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Research Paper

Modeling of Mono-Commodity Multi-Location Linear Programming Techniques for Determining Optimum Transportation Network of a Manufacturing Industry

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ABSTRACT

This research on Modeling and Application of Mono-Commodity Multi-Location Linear Programming Techniques for Determining Optimum Transportation Network was carried out at a Manufacturing Industry in Lagos, which comprises of two plants, three depots and twenty retailers axis. The model was analyzed using Micro Soft Excel Software. The analysis to determine the optimal transportation network was carried out in two phases by considering numbers of truckload transported and each commodity from plants to depots and depots to retailers and their optimals. It was discovered that the existing practices transportation cost for truckloads moving from plant to retailers is N3,544,000,000,000 and when optimized, cost is N1,932,650,000,000 while considering each product the optimized transportation cost is N1,871,065,369,000. This implies that the transportation network generated considering each product will yield 47.2% gain in profit than existing network. Hence, it is recommended that mono-commodity multi-location transportation network be used.

Keywords: Excel Software, Mono-Commodity Multi-Location Model, Transportation Cost, Transportation Model, Transportation Network.

INTRODUCTION

Transportation Modes and Cost

The means of transportation is referred to as transportation modes which are air, railway, road, maritime and inland water ways and pipes and pipelines. Transportation service can be any of the above or combination of it.

Crespo de Carvalho (2010) presented characteristics that can be used to compare different alternatives of modes of transportation in terms of price, transit time and variability, flexibility, capacity, frequency and losses and damages.

Based on the above characteristics, road transport system is the most realistic and very common mode of transportation in manufacturing industries in Nigeria. However, it is characterized with a lot of delays which result from heavy traffic, accidents and breakdown on the way.

Based on the anomalies, an efficient and effective transportation system is needed for business and industries to function in any industrialized society. Transportation cost is defined by Rodrigue and Notteboom (2013) as "a monetary measure of what the transport provider must pay to produce transportation services". The transportation services incur in several costs such as labour costs, fuel, maintenance, roads and administrative costs and others. The costs can be classified as variable and fixed costs. Some of the most significant conditions affecting transportation costs and consequently prices are; distance, weight/volume, mode of transportation and quality of service in terms of speed, reliability, punctuality, accessibility and frequency.

A. 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.

B. 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.

C. 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.

Specific Objectives

1. To develop a mono-commodity multi-location model for solving transportation problem
2. Evaluate the model using EXCEL software
3. Determine optimal transportation network of each product

LITERATURE REVIEW

Transportation Model Methodology

Optimization of transportation cost for Raipur Steel and thermal power plant was studied by Dharmendra and Kumar (2017). The outcome of the research reveals that proper routing, scheduling of vehicles and crew reduce the cost of transportation with application of TORA I.O software to various transportation methods, where Vogel Approximation method resulted in the minimum cost.

Akpan and Ojoh (2017), applied the Karmarkar's algorithm of the interior point method and compared to simplex method by ascertaining the effect of interior point algorithm on Linear programming model with high numbers of variables. The Karmarkars algorithm was applied to Nigerian Bottling Company's products and it gave a better result.

Ogbeide and Ejechi (2018) examined product mix optimization in a manufacturing industry. The data collected were modelled into a transportation problem and analyzed in order to predict which of the products must be given more attention or produced to maximize profit. From the result it was clearly shown that Satzen bran should be produced more in order to attain maximum profit.

Anand and Raghunayagan (2018), applied transportation model using LINGO software by given a case where there is availability in three supply points and three required area with unit cost of transportation to reveal the simplicity of the program which utilizes the power of linear and non 0 linear optimization to formulate, solve and analyze problems.

Chong and Osorio (2018) in a research used Simulation-based optimization algorithm for dynamic large scale urban transportation problems. A meta model approach which are dynamic and static was is more efficient. The dynamic is the optimization problem that depends on time like signal control. The proposed model can easily identify signal plans for good performance of Lansanne city.

Debapriya and Hassan (2018), applied Transportation cost optimization to an on-line business using Vogel's Approximation method (VAM) to expand the business over the whole Ragshash District. Due to lack of manufacturing cost, it was discovered that the only factor that can maximize the profit is the product transportation cost. The challenge faced is determination of optimum and reliable transportation medium. Hence, a suitable destination for products distribution in selected location was carefully chosen on the basis of demand and minimum rent of warehouse. C program algorithm was developed to solve Vogel's approximation method.

Elkazzaz et.al (2018), propose a meta-heuristic algorithm called Cuckoo search algorithm for multi-objective supply chain. Problem to find optimum configuration for SC problem which minimizes total lead time and cost. The proposed algorithm pareto solutions were compared with Bee and Genetic Algorithm (GA), it was discovered that Cuckoo is more powerful tool for pare to solutions for supply chain problem.

Ravi, et.al (2019), proposed a new hybrid Transportation problem by using DFSD (Difference from standard deviation method). The difference is standardized based on normal distribution. DFSD is applied to find optimal solution to transportation problem. Using this approach reduces number of iterations, saves time optimal result compare to North West corner, least cost and Vogel approximation method.

Stoilova et.al (2019), proposed a methodology based on multi-criteria in choosing container handling equipment in a rail-road intermodal terminal. The methodology consists of four steps which includes; determination of alternative variants of handling equipment. Electric-Rail Mounted Gantry Crane (RMG), Diesel Driven Rubber Tyred Gantry (RFG) and Mobile Reach Stacker (RS); Technical, Economical, Technological and Ecological (TETE), analysis, Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment of Evaluation (PROMETHEE). The subsequent step depends on the previous. The result verified by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) multicriteria method. It was confirmed that both TOPSIS and PROMETHEE gave similar outcome which confirms that the developed methodology and the result obtained are correct.

In the research carried out by Aliyu et al (2019), the study utilizes transportation models for cost minimization for goods transported from factories to warehouses. The data collected were modelled into a tableau, from the result; all the methods gave varying outcomes at initial basic feasible solution. VAM appears to be best method with the least transportation cost. After optimization the three method outcomes are equal, implying they can all result in optimal solution.

2.2 Model Evaluation Using Microsoft Excel Software

Spreadsheet modeling for solving combinatorial problems; the vendor selection problem was studied by Ipsitandis (2008), it was revealed that spreadsheet have grown up and became very powerful and easy to use tools in applying analytical techniques for solving business problems; operation managers, production managers, planners and schedulers can work with them in developing solid and practical Do-It-

Yourself decision support systems. This fact was buttressed as Novak et.al (2003) was referenced that optimization problems were typically solved using special purpose optimization software package such as LINDO, MATLAB, SAS etc which is widely available in the academic world, but is not commonly found in businesses since it is not considered as part of everyday business tools that manager use.

Ghazali (2012), the study highlights the application of linear programming and spreadsheet that facilitate managers in a Malaysian Trading Company in determining the optimum transportation plan that leads to the lowest transportation cost of polymer from four plants to four demand destinations, also sensitivity analysis conducted reveals the impact of uncertainty of unit shipping cost to the total shipping cost of the trading company.

Chandrakantha (2014) ascertained that optimization problems in many fields can be modeled and solved using Excel solver in "Using Excel solver in optimization problems", it does not require knowledge of complex mathematical concepts behind the solution algorithms. This way is particularly helpful for researchers who are non-mathematics majors and companies to apply from time to time in decision making. The use of spreadsheet modeling and excel solver in solving linear and non linear programming problems was illustrated.

Khan (2014) applied Microsoft Excel solve in solving a real world transportation problem that involves transporting mosquito coil from company's warehouse to distributors warehouse. This is modeled into a transportation problem in order to find optimal transportation cost. The application is feasible and encouraging which yielded increase in profit.

Azizi et.al (2015) utilized transportation model in solving a problem of a sharp decline in profits experienced by Bio Pharma Company in distribution of their products from six different plants to retailers. With the aid of Excel 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.

Cerkini et.al (2015) utilized transportation cost optimization using excel solver to find a cheaper way to make and ship products to the customers and meet customers demands. ProPlast Company that manufactures doors and windows which is located at three places and supplies wine shops was used as a case study with the aim of minimizing cost of transportation and distance meeting customers demand and having competitive advantage. It was revealed that this can be achieved using Excel solver.

Ezeokwelume (2016) presented a paper on "solving linear programming problems and transportation problems using Excel solver", outline of steps required for installing Excel solver in Microsoft Word 2010 for use in solving linear problems, it provides a step by step procedure with snapshots for improved performance and it was affirmed that the use of Excel solver for analysis of operation research problems is important and necessary tool in present day technological world rather than the use of manual computation which is time consuming and prone to errors. It was also ascertained that Excel solver has proven to be relevant in other disciplines such as finance, production management et. Cetera.

Abdelwali et.al (2019) carried out a research work on solving a real life transportation problem using excel solver based on the actual data of a transportation company. The studied transportation network includes ten sources and nineteen destinations. It was required to minimize the total ton-kilometers. A step by step tutorial was initially demonstrated using excel before the real life application.

Abdelwali (2020), researched on "An Optimal Solution for a Real Transportation Problem with LINGO Code". In this paper, a Lingo code is prepared based on the formulation of transportation problem to solve an actual case study with the aid of Excel solver or spreadsheet. The optimal solution reduces the total ton-kilometers by 9:1702% of the real distribution amounts.

Ghosh et.al (2020) used an excel solver to solve a single stage Multimodal Fixed- Cost Transportation Model and the result show that the Rail route is the most cost effective but it leaves some demand unfulfilled. But the combination of both road and rail routes provides the most cost effective solution satisfying the demands of the destination. The results were compared by conducting cost analysis to select the most optimized one for the organizations. After a thorough cost analysis, it is evident that the multi-modal network provides the most efficient results for the supply of raw materials for the respective companies.

a. Formulation Of A Mono-Commodity, Multi-Location Model For A Manufacturing
MODEL FORMULATION
Industry

- Assumptions

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.

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 ito destinations j, i=1,2,…m, j = 1,2,…n respectively. The capacities of sources iand the minimal demands of destinations j are denoted by ai and bj, i=1,2,…m, j = 1,2,…n, respectively. Therefore, the transportation problem can be described as follows;

Minimizing the transportation cost

$$\text{minimize} \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$$

Subject to:

$$\sum_{j=1}^{n} Xij \leq a_i\, i = 1, 2 \ldots m$$

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

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

- **Transportation Tableau**

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 of Mono-Commodity Multi-Location Model

Indices:

i = 1, 2 -------- I Index for plants
j = 1, 2 -------- J Index for depots.
k =1, 2 -------- K Index for retailers

Parameters

C_{ij} = Transportation cost per unit of products from plant i to depot j.

C_{jk} = Transportation cost per unit of products from depot j to retailer k.

P_{ij} = Quantities of product transported from plant i to depot j.

P_{jk} = Quantities of product transported from depot j to retailer k.

S_i = Production capacity from product at plant i.

D_j = Quantities of product demanded at depot j.

D_k = Quantities of product demanded at retailer k.

Z_{ij} = Total cost of transportation from Plant i to Depot j.

Z_{jk} = Total cost of transportation from Depot j to Retailer k.

Z = Total cost of transportation from Plant i to Depot j and depot j to retailer k..

The General Form of the Model (plants to depots)

$$\text{Min } Z_{ij} = \sum_{i=1}^{I} \sum_{j=1}^{J} C_{ij}.P_{ij}$$

$$\sum_{i=1}^{I} S_i \geq \sum_{j=1}^{J} D_j = \sum_{i=1}^{I} \sum_{j=1}^{J} .P_{ij}$$

Subject to;

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

From Depots to Retailer

The Model

$$\text{Min } Z_{jk} = \sum_{j=1}^{J} \sum_{k=1}^{K} C_{jk} P_{jk}$$

$$\text{Subject to: } \sum_{j=1}^{J} S_j \geq \sum_{k=1}^{K} D_k = \sum_{j=1}^{J} \sum_{k=1}^{K} P_{jk}$$

$P_{jk} \geq 0$ j = 1, 2 …. J k = 1, 2 …. K

THE MONO-COMMODITY MULTI-LOCATION MODEL

$$\text{Min } Z_{jk} = \sum_{i=1}^{I} \sum_{j=1}^{J} C_{ij}.P_{ij} + \sum_{j=1}^{J} \sum_{k=1}^{K} C_{jk} P_{jk}$$

$$= \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} C_{ijk}..P_{ijk}$$

$$\text{Subject To: } \sum_{i=1}^{I} \sum_{j=1}^{J} .P_{ij} = \sum_{j=1}^{J} \sum_{k=1}^{K} .P_{jk}$$

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

k = 1, 2 …. K

Indices:

i = 1, 2 -------- I Index for plants

j = 1, 2 -------- J Index for depots.

k =1, 2 -------- K Index for retailers

Parameters

C_{ij} = Transportation cost per unit of products from plant i to depot j.

C_{jk} = Transportation cost per unit of products from depot j to retailer k.

C_{jjk} = Transportation cost per unit of products from plant I to depot j to retailer k.

P_{ij} = Quantities of product transported from plant i to depot j.

P_{jk} = Quantities of product transported from depot j to retailer k.

P_{jjk} = Quantities of product transported from plant I to depot j to retailer k.

Z = Total cost of transportation from Plant i to Depot j and depot j to retailer k..

- Model Evaluation Procedure Using Excel

Steps Involved In Using Microsoft Excel Solver for Optimization

The steps involved in the use of Microsoft Excel software is as follows;

At first, we construct a table in excel that will contain the cost parameters between each destination. Now, we construct another table which is a copy of the first, but with a "new supply" and "new demand" row and column respectively, the cost of the transportation between each destination will be made zero and the cells which contained the cost of transportation between destinations are now known as the **Changing cells.**

The "new supply" cells will be given a formular which is equal to the sum of the transportation cost of their respective rows and the "new demand" cells will be given a formular which is equal to the sum of their respective columns.

A new cell is created which will contain the value of the minimum transportation cost of the model and to calculate this, we will give the cells a formular to find the sum product of the changing cells and the original cost of transportation between destinations.

The next step is to invoke the excel solver; then we set the cell which was created to contain the minimum transportation cost as the "set target cell". Since we want to minimize transportation cost, at the "equal to" option we select "min", then we click on the "by changing cells" space, and highlight the changing cells which is on the spreadsheet and is currently empty.

We add the subjects to constraint by selecting the "add" in the dialogue box, which will redirect us to another dialogue box which contains a "cell reference", a space for symbol and "cell constraint" space. (Note; the symbol space consist of the =, < =, >=, int, bin).

At the "cell reference" space, we will select or highlight all the new supply cells or the new supply column, and at the space for symbol, select the "=" symbol and add the constraints in the "cell constraint" space by highlighting the original supply cells or column of the original transportation model on the spreadsheet. We select the add button in the option inside the dialogue box, then the same dialogue box will be re-opened but this time, it will be empty, this will be for the demand and it's constraints, therefore the same steps will be repeated but with the new demand row or cells and the original demand row or cells on the spreadsheet.

Then click on the "OK" button. You will be returned to the first dialogue box where you add your changing cells and set target cell, then, click on "option". You will be redirected to a new dialogue box where you will see two options at the bottom left which are "assume linear model", Assume non-negative; select the two. Then click "Ok". You will be returned to the first dialogue box again, click on "solve".

The changing cells will automatically be filled with the amount or quantity of commodity that should be transported between destinations in order to minimize transportation cost, and the cell that was elected to contain the minimum transportation cost will now be filled with the value of the minimum transportation cost of the model.

DATA PRESENTATION AND ANALYSIS

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

Table 5: Optimal Result of Existing Transportation Network (Plants-Depots) (2014-2018)

Plant/Depots	D1	D2	D3		Supply
PLANT 1	0	56150	70560	126710	126710
PLANT 2	70560	0	0	70560	70560
	70560	56150	70560		
Demand	70560	56150	70560		
Optimal Transportation Cost = ₦5.02E+11					

In the same vein Optimal transportation cost from depots to retailers is N1.43E+12.

Total Transportation Cost of Existing and Optimal of Each Product in Cases From Plants to Depots

Table 6: Total Transportation Cost of Product 1 and Optimal Transportation Cost

Plant/Depots	D1	D2	D3	Supply	
PLANT 1	7977.6	6724.8	0	99224572	
PLANT 2	0	0	2289.6	49717446	
Demand	55359270	43865302	49717446		
Total Transportation Cost for Existing N8.50453E+11					
Plant/Depots	D1	D2	D3	Supply	Supply
PLANT 1	5641824	43865302	49717446	99224572	99224572
PLANT 2	49717446	0	0	49717446	49717446
Demand	55359270	43865302	49717446		
Demand	55359270	43865302	49717446		
Total Transportation Cost for Optimal = ₦ 3.3999E+11					

Table 7: Total Transportation Cost of Product 2 and Optimal Transportation Cost

Plant/Depots	D1	D2	D3	Supply	
PLANT 1	2664	2246.4	0	78872488	
PLANT 2	0	0	763.2	31423900	
Demand	47490500	31381988	31423900		
Total Transportation Cost for Existing = N 2.20994E+11					
Plant/Depots	D1	D2	D3	Supply	Supply
PLANT 1	16066600	31381988	31423900	78872488	78872488
PLANT 2	31423900	0	0	31423900	31423900
Demand	47490500	31381988	31423900		
Total Transportation Cost for Optimal = ₦ 1.133E+11					

Table 8: Total Transportation Cost of Product 3 and Optimal Transportation Cost

Plant/Depots	D1	D2	D3	Supply	
PLANT 1	6912	5817.6	0	31483642	
PLANT 2	0	0	1987.2	31902910	
Demand	15840130	15643512	31902910		
Total Transportation Cost for Existing = N 2.63892E+11					
Plant/Depots	D1	D2	D3	Supply	Supply
PLANT 1	0	0	31483642	31483642	31483642
PLANT 2	15840130	15643512	419268	31902910	31902910
Demand	15840130	15643512	31902910		
Total Transportation Cost for Optimal = ₦ 833,169,370					

Table 9: Total Transportation Cost of Product 4 and Optimal Transportation Cost

Plant/Depots	D1	D2	D3	Supply	
PLANT 1	3715.2	3139.2	0	21422927	
PLANT 2	0	0	1065.6	15839907	
Demand	13211800	8211127	15839907		
Total Transportation Cost for Existing = N91739854138					
Plant/Depots	D1	D2	D3	Supply	Supply
PLANT 1	0	5583020	15839907	21422927	21422927
PLANT 2	13211800	2628107	0	15839907	15839907
Demand	13211800	8211127	15839907		
Total Transportation Cost for Optimal = ₦ 1.7526E+10					

In the same manner the existing transportation cost from depots to retailers for Product 1, Product 2, Product 3 and Product 4 are respectively ₦1.20111E+12, ₦3.11074E+11, ₦4.04872E+11 and ₦1.40896E+11 and the optimal costs are N8.23857E+11, N 2.12703E+11, N 2.65313E+11 and N9.75414E+10 respectively

C. The Company's Transportation Problem

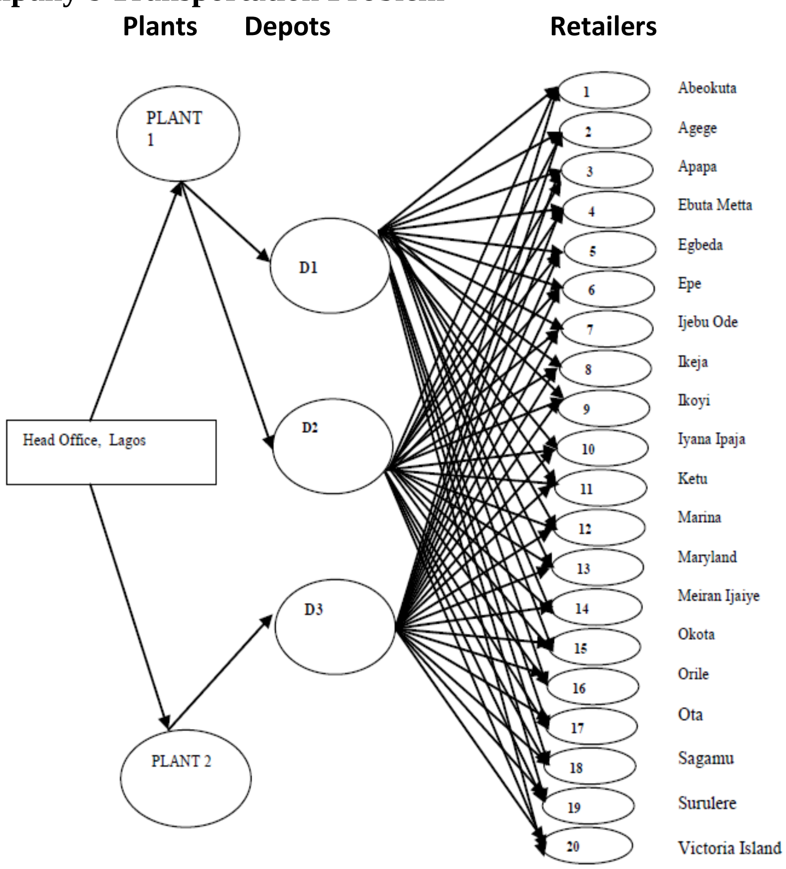

Fig. 1: The Company's Transportation Problem

d. Optimal Transportation Network for Truckload from Plants to Depots, Depots to Retailers

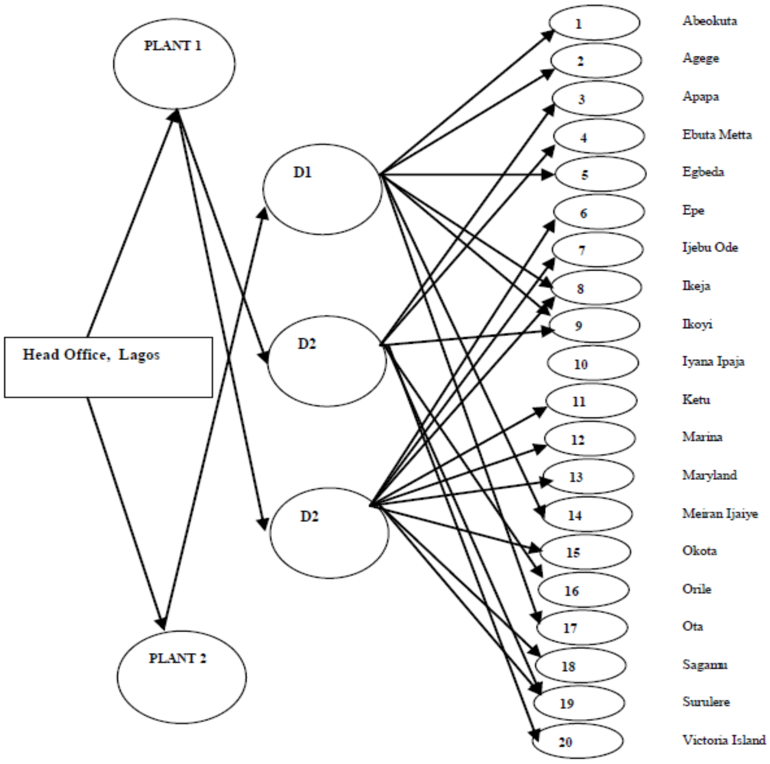

Fig. 2: Optimal Transportation Network of Truckload

e. Proposed Mono-Commodity Multi-Location Optimal Network for Product 1

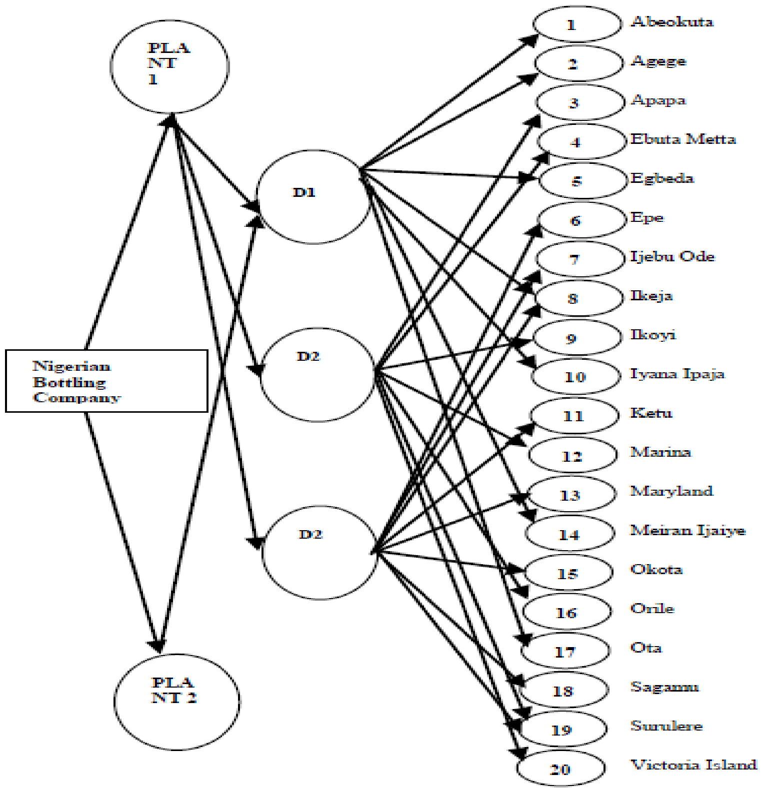

Fig. 3: Proposed Transportation Network for Product 1

f. Proposed Mono-Commodity Multi-Location Optimal Network for Product 2

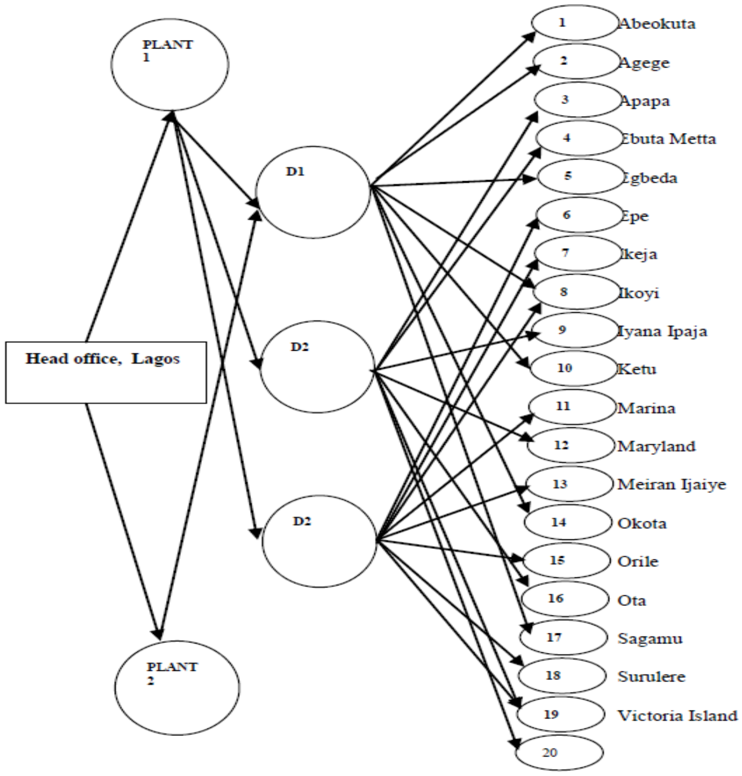

Fig. 4: Proposed Transportation Network for Product 2

g. Proposed Mono-Commodity Multi-Location Optimal Network for Product 3

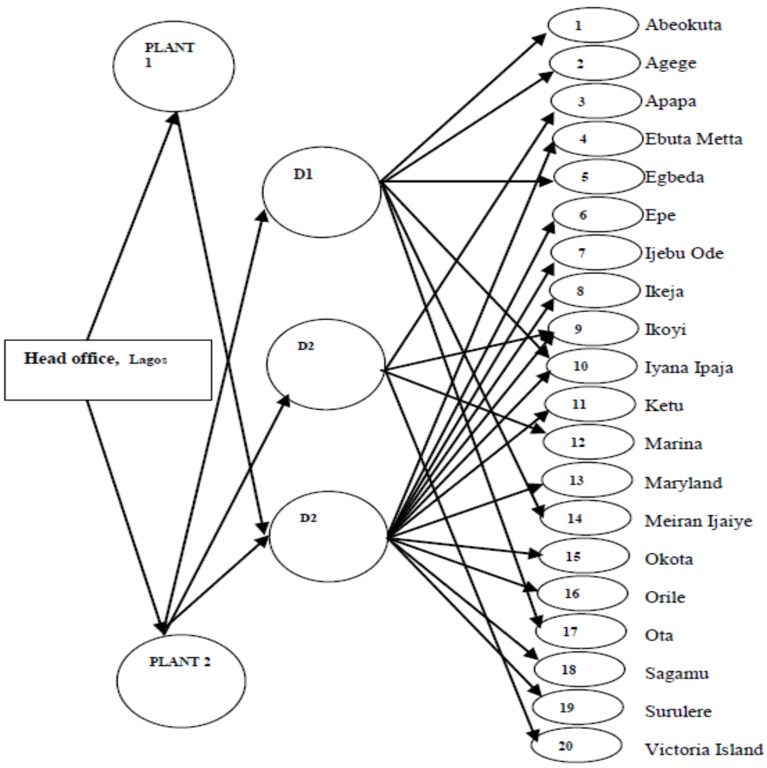

Fig. 5: Proposed Transportation Network for Product 3

h. Proposed Mono-Commodity Multi-Location Optimal Network for Product 4

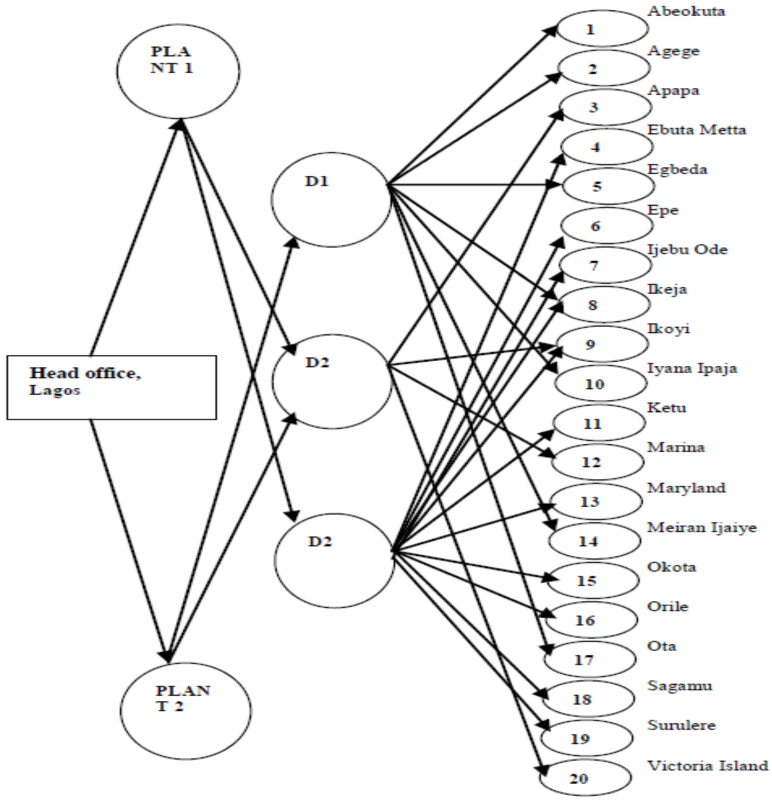

Fig. 6: Proposed Transportation Network for Product 4

CONCLUSION

The analysis to determine the optimal transportation network is carried out in two phases: The first phase is by optimizing the existing practice by taking into consideration the numbers of truckload transported from plants to depots and depots to retailers and secondly, by optimizing each of the product from plants to depots and depots to retailer. The two phases were evaluated using EXCEL software package. The total transportation cost of existing practices are estimated but far higher than the optimal results, hence it is realized that the best optimal transportation cost (minimal) is from Mono-Commodity Multi-Location Model with total transportation cost of ₦1,871,065,369,000 (One Trillion, Eight Hundred And Seventy One Billion, Sixty Five Billion And Three Hundred And Sixty Nine Thousand Naira Only) using EXCEL software and the least is optimizing taking into consideration the numbers of truckload with a total transportation cost of ₦1,932,650,000,000 (One Trillion, Nine Hundred And Thirty Two Billion And Six Hundred And Fifty Million Naira Only). Comparing the total optimal Mono-Commodity Multi-Location transportation cost to existing transportation cost of truckload ₦3,544,000,000,000 (Three Trillion, Five Hundred And Forty Four Billion Naira), the difference is ₦ 334, 586, 926,200 (Three Hundred and Thirty-Four Billion, Five Hundred and Eighty Six Million, Nine Hundred and Twenty Six Thousand, Two Hundred Naira Only) annually resulting to 47.2% additional profit.

It is pertinent to note that if the transportation network generated from the Mono-Commodity Multi-Location Model using EXCEL 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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