes cars to go from one point to the other. It was emphasized that the model can be used for flow of products through a manufacturing line. Bradley and Arntzen (1999), developed a model that simultaneously determines the optimal capacity level, production schedule, inventory levels and finished goods. The model was applied to an electronics manufacturing company and a manufacturer of office supplies. From the analysis result, it was suggested that a manufacturing strategy based on minimizing unit cost and maximizing equipment utilization is likely to produce suboptimal financial outcome. It was resolved that increasing capacity and lowering inventories gives higher return on operating assets and instead of prebuilding the cheap products that have lowest ratio of value to processing time. Regan and Garrido (2001) presented a review and synthesis of research work on freight demand and shipper behavior modeling- stating clearly advantages and their disadvantages. The models were grouped according to nature of required data and geographical scope into aggregate, disaggregate, international, inter city (inter regional) and urban, the lapses and future areas of research were discussed. Mehmet et.al (2008), developed mixed integer programming models in order to jointly optimize production allocation and weekly transportation of customers order for leading forest product company. The models were tested using real order files and runs with the aid of user interface to be used by staff. It was discovered that significant cost savings is achieved. Cranic and Michael (2008) focused on analysis of multimodal, multiproduct transportation system at all levels; international, national and regional. In their research, models were developed and methodology of performing national planning activities were incorporated, also result obtained were transferred through decision-support software (STAN) commercially distributed worldwide. STAN software developed is an interactive-graphic software system made up of large numbers of tool to develop, compare scenarios, input, display, analyze, modify and output data as well as define supply network and so on (Crainic and Michael 2008).

Falcone et.al (2008) described the application of Evolutionary Algorithms (EAs) to the optimization of a simplified supply chain in an Integrated-Production-Inventory-Distribution system. The performance of four EAs Genetic Algorithm (GA), Evolutionary Programming (EP), Evolutionary Strategies (ES) and Differential Evolution (DE) were evaluated with numerical simulations and comparisons were made. It was discovered that Differential Evolution had the highest efficiency after taking into consideration Mixed-Integer programming problem encompassing the optimization of cost related to stocking, manufacturing, transportation and shortage from a supply chain comprising three raw materials, two products, three retailers and three planning periods.

Lukac et.al (2008) formulate two models, the first with several plants at different locations producing certain number of products and large numbers of customers of the products which is characterized by each plant operating in several modes, different quantities of products and variable production cost with known period reiterating customers' demand for each product in a short time planning period with known transportation costs from plants to customers. The Production Transportation Model (PTP) determine producer's production program and transportation of products to the customers at minimal production and transportation costs and customers satisfaction (demand). The second model is Bi-Level production-transportation model (BPTP) which involves two independent decision maker; the leader and subordinate, with the leader's decision, subordinate reacts optimally and sets of feasible choices available is interdependent where the leaders decisions affects the subordinate objective and vice versa. The problem involves having two sets of available data and problem solved using C PLEX 9.0 Programming Package and AMPL Mathematical Programming language. Salehi et.al (2013), carried out a research on optimization of transportation system in cement industry a Linear Programming model was developed from the data collected to achieve the first phase that entails determining number of needed trucks for any route of each period and the second phase that entails determination of quantity of needed trucks to each route for any period, a linear programming model is utilized using LINGO software package which possess special facilities to solve models with numerous variables with high constraints.

The third phase is to bridge gap. Due to solution in first and second phases, the extra trucks were used to bridge the gap. The algorithms developed gives rooms to update of information and data.

Seyedhosseini and Ghoreyshi (2014) formulated an integrated production and distribution planning model for perishable products with inventory and routing considerations. The model supply chain network is single production facility with multiple distribution centres, considering a perishable product that has a fixed lifetime. A homogenous fleet of vehicles is used for products transportation. The model is developed to minimize total cost by reducing trip rate, using a heuristic method due to complexity of the model which have submodels. The production submodel is solved using LINGO and a particle swarm heuristic for distribution submodel.

The efficiency of the model is deduced from randomly generated test problems. Azizi et.al (2015) utilized transportation model in solving a problem of a sharp decline in profits experienced by Biopharma Company in distribution of their products from six different plants to retailers. With the aid of solver tool, optimal solution was computed which gave room to generation of new shipment plan that effectively cut down 12% of the company's loss. Galadima et.al (2015) developed a transportation model from data obtained from maizube farms limited in Niger State, the primary data was collected using questionnaire and interviews and secondary data from existing records about the company. The model was evaluated using TORA software and the result of the analysis minimized transportation cost by saving 16.1% of usual practice. The researchers advice the company to adopt the recommended network to enhance better output. Patel, et.al (2017) ascertained in the paper "an alternate approach to finding an optimal solution of a transportation problem" that transportation problem is the most useful special class of Linear Programming problem which is used for different sources of supply to different destination that minimizes total transportation cost. The proposed model with less number of steps and easy to understand. The optimal results enhanced better decision making. Tayyeh and Abdul-Hussein (2018) reiterate the importance of using transportation model for aggregate planning which was applied to soft drinks industry. The aggregate plan determines quantities of production necessary to meet the variable demand in a given time at lowest cost with the aid of transportation model. From the result, aggregate plan proposed is better than the company's plan. It was deduced from the findings that total production cost of the company is higher than the corresponding costs resulting from the optimal plan outcome. It was concluded that optimal plan is better than the company's plan. Pribadi et.al (2019) explored Robust optimization model for location transportation problems with Ellipsoidal uncertainty set.

The problem includes locating, routing and inventory facilities and it entails strategic and operational decisions.

The model developed aims to apply single-stage with an ellipsoid approach to the problem of transportation with demand uncertainty. The strategic and operational costs can be affected with uncertainty in demand. Anser et.al (2020) asserted that smart production systems for green production is germane to manufacturers but the vision to achieve green supply chain management process (GSCMP) remains unattended to due to the use of less fuel-efficient technologies. The study of "The Role of Technological Innovation in a Dynamic Model of the Environmental Supply Chain Curve; Evidence of a Panel of 102 countries" used patent application and trademark to analyze technological process, logistics performance Indices (LPI -1) for assessing quality and comP2ence services and LPI-2 for trade and transport infrastructure are used to determine supply chain management process (SCMP) across countries. The results shows that technological innovation enhances decrease in carbon damages and henceforth adopt fuel efficient technologies to minimize carbon damages across countries.

Dong et.al (2020), used TransCAD to combine a variety of information such as road transportation risk, sensitive target population and transportation time as optimization parameters and a hybrid algorithm is designed to solve the hazardous materials optimal transportation problem.

The optimization problem uses an artificial vectorized map. The optimization model is applicable to multi-destination, multi-terminal and multivehicle networks that transport hazardous materials at minimal risk and cost.
From the researches carried out so far, it can be clearly perceived that due to the peculiarity of Lagos State where the manufacturing company is situated and the impact of the company particularly in Nigeria economy and the world at large, no researcher have done any findings in the state in this regards concerning this manufacturing Company.
Therefore, this research will develop an efficient transportation model for a manufacturing industry situated in Lagos as a case study. Those researches done in the company so far were only based on product 1, this research extends to other products 2, 3and 4 of the Company.

III. MODEL FORMULATION

A. Formulation Of A Multi-Commodity, Multi-Location Model For A Manufacturing Industry

- Assumptions And Limitations
- Assumptions

The following assumptions were made:

1. Standard truckload used for transportation is 24 pallets truck to enhance easy estimation
2. That all products moves from plants to depot and depots to retailers
3. There is no product mixed up from plants to depots
4. Only finished products were considered
5. The required amount of goods at destination equals the quantity available at the source.
6. Transportation cost is independent of the shipped amount

- Limitations

The TORA software usually result to Run-time Error '9' (Sub-Script out of Range) if supply and demand is more than 6 digits.

- Merit of TORA

TORA gives direct answer. For instance, will indicate movement of products from plants to depots and depot to retailers.

B. Methodology

This heading explained the method adopted in data collection, model development and model analysis.

- Data Collection

The data was collected through the Manufacturing Company Transportation System Survey (MCTSS) and the secondary data (Journal, books and newspapers). The information collected through both sources includes;

- Interview with management personnel in transport, stores, production and maintenance department.
- Relevant data from production, maintenance, stores and transport department.
- Relevant data from the company's annual report and journal.
- Relevant data from depots

The research information includes;

- Numbers of plants and depots
- Numbers of dealers or retailers and customers
- Numbers of production lines, products produced and production capacity
- Transportation cost
- Annual demands at depot
- Average numbers of truckload transported per day per plant.
- Average numbers of truckload per day per depot
- Brand of products produced
- Raw materials, type, source and quantity available
- Quantity of raw materials needed for each product
- Model Development

The mathematical model that describes this system can be conceived in a simplified Linear Algorithm (LA) also referred to as transportation model below.

Suppose that there are *m* sources, *n* destinations in a transportation problem. The goal of the problem is to make a transportation plan so that the total transportation cost is minimized. Let C_{ij} denote the costs of unit transportation amount from sources *i* to destinations *j* and X_{ij} the capacities transported from sources *i* to destinations *j*, $i=1,2,\dots m$, $j = 1,2,\dots n$ respectively. The capacities of sources *i* and the minimal demands of destinations *j* are denoted by *ai* and *bj*, $i=1,2,\dots m$, $j = 1,2,\dots n$, respectively. Therefore, the transportation problem can be described as follows;
Minimizing the transportation cost

$$\text{minimize} \sum_{i=1}^{m} \sum_{j=1}^{n} Cij\, Xij$$

Subject to:

$$\sum_{j=1}^{n} Xij \le a, i = 1, 2 \dots m$$

$$\sum_{i=1}^{m} Xij \ge bj, j = 1, 2, \dots n$$

$X_{ij} \geq 0,\ i = 1,2, \dots m,\ j = 1,2,\dots n$

In this model, the first constraint suggests that the total capacities transported from sources *i* are no more than the supply capacities a_1 of sources *i* and the other constraints implies that the total amounts transported to destinations *j* should satisfy the demands of *j*, $i = 1,2, \dots,m$, $j=1,2,\dots,n$, respectively. In the real world, as the transportation programming is needed to make in advance, so the decision makers might meet various uncertainty, including for instance health factor, weather factor and traffic factor. As a result, the parameters in the above model are unknown and indeterminate. Thus, for the suppliers, the decision-makers could make a prediction to the capacities of supply according to the capacity of production in the past 5 years. That is to say, the capacities of supplying should be regarded as random variables. But facing to the new demanders, the decision makers could make a prediction to the capacities of demanding and the unit costs of transportation only depending on the experts' data. Hence, based on the above reasons, we may assume that C_{ij} and b_j are independent uncertain variables, and a_i are random variables, $i = 1,2,\dots m$, $j = 1,2, \dots, n$.

- Transportation Tableau

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The transportation problem can be described using linear programming mathematical model and usually it appears in a transportation tableau (Table 3.1). The model of a transportation problem can be represented in a concise tabular form with all the relevant parameters. The transportation tableau (A typical TP is represented in standard matrix form), where supply availability (a_i) at each source is shown in the far right column and the destination requirements (b_i) are shown in the bottom row. Each cell represents one route. The unit shipping cost (C_{ij}) is shown in the upper right corner of the cell, the amount of shipped material is shown in the centre of the cell. The transportation tableau implicitly expresses the supply and demand constraints and the shipping cost between each demand and supply point.

Table 1: The Transportation Tableau

	Destination				
	1	2	…….	N	Supply
Source 1	C_{11}	C_{12}	….	C_1n	S_1
Source 2	C_{21}	C_{22}	….	C_2n	S_2
Source m	Cm_1	Cm_2	……	Cmn	Sm
Demand	d_1	d_2		Dn	

Source: Hillier and Lierberman 2010

- Formulation

Indices:
i = 1, 2 -------- I Index for products I = 1 = P1
j = 1, 2 -------- J Index for plants. I = 2 = P2
k =1, 2 -------- K Index for depots I = 3 = P3
l = 1, 2 -------- L Index for retailer I = 4 = P4

Model Formulation 1 From Plants To Depots
Parameters
C_{ijk} = Transportation cost per case of product i from plants j to depot k.
P_{ijk} = Quantities of product i in cases transported from plant j to depot k.
S_{ij} = Production capacity from product i at plant j.
D_{ik} = Quantities of products i demanded at depot k.
Z_{PD} = Total cost of transportation from Plants to Depot.
Z_{DR} = Total cost of transportation from Depot to Retailers.
Z_{PR} = Total cost of transportation from Plants to Retailer.
The General Form of the Model

$$\text{Min } Z_{PD} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} C_{ijk}P_{ijk}$$

$$\text{Subject to; } \sum_{i=1}^{I}\sum_{j=1}^{J} S_{ij} \geq \sum_{i=1}^{I}\sum_{k=1}^{K} D_{ik}$$

$P_{ijk} \geq 0$ i = 1, 2 ….. I, j = 1, 2 --- J k = 1, 2 ---- K

Model Formulation 2 From Depots to Retailer
Parameters
C_{ikl} = Transportation cost per case of product i from Depot k to Retailer l
P_{ikl} = Quantities of product i in cases demanded from Depot k by Retailer l
D_{il} = Quantities of product i demanded by Retailer l
S_{ik} = Quantities of product i supplied to Depot k

The Model In General Form

$$\text{Min } Z_{DR} = \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} C_{ikl}P_{ikl}$$

$$\text{Subject to: } \sum_{i=1}^{I}\sum_{k=1}^{K} S_{ik} \geq \sum_{i=1}^{I}\sum_{l=1}^{L} D_{il}$$

$P_{ikl} \geq 0$ i = 1, 2 …. I k = 1, 2 …. K l = 1, 2 …..L
Formulation Of Multi-Commodity Multi-Location Integrated Model
(PLANTS - DEPOTS - RETAILERS)

The General Form Of The Model
$\text{Min } Z_{PR} = \text{Min } Z_{PD} + \text{Min } Z_{DR}$

$$= \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} C_{ijk}P_{ijk} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} C_{ikL}P_{ikL}$$

Subject to:

$$\sum_{i=1}^{I}\sum_{j=1}^{J} S_{ij} \geq \sum_{i=1}\sum_{k=1}^{K} D_{ik} = \sum_{i=1}^{I}\sum_{l=1}^{L} D_{il}$$

$P_{ikl} \geq 0$, $P_{ijk} \geq 0$ i = 1, 2 …I j = 1, 2…..J k = 1, 2, ….K l = 1, 2, ….. L

The Multi -Commodity Multi-Location Integrated Model

Q_{ijkl} = Total quantities of product i in cases demanded from plants j to depot k and from depot k to retailer l

$$Q_{ijkl} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} P_{ijk} = \sum_{i=1}^{I}\sum_{K=1}^{K}\sum_{L=1}^{L} P_{ikl} = \sum_{i=1}^{I}\sum_{J=1}^{J}\sum_{K=1}^{K}\sum_{L=1}^{L} P_{ijkl}$$

While P_{ijkl} = Quantities of product i in cases transported from plant j to depot k and from depot k to retailer l

hence the associated cost will be

$$Z_{ijkl} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} C_{ijk}\,.\,P_{ijk} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} C_{ikL}P_{ikL}$$

$$= \sum_{i=1}^{I}\sum_{J=1}^{J}\sum_{K=1}^{K} C_{ijkl}.\ P_{ijkl}$$

To know quantities of product 1 that moves from plants to depots and from depots retailer

$$\text{i.e. } Q_{1jkl} = \sum_{J=1}^{J}\sum_{K=1}^{K} P_{1jk} = \sum_{K=1}^{K}\sum_{L=1}^{L} P_{1kl} = \sum_{J=1}^{J}\sum_{K=1}^{K} P_{1jk1}$$

The associated cost will be

$$\sum_{J=1}^{J}\sum_{K=1}^{K} C_{1jk}.\ P_{1jk} + \sum_{K=1}^{K}\sum_{L=1}^{L} C_{1kl}.\ P_{1kl} =$$

$$Z_{1jkl} = \sum_{J=1}^{J}\sum_{K=1}^{K} C_{1jk1}.\ P_{1jk1}$$

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In the same vein, to determine the quantities of product 2 that moves from plants to depots and depots to retailer 1.

$$Q_{2jk1} = \sum_{J=1}^{J}\sum_{K=1}^{K} P_{2jk} = \sum_{k=1}^{K}\sum_{l=1}^{L} P_{2kl} = \sum_{J=1}^{J}\sum_{K=1}^{K} P_{2jk1}$$

$$Z_{2jk1} = \sum_{J=1}^{J}\sum_{K=1}^{K} C_{2jk}.\ P_{2jk} + \sum_{K=1}^{K}\sum_{L=1}^{L} C_{2kl}.\ P_{2kl} = \sum_{J=1}^{J}\sum_{K=1}^{K} C_{2jk1}.\ P_{2jk1}$$

ZOSU'S MULTI-COMMODITY, MULTI-LOCATION INTEGRATED MODEL

$$\text{Min } Z = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} C_{ijk}.\ P_{ijk} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} C_{ikL}\ P_{ikL} + L_F$$

$$= \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{L=1}^{L} C_{ijkl}.\ P_{ijkl} + L_F$$

Subject to: $\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} P_{ijk} = \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{l=1}^{L} P_{ikl} = \sum_{l=1}^{L}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} P_{ijkl}$

$P_{ijk} \geq 0$ $P_{ikl} \geq 0$ $P_{ijkl} \geq 0$ $i = 1, 2 \ldots I$, $k = 1, 2, \ldots K$ $l = 1, 2 \ldots\ldots L$

Indices:

i = 1, 2 -------- I Index for products
j = 1, 2 -------- J Index for plants.
k =1, 2 --------K Index for depots
l = 1, 2 -------- L Index for retailer

C_{ijk} = Transportation cost per case of product i from plants j to depot k.
P_{ijk} = Quantities of product i in cases transported from plant j to depot k.
C_{ikl} = Transportation cost per case of product i from Depot k to Retailer l
P_{ikl} = Quantities of product i in cases demanded from Depot k by Retailer l
P_{ijkl} = Quantities of product i in cases transported from plant j to depot k and from depot k to retailer l
C_{ijkl} = Cost of product i in cases transported from plant j to depot k and from depot k to retailer l To the above model a landed cost factor L_F can be added to the total transportation cost The major cost used in considering the transportation cost of items are the maintenance, fuel, personnel, loading and offloading (Okafor & Nnanna 2018). In order to obtain an accurate total transportation, cost a landed cost can be added A landed cost is the total charge associated with getting a shipment to its destination. It's most associated with *International Shipping*, and usually refers to the cost of shipping, plus applicable duties, taxes and fees. The total landed cost can include a range of additional factors such as insurance fees, custom duties and any other charges incurred along the way that are part if he above (www.freitos.com).Not only in knowing how to calculate the landed cost is important, it is necessary to running a successful business In most cases Landed cost factor L_f is a proportion of the transportation cost in order to obtain total transportation cost. Landed cost formula= Shipping + Customs + Risks + Overhead. Landed cost factor is used in calculating the landed cost per item, It is a multiplier for the product that can be used to zero out, double, triple, etc. to get a more accurate landed cost (hub.activate.com)
Where 0= Do not factor 1= One per allocation factor 2= Double items allocation 0.5= Half the allocation of this item. For the purpose of this research analysis, it is zero-out. This is done because it does not involve international shipping and those likely factors have been factored or included into personnel cost.

THE MULTI-COMMODITY MULTI-LOCATION MODEL FOR REAL LIFE SITUATIONS

$$\text{Min } Z = \sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{3} C_{ijk}.\ P_{ijk} + \sum_{i=1}^{4}\sum_{k=1}^{3}\sum_{l=1}^{20} C_{ikL}\ P_{ikL} = \sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{3}\sum_{l=1}^{20} C_{ijkl}.\ P_{ijkl}$$

Subject to: $\sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{k=1}^{3} P_{ijk} = \sum_{i=1}^{4}\sum_{k=1}^{3}\sum_{l=1}^{20} P_{ikl} = \sum_{i=1}^{4}\sum_{j=1}^{2}\sum_{K=1}^{3}\sum_{L=1}^{20} P_{ijkl}$

$P_{ijk} \geq 0$ $P_{ikl} \geq 0$ $P_{ijkl} \geq 0$ $i = 1, 2 \ldots 4$, $k = 1, 2, 3$ $l = 1, 2 \ldots\ldots 20$
I = P1, I=2=P2, I=3=P3 and I=4=P4

IV. DATA PRESENTATION AND ANALYSIS

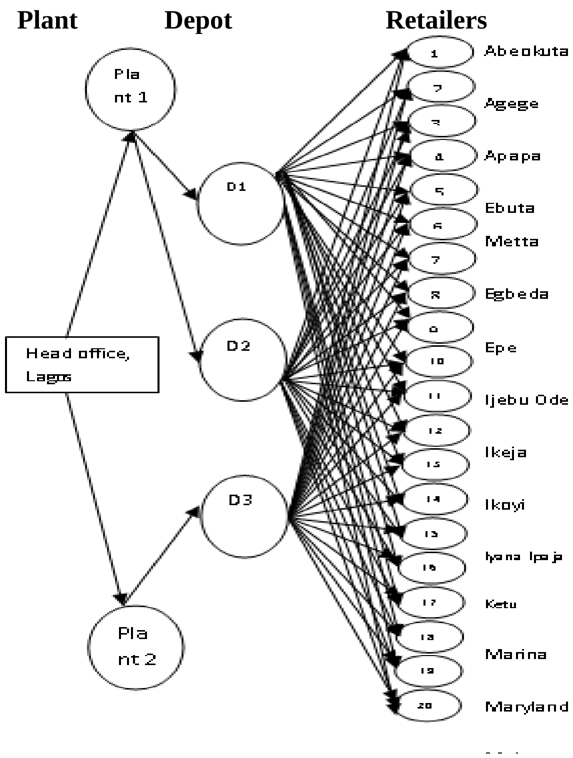

Fig. 1: The Company's Transportation Proble

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A. Total Transportation Cost of the Existing Transportation Network Considering Truckload (Plants To Depots)

TABLE 2. Transportation Costs Per Truckload (₦m) (2014 – 2018)

Plant/Depots	D1	D2	D3	Supply
PLANT 1	10.6091	8.9416	0	126710
PLANT 2	0	0	3.0467	70560
Demand	70560	56150	70560	

Source: Author's Compilation (2020)

TABLE 3. Numbers Of Truckload Transported (2014 – 2018)

Plant/Depots	D1	D2	D3	Supply
PLANT 1	70560	56150	0	126710
PLANT 2	0	0	70560	70560
Demand	70560	56150	70560	

Source: Author's Compilation (2020)

TABLE 4. Total Transportation Cost of Truckloads (₦m) (2014 – 2018)

Plant/Depots	D1	D2	D3	Supply
PLANT 1	748578.1	502070.84	0	126710
PLANT 2	0	0	214975.2	70560
Demand	70560	56150	70560	

Total Transportation Cost of existing network = **₦1.47E+12**

In similar manner, the total transportation cost from depots to retailers is calculated and the result is ₦2,074,000,000,000 Therefore, the total cost from plants to retailers
= Transportation cost from plants to depots + Transportation cost from depots to retailers
= ₦1,470,000,000,000 + ₦2,074,000,000,000
= ₦3,544,000,000,000

B. Total transportation cost of products, demands and supply for multi-commodity multi-location integrated model(plants to depot) (2014 -2018)

TABLE 5. Transportation Cost From Plants To Depot (₦)

Plant/Depots	D1	D2	D3	Supply
PLANT 1 P1	7977.6	6724.8	0	99224572
PLANT 1 P2	2664	2246.4	0	78872488
PLANT 1 P3	6912	5817.6	0	31483642
PLANT 1 P4	3715.2	3139.2	0	21422927
PLANT 2 P1	0	0	2289.6	49717446
PLANT 2 P2	0	0	763.2	31423900
PLANT 2 P3	0	0	1987.2	31902910
PLANT 2 P4	0	0	1065.6	15839907
Demand	131901700	99101929	128884163	

Source: Author's Compilation (2020)

TABLE 6. Numbers of Products In Cases That Is Transported From Plants To Depots (2014-2018)

	PLANT 1		PLANT 2
	D1	D2	D3
PLANT 1 P1	55359270	43865302	0
PLANT 1 P2	47490500	31381988	0
PLANT 1 P3	15840130	15643512	0
PLANT 1 P4	13211800	8211127	0
PLANT 2 P1	0	0	49717446
PLANT 2 P2	0	0	31423900
PLANT 2 P3	0	0	31902910
PLANT 2 P4	0	0	15839907

TABLE 7. Total Transportation Cost Of Existing Network (₦)

	PLANT 1		PLANT 2
	D1	D2	D3
PLANT 1 P1	4.41634E+11	2.94985E+11	0
PLANT 1 P2	1.26515E+11	70496497843	0
PLANT 1 P3	1.09487E+11	91007695411	0
PLANT 1 P4	49084479360	25776369878	0
PLANT 2 P1	0	0	1.14E+11
PLANT 2 P2	0	0	2.4E+10
PLANT 2 P3	0	0	6.34E+10
PLANT 2 P4	0	0	1.69E+10
TOTAL TRANSPORTATION COST OF EXISTING NETWORK = ₦1.42708E+12			

C. TORA Software Application

1. Run the TORA software
2. From the pop-up menu, select transportation model
3. Select enter "new problem" and "scientific notation", then click on the "go to input screen" option.
4. On the input screen, type the problem title, the number of sources and the number of destinations, then click enter.
5. A table is displayed with the number of sources and destinations required.
6. Type in the values of demand, supply and cost into the table in their respective positions
7. Click on the "solve" option.
8. Select solve problem then final solution

The solution will be displayed, then click on "write to print" to print the result.

D. Optimal Result Of Multi Commodity Multi Location Integrated Model

TABLE 8. Plants To Depots (2014 – 2018)

Plant/Depots	D1	D2	D3	New Supply	Supply
PLANT 1 P1	5641824	43865302	49717446	99224572	99224572
PLANT 1 P2	16066600	31381988	31423900	78872488	78872488
PLANT 1 P3	0	0	31483642	31483642	31483642
PLANT 1 P4	0	5583020	15839907	21422927	21422927

PLANT 2 P1	49717446	0	0	49717446	49717446
PLANT 2 P2	31423900	0	0	31423900	31423900
PLANT 2 P3	15840130	15643512	419268	31902910	31902910
PLANT 2 P4	13211800	2628107	0	15839907	15839907
New Demand	131901700	99101929	128884163		
Demand	131901700	99101929	128884163		
OPTIMAL TRANSPORTATION COST = 4.72E+11					

TABLE 9. Depots to retailers (2014 – 2018)

S/N	DEPOTS/ PRODUCTS	RETAILERS SUPPLIED	QUANTITIES SUPPLIED IN CASES
1	D1 P1	AGEGE	1,99,93,766
		EGBEDA	1,53,69,740
		MEIRAN	99,96,883
		OTA	99,98,881
2	D1 P2	ABEOKUTA	3,99,87,532
		KETU	75,02,968
3	D1 P3	EGBEDA	46,24,426
		IKEJA	12,19,221
		IYANA	99,96,883
4	D1 P4	IKEJA	1,32,11,800
5	D2 P1	APAPA	1,99,93,766
		EBUTE M	49,98,442
		MARINA	49,98,441
		ORILE	49,98,442
		V–ISLAND	88,76,211
6	D2 P2	IKOYI	91,31,976
		V–ISLAND	2,22,50,012
7	D2 P3	V-ISLAND	1,56,43,512
8	D2 P4	V–ISLAND	82,11,127
9	D3 P1	MARYLAND	49,98,442
		OKOTA	4,47,19,004
10	D3 P2	EPE	49,98,442
		IJEBU-ODE	99,96,883
		IKOYI	8,64,907
		KETU	55,66,786
		SAGAMU	99,96,882
11	D3 P3	IKEJA	2,16,39,060
		SURULERE	49,98,442
		OKOTA	52,65,408
12	D3 P4	IKEJA	1,39,14,336
		KETU	19,25,571
OPTIMAL TRANSPORTATION COST = ₦1,058,490,000,000			

Total optimal cost = ₦472,000,000,000 + ₦1,058,490,000,000 =₦1,530,490,000,000

PROPOSED TRANSPORTATION NETWORK FOR THE COMPANY RETAILER DEPOT PLANT

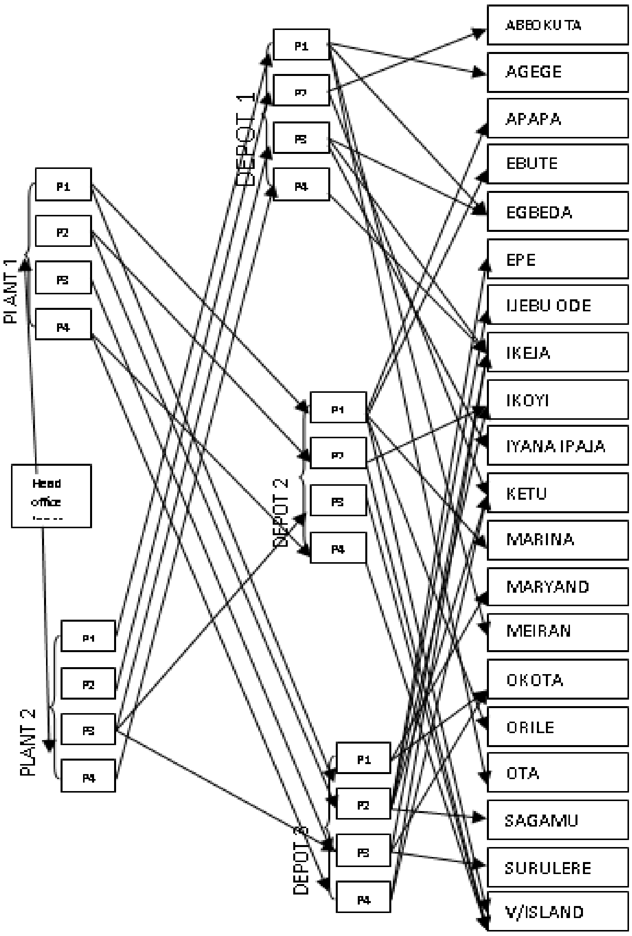

Fig 2: Proposed Transportation Network.

V. CONCLUSION

Comparing the optimal Multi-Commodity Multi-Location transportation cost of ₦1,530,490,000,000 (One trillion, Five Hundred And Thirty Billion And Four Hundred And Ninety Million Naira) to existing transportation cost of truckload ₦3,544,000,000,000 (Three Trillion, Five Hundred And Forty Four Billion Naira), the difference is ₦2,013,510,000,000 (Two Trillion, Thirteen Billion And Five Hundred And Ten Million Naira) which is ₦402,702,000,000 (Four Hundred And Two Billion And Seven Hundred And Two Million Naira) annually resulting to 56.82% gain in profit. It is noteworthy that the two plants are expected to supply the three depots but specified products as against the current practices where PLANT 1 supplies D1 and D2 and PLANT 2 supplies only D3. It is pertinent to note that if the transportation network generated from the Multi-Commodity Multi-Location Integrated Model is utilized, the company's profit will increase, cost of product reduced and customer's satisfaction will be enhanced which will eventually lead to sustainability, good image and competitive advantage of the company.

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