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Comparative Study of Algorithm Tools Used On Multi-Commodity Multi-Location Integrated Model for Manufacturing Industry

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ABSTRACT
In this paper, an attempt is made in determining the best optimization software suitable for solving transportation problem of a manufacturing industry producing different products that is transported to several locations. EXCEL, LINGO and TORA evaluating tools were used. It can be deduced that LINGO and TORA can accommodate more constraints than EXCEL and EXCEL can perform mathematical computations effectively than both. From the findings, it can be drawn that finished goods should be transported according to the routes that minimized the cost of transportation. Finally, the result obtained from the three algorithms were compared and the best software was chosen to propose a new transportation network for the company. Hence TORA is rated higher for optimization than LINGO and EXCEL because it saves more cost which invariably will increase the company's profit by 56.82 percent, enhance customer satisfaction, gives the company good image, competitive advantage and sustainability.

***Keywords* -** EXCEL, LINGO and TORA Software, Multi-Commodity Multi-Location Integrated Model, Transportation Cost, Transportation Model, Transportation Network.

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I. INTRODUCTION

Transport system modeling plays some parts in the development of transport policies and strategies. If models were more appropriate and were better applied, they would considerably enhance the formulation of transport policies and the development of strategies (Furnish and Wignall, 2009). 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. However, models can also be used to estimate other important impacts, such as fuel use, emissions, air pollution and casualties.

Optimum transportation system could be defined as "the art of combining the right amount of the right products, delivered to the right place at the right time". Nowadays, the success of a company depends on its efficiency in managing its transportation network.

Transportation network is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Transportation network exists in both service and manufacturing organizations. Realistic optimum transportation network have multiple end products with shared components, facilities and capacities (Ermis, et.al, 2004).

The efficiency of a supply chain is influenced by several factors such as; stock management, production planning, risk/hazard management, production costs, scheduling and distribution strategies and customer specific demand among others.

II. MODEL EVAUATION

Several authors have developed different optimization models in literature and different tools are used to evaluate the models. The tools include EXCEL, LINGO, LINDO, C.PLEX, GAMS etc.

Models evaluation is a key factor that gives the actual picture of decision to be taken by managers to enhance effectiveness, efficiency and or performance. For the purpose of this study, EXCEL, LINGO and TORA software are used

A. Model Evaluation Using Microsoft Excel Software

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 (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 (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 provide 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.

B. Model Evaluation Using Lingo Software

Anand, et al (2017) used LINGO program to solve aggregate planning problem of red tomato tools, a small manufacturer of gardening equipment with manufacturing facilities in Mexico red tomato's products are sold to retailers in the united states. Red tomato products consist of the assembly of purchased parts into multipurpose gardening tool. With the aid of the LINGO program the company was able to overcome the obstacle of seasonal demand and maximize profit

Rizwanullah, et al(2017), used a LINGO based three-tier distribution approach in modeling of supply chain dynamics and it was ascertained that not every optimization procedure is suitable for all supply chain models and it is necessary to choose the appropriate procedure depending on the features of supply chain. The model can be generalized for multi-complex problem if the system supports to run the program. There are many hidden parameters in heuristics method while in LINGO based method, no need to add any such variables and the solution becomes easier and applicable.

Woubante(2017), utilized LINGO 16.0 in the optimization problem of product mix in Apparel Industrial unit in Ethiopia. The data gathered was used to estimate the parameters of the linear programming model. The findings of the study show that the company can be improved by 59.84%.

Anand, et al(2018), applied LINGO software in solving supply chain location allocation in multiple stages and dedicated supply problem.

Location of plants and warehouse are taken into consideration. The problem was mathematically modeled and solved, it was discovered that LINGO software solved the problem faster and it is easier to apply.

Baohui and shiyang(2018), worked on application of LINGO in water resources optimization teaching based on Integer programming to improve the teaching quality of water resources optimization teaching and train students to master advanced and quick methods or techniques to solve the problems of integer programming of Engineering project due to problems Northwest China and North China is facing in terms of shortage of water resources for survival of human society, it was concluded that LINGO software is consistent, speedy and has a wide application space in solving water resources optimization problems. Also, it is beneficial to cultivate college student' innovative thinking and innovative consciousness.

Jibina and Lavanya(2019), worked on management of construction resources by using Integer and Dynamic programming with the aim of maximizing profit and allocation of limited resources in this project, the building raw material data was collected in the construction company. The construction schedule data was solved by Dynamic programming multi-stage graph method. The multi-stage graph problem which solve the shortest part and its minimum duration for each construction activity. So as it helps the construction project, each activity completed within duration period. The resource data was solved by Integer programming gomory's cut method and LINGO software program to enable management to know how profit will be affected by increase or decrease in resource level and change in cost of raw materials. In this types of changes analyzed and profit was calculated by use of Integer programming and LINGO software programs. The result was compared and each way of calculation was accessed. Finally, the profit was easily found by LINGO software.

C. Model Evaluation Using TORA Software

Farnalskiy (2006), used TORA software in solving transportation and forecasting problems of SMT Transport and Services Limited using real-life data, minimum cost of transportation flow and forecast for the company's future activities was achieved

Anieting et al (2013), utilized TORA software to determine optimum production capacity of Usmar Water Company using the company's real-life data and transforming it into a linear programming problem. The software was effective and fast

Chug et al(2018), formulate a transportation problem from data obtained from Shri Mahavir Agritech, a renowned supplier of wheat. TORA software was used to evaluate which resulted to customers satisfaction at a reduced cost.

Hosseinabad (2019), explored the use of TORA software in minimizing safety equipment cost in Lafarge Surma Cement Company. The company give much emphasis on the safety of the company's workers and that's why they wanted to allocate their safety equipment to their different branches at minimum costs. At the end transportation cost was minimized and expected demand met.

Aliyu et al (2019), utilized transportation models for cost minimization of goods transported from factories to warehouses. The data collected were modeled into a tableu which was solved with R-programming and TORA software version 1.0.0. to generate initial feasible solution and optimal solution

Bala et al(2020), worked on application of linear programming approach for determining optimum production cost. The mathematical formulation of the problem under consideration is performed by using a linear programming approach. An operation research software, TORA (Temporary Ordered Routing Algorithm) was used in solving the problem and analyzing the results. Results reveal that a specific schedule has impact on optimizing the production cost.

III. METHODOLOGY

A. 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 option 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.

B. Program And Steps Involved In Using LINGO software

```
SETS:
PLANTS/DEPOTS: SUP;
DEPOTS/RETAILERS: DEM;
LINKS(PLANTS/DEPOTS,
DEPOTS/RETAILERS): QTY, CST;
ENDSETS
DATA:
PLANTS/DEPOTS = P1 P2 P3 . .. . .PN/D1 D2 D3 .
. .. .DN;
DEPOTS/RETAILERS = D1 D2 D3 . . .. .DN/R1
R2 R3 . . . RN;
SUP = A_I/B_I;
DEM = B_J/R_J;
CST = C_IJ/B_IJ;
ENDDATA
MIN = @SUM(LINKS(I,J):CST(I,J)*QTY(I,J));
@FOR(PLANTS/DEPOTS(I):
  @SUM(DEPOTS/RETAILERS(J):QTY(I,J))<=
SUP(I));
@FOR(DEPOTS/RETAILERS(J):
  @SUM(PLANTS/DEPOTS(I):QTY(I,J))          =
DEM(J));
```

To operate the code for the optimization of the transportation model, you have to input the values of the transportation matrix in their respective positions

i.e input the name of the plants or depots at P1, P2 or D1, D2 an so on and also for depots or retailers at D1, D2 or R1, R2 and so on.

Then input the values of the supplies at SUP and demand at DEM. The cost of the commodity from plants to depots is typed at CST.

Then move to the LINGO ribbon and click solve. The result will be displayed.

C. Steps Involved In Using TORA SoftwareFor Optimization

Run the TORA software

From the pop-up menu, select transportation model

Select enter "new problem" and "scientific nD1tion", then click on the "go to input screen" option.

On the input screen, type the problem title, the number of sources and the number of destination then click enter.

A table is displayed with the number of sources and destinations required.

Type in the values of demand, supply and cost into the table in their respective positions

Click on the "solve" option.

Select solve problem then final solution

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

*D. **THE MODEL***

- ***Assumptions And Limitations***

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.

Limitations

1. The standard excel solver has a limit of **200** decision variables or changing cells for both linear and non-linear problems, therefore it is limited to only 200 constraints.
2. The TORA software usually result to Run-Time Error '9' (Sub-Script out of Range) if supply and demand is more than 6 digits

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

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

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

Subject to:

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

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

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

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

E. Total Transportation Cost Of Existing Transportation Network Considering Truckload(Plants to Depots)

TABLE 1
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**	

TABLE 2
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**	

TABLE 3
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 the same manner, the total transportation cost from depots to retailers is calculated ₦2,074,000,000,000. Therefore, the total transportation cost for existing network
= ₦1,470,000,000,000 + ₦2,074,000,000,000
= ₦3,544,000,000,000

TABLE 4
Optimal Result of Existing Transportation Network (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					

F. 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			

In the same vein, the Total transportation cost from depots to retailers is calculated = ₦ 2,057,950,000,000
The Total transportation cost of existing network using Multi-Commodity Multi-Location Model
= ₦1,427,080,000,000 + ₦2,057,950,000,000
=₦3,485,030,000,000

TABLE 8
Optimal result of multi commodity multi location integrated model 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					

In the same manner, the optimal result from depot to retailer is ₦1,077480,000,000 and the Total optimal cost using excel =₦472,000,000,000 + ₦1,077480,000,000 =
₦ 1,549,480,000,000

TABLE 9
Summary of Result

	EXISTING COST (₦) PLANTS TO DEPOT AND DEPOT TO RETAILERS	OPTIMAL COST (₦) EXCEL	OPTIMAL COST (₦) LINGO	OPTIMAL COST (₦) TORA
PLANT TO RETAILER OF TRUCKLOA	1,470,000,000,000 +2,074,000,000,000	502,070,000,000 +1,430,580,000,000	502,070,000,000 +1,430,580,000,000	502,070,000,000 +1,430,580,000,000
TOTAL	**3,544,000,000,000**	**1,932,650,000,000**	**1,932,650,000,000**	**1,932,650,000,000**
MULTI-COMMODITY MULTI-LOCATION INTEGRATED MODEL	1,427,080,000,000 + 2,057,950,000,000	472,000,000,000 + 1,077,480,000,000	472,000,000,000 +1,058,491,000,000	472,000,000,000 + 1,058,490,000,000
TOTAL	**3,485,030,000,000**	**1,549,480,000,000**	**1,530,491,000,000**	**1,530,490,000,000**

TABLE 10
Product Movement Recommended By Multi Commodity Multi Location Model Using The Three Software Package From Plants To Depots And Depots To Retailers

- **Plants To Depots**

	QUANTITIES SUPPLIED IN CASES		
Plant/Depots	D1	D2	D3
Plant 1 P1	5641824	43865302	49717446
Plant 1 P2	16066600	31381988	31423900
Plant 1 P3	0	0	31483642
Plant 1 P4	0	5583020	15839907
Plant 2 P1	49717446	0	0
Plant 2 P2	31423900	0	0
Plant 2 P3	15840130	15643512	419268
Plant 2 P4	13211800	2628107	0

- **Depots to Retailers**

			QUANTITIES SUPPLIED IN CASES		
S/N	DEPOTS/ PRODUCTS	RETAILERS SUPPLIED	EXCEL	LINGO	TORA
1	D1 P1	AGEGE EGBEDA MEIRAN OTA IYANA	19,993,766 5,372,857 9,996,883 9,998,881 9,996,883	19,993,766 15,369,740 9,996,883 9,998,881	19,993,766 15,369,740 9,996,883 9,998,881
2	D1 P2	ABEOKUTA KETU SAGAMU	39,987,532 7,502,968	39,987,532 7,502,968	39,987,532 7,502,968
3	D1 P3	EGBEDA IKEJA IYANA	14,620,909 1,219,221	4,624,426 1,219,221 9,996,883	4,624,426 1,219,221 9,996,883
4	D1 P4	IKEJA	13,211,800	13,211,800	13,211,800
5	D2 P1	APAPA EBUTE M MARINA ORILE SURULERE V–ISLAND	19,993,766 4,998,442 4,998,441 4,998,442 8,876,211	19,993,766 4,998,442 4,998,441 4,998,442 8,876,211	19,993,766 4,998,442 4,998,441 4,998,442 8,876,211
6	D2 P2	IKOYI V–ISLAND	255,765 31,126,223	9,131,976 22,250,012	9,131,976 22,250,012
7	D2 P3	V-ISLAND	15,643,512	15,643,512	15,643,512
8	D2 P4	V–ISLAND	8,211,127	8,211,127	8,211,127
9	D3 P1	IKEJA MARYLAND OKOTA SURULERE	3,610,801 4,998,442 41,108,203	 4,998,442 4,998,442 39,720,562	 4,998,442 44,719,004
10	D3 P2	ABEOKUTA EPE IJEBU-ODE IKOYI KETU MARYLAND SAGAMU	1,870,436 4,998,442 9,996,883 9,741,118 3,145,157 1,048,386 623,478	 4,998,442 9,996,883 864,907 5,566,786 9,996,882	 4,998,442 9,996,883 864,907 5,566,786 9,996,882
11	D3 P3	IKEJA	31,902,910	21,639,060	21,639,060

		SURULERE OKOTA		10,263,850	4,998,442 5,265,408
12	D3 P4	IKEJA KETU MARYLAND	39,683 10,533,483 8,989,259	13,914,336 1,925,571	13,914,336 1,925,571

IV. THE COMPANY'S TRANSPORTATION PROBLEM

The Manufacturing Company's transportation problem is as shown in figure 1 below

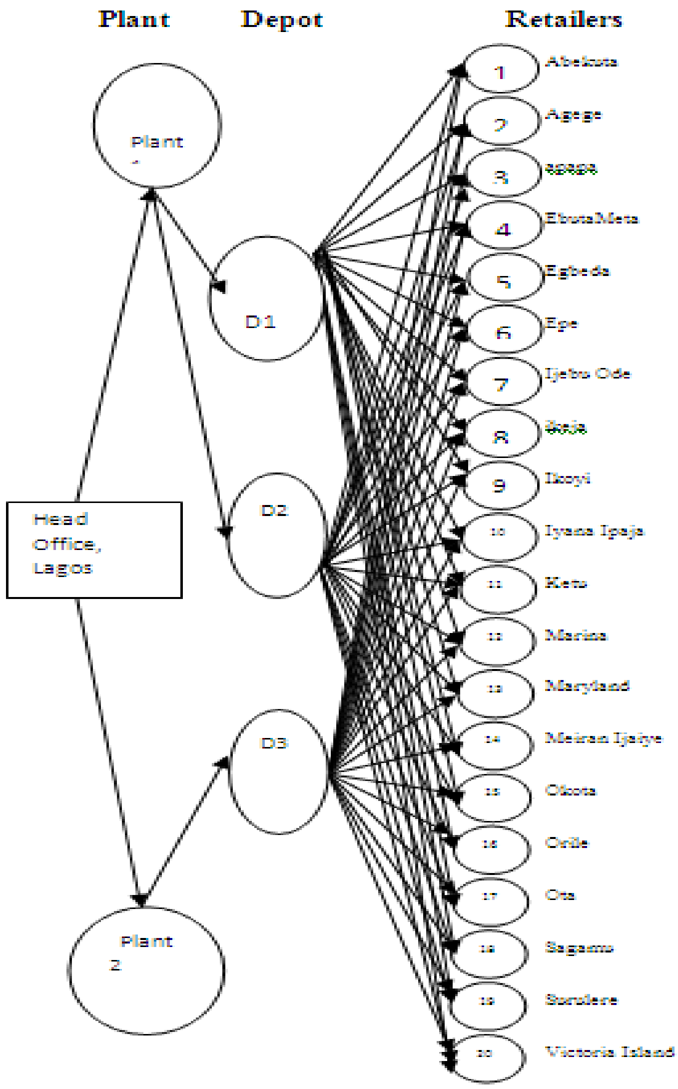

Fig 1: The Company's Transportation Problem

A. Optimal Transportation Network of the Manufacturing Company, Lagos (EXCEL) RETAILERS

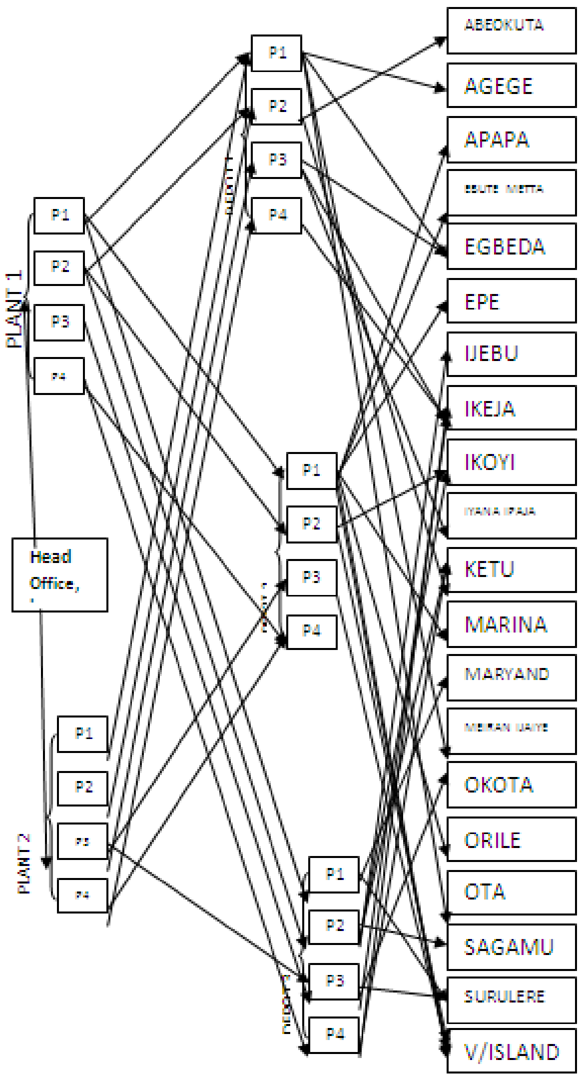

Fig 2: Optimal Transportation Network of the Manufacturing Company

B. Optimal Transportation Network of the Manufacturing Company, Lagos (LINGO) RETAILERS

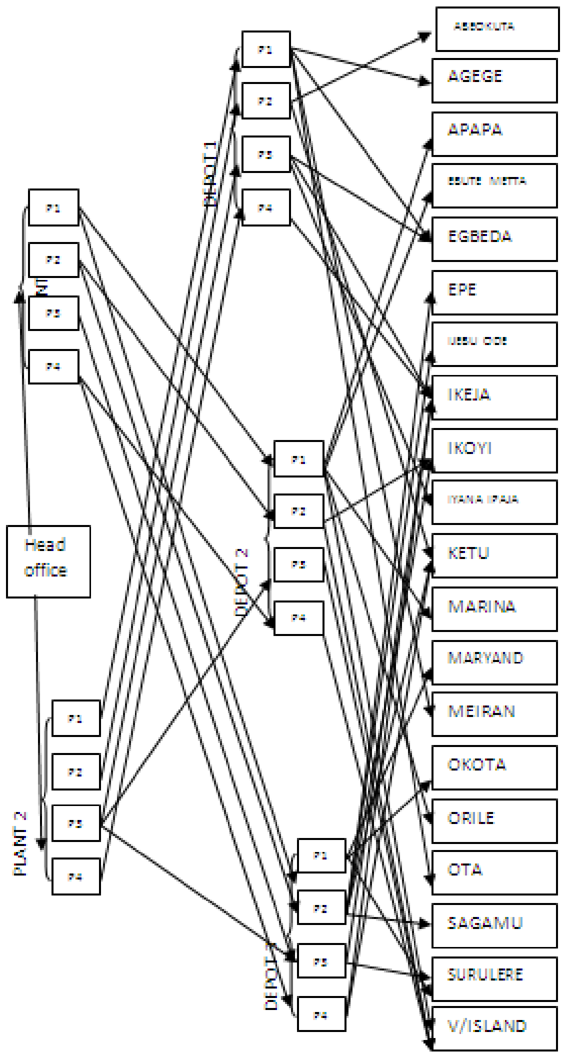

Fig 3: Optimal Transportation Network of the Manufacturing Company

C. Proposed Optimal Transportation Network of the Manufacturing Company, Lagos (TORA)

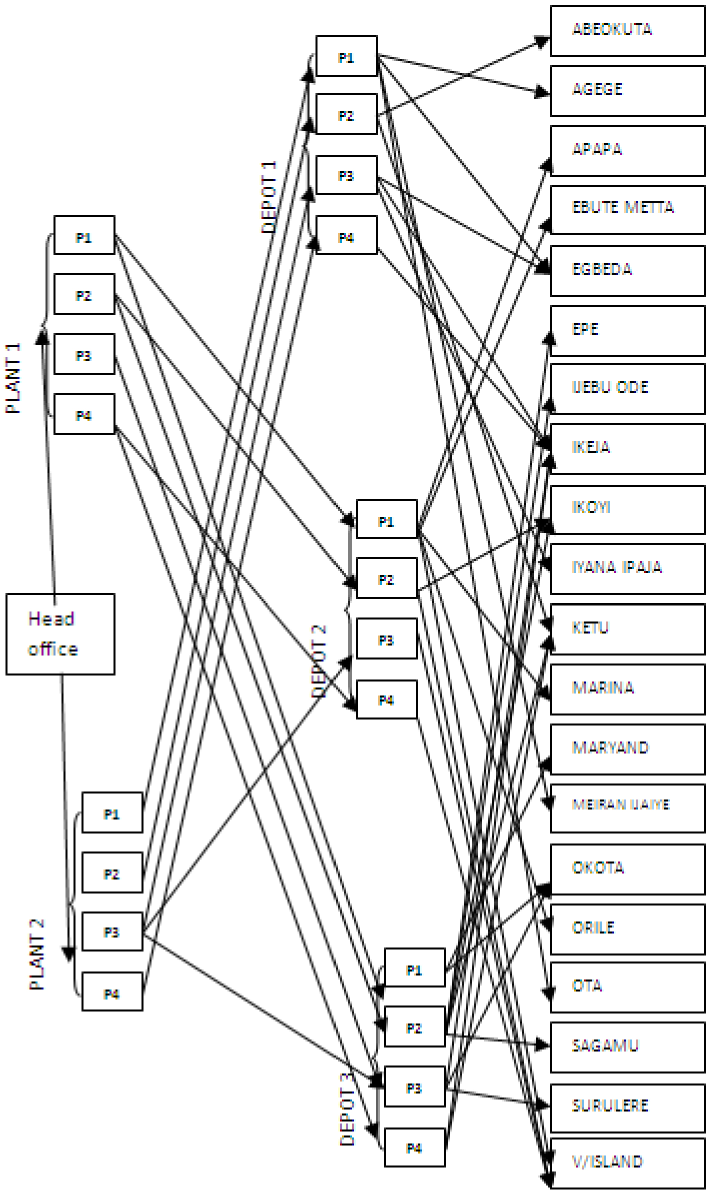

Fig 4: Optimal Transportation Network of NBC

II. CONCLUSION

From the findings and discussions above, it P3 be drawn from this study that finished goods should be transported according to the routes that minimized the cost of transportation using TORA software **.** It P3 be deduced that LINGO and TORA P3 accommodate more constraints than EXCEL and EXCEL P3 perform mathematical computations effectively than LINGO and TORA. TORA P3 be prompt to 'run time error 9'and always gives precise result, LINGO is very explicit and P3 accommodate over 200 constraints like TORA Hence TORA is rated higher for optimization than EXCEL and LINGO by virtue of result obtained.

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