Case Study On Transport Of Petroleum In Nigerian Cities

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***Abstract*— Every company in today's time intends to maximize their profits. As we are in a fast-growing world, the need for products has increased drastically. Price of products depends on majorly two things, the cost of production (including transportation costs) and profit margins. Transportation problems are used to either minimize transportation cost or to maximize profits on shipping commodities. In this paper, we focus on how to minimize transportation cost while fulfilling the supply and demand conditions.**

The problem taken by us contain 3 sources and 3 destinations based in Nigeria and the Cost matrix was converted from Nigerian currency (Naira) to Dollars (conversion done according to rates on 15th October, 2022) for ease of calculation. Using Vogel's Approximation Method (VAM), Least Cost Method (LCM) and the North-West Corner Method (NWCM), we found that VAM was the most optimal. Self-written Python codes were used to verify the manual solutions. The unavailable or forbidden routes have also been considered in the code. The output displayed the allocations for the 3x3 matrix, and printed the total cost. After this, MS-Excel and Excel-QM software were used for verification. We found that VAM is 25.11 percent better than the LCM and 52.65 percent better than the NWCM for this problem. In every enterprise, generating higher revenue remains one of the most essential objectives. If codes for such methods are made universally available, enterprises would benefit highly. Use of transportation problems for optimal solutions have great potential, if one has knowledge about them.

***Keywords*: Transportation problem, Vogel's Approximation Method, Least Cost Method, North-West Corner Method, Python.**

I. INTRODUCTION

In a rapidly advancing world as ours, each company sees the potential to make achieve success. A lot of factors affect the growth of the company. Factors such as transportation cost, production cost, profit margin and other miscellaneous costs define the cost of the product. In operations research, multiple methods have been derived to help manage these factors. It was originally researched by F.L. Hitchcock and T.C. Koopmans in 1941 and 1947 respectively and Dantzig in 1951 who used the simplex approach to solve it within the context of linear programming, as evidenced by the study of Muhammad K.H. in 2012. Since then, numerous researchers have refined the processes and created fresh solutions, demonstrating how the application is continually developing. In addition, several techniques have been developed to identify the best option. The LCM, VAM, and other techniques are included in the transportation model. For the VAM, optimality is checked using Modified Distribution (MODI) method [1, 2]. There are two alternative objectives in transportation problems, one being to minimize transportation cost and the other includes maximizing profits on shipping commodities. Also, the transportation problem's Initial Basic Feasible Solution (IBFS) can be computed using the South-East Corner Method (SECM)and North-East Corner Method (NECM). In a study, SECM technique was derived and then it was demonstrated that the NECM, SWCM, and SECM all lead to the same answer [3]. A study was presented showing SECM and NECM were better than earlier methods, for which a lot of transportation problems were solved [4]. Modified Average Transportation Cost (MATC) was developed in 2018, in which the penalty was determined by the average lowest value for each row and column. The Total Opportunity cost matrix was used and the penalty cost has been calculated. Then, to reduce the computational complexity, allocate it to the minimum cost cell that corresponds to the greatest penalty cost, avoiding computing the penalty cost for each allocation. [5, 6, 7]. In the paper by Anubhav and Dharm, a two-step exact algorithm, working for both balanced and unbalanced problems, was derived using the basic idea of Least Cost Cell as well as modified distribution method [8]. Even in the VAM some errors were considered and developments were made and 'Advanced Vogel Approximation Method' (AVAM) was developed [9]. In another study, a multi-objective approach for a two-stage fixed charge transportation planning problem was investigated. The capacity of the distributors, the demand of the clients, and the availability at the production facilities are all thought of as fuzzy numbers [10, 11]. Transportation problems have multiple uses, for multiple products. For example, a case study was done in to see how transport cost could be minimum for Maisango Cement Plc [12] and Dangote cement factory, in Nigeria [13]. In 2021, research was done using VAM to find the most suitable system for a program "rice for a prosperous people" (RASTRA) [14]. VAM and MODI method was also used for a case study for MITCO Labuan Company Limited (MLCL) in Malaysia [15] and for an oil transport in Saudi Arabia [16].

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In our paper, we focus on how to minimize transportation cost while fulfilling the supply and demand conditions. We studied the distribution of petroleum products between 3 sources and 3 destinations based in Nigeria.

II. Methodology

The problem taken by us contains 3 sources and 3 destinations based in Nigeria. Each source contains a certain amount of petroleum product (supply) and each destination requires a certain amount of product (demand). The matrix used in the calculations was made from a paper that showed transport cost for locations in Nigeria [17]. For forbidden routes, penalty costs were considered [17]. Cost matrix was converted from Nigerian currency (Naira) to Dollars (conversion done according to rates on 15th October, 2022) for ease of calculation. Minimizing distribution cost was the main objective. Using these three methods -VAM, LCM and NWCM the most efficient one was derived. Other than this, optimality of the solution for VAM was verified. Self-written Python codes were used to verify the manual solutions. After this, MS-Excel and Excel-QM software were used for verification. Excel-QM helps in using Excel Sheets to solve problems in management sciences, operation research, etc.

A. MS-Excel Calculations

The formulated matrix is created in MS-Excel. The cost matrix is created separately and all the formulas are applied to the appropriate cells. The Solver function in MS-Excel is used to find the optimal solution for the matrix. The result cell is selected and all the constraints are added. Simplex LP method is used to solve the above transportation problem. The total cost is displayed in the objective cell.

B. Excel-QM Calculations

The data for the transportation problem is selected. Then the sources and destinations are selected to generate a matrix. Transportation cost per unit as well as the demands and supplies for each source and destination respectively are selected. The suitable method for solving the transportation problem is chosen and the output is generated which consists of the allocations as well as the total cost for optimal transportation.

C. Calculation through Python code

On Python, codes for all three methods discussed above were made for further confirmation and ease of calculating the optimal solution for the transportation problem. For LCM and NWCM, the NumPy library was used and for VAM, dictionaries were used. The unavailable or forbidden routes have also been considered in the code. The output displayed the allocations for the 3x3 matrix, and printed the total cost. All the total costs that were received by the code matched the cost obtained in the section above.
Both Ms-Excel and Excel-QM were used to further verify the total costs and allocation by the Python code.

III. Cost Matrix

TABLE I
Demand And Supply Values
(in 1000s of litres) In Nigerian
Currency

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	151673	186598	19957	=	261
JOS	84019	-	47498	=	155
MAIDUGURI	122536	-	-	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

Source: [17]

TABLE II
Demand And Supply Values
(in 1000s of litres) In Dollars

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	349	429	46	=	261
JOS	193	-	109	=	155
MAIDUGURI	282	-	-	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

If petroleum is supplied through a forbidden route penalty costs will be applicable to supplier. Considering these cost the final demand and supply table is created, and can be seen in Table III.

TABLE III
Demand And Supply Values
(in 1000s of litres) In Dollars
Including the Penalty Costs

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	349	429	46	=	261
JOS	193	195	109	=	155
MAIDUGURI	282	400	400	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

Source: [17]

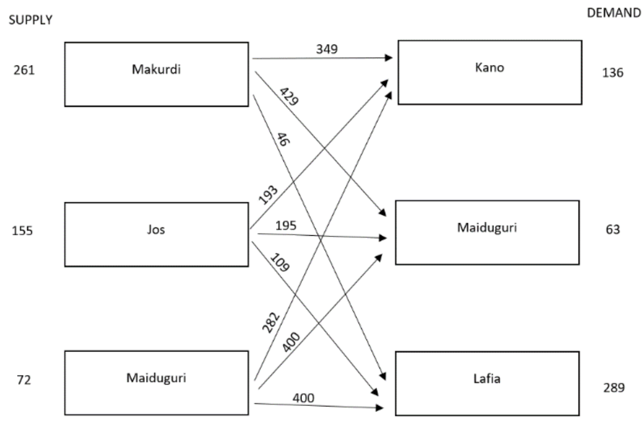


Fig. 1. The cost allocation between sources and destinations (in Dollars)

Fig 1. depicts the cost (in Dollars) for transportations of petroleum from each supply source to all the possible demand source. The columns on the side show the demand and supply for each source.

IV. Findings and Analysis

A. *Least Cost Method (LCM)*

First, we select the least cost in the entire table and allocate the supply. If the supply gets exhausted, we ignore the row. If the demand gets exhausted, we ignore the column. We then move to the next lowest cost and allocate the supply. These steps are repeated until all allocations are made and the demand and supply get exhausted.

TABLE IV
Allocations According to
LCM

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	-	-	261	=	261
JOS	127	-	28	=	155
MAIDUGURI	9	63	-	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

According to Table IV. we see that for a cost of 46 dollars- 2,61,000 litres, 193 dollars- 1,27,000 litres, 109 dollars- 28,000 litres, 282 dollars- 9,000 and for 400 dollars- 63,000 litres have been allocated.
Hence, the cost obtained with LCM is: **$6,73,07,000**

B. *North-West Corner Method (NWCM)*

First, we select the cell in the north west corner, then we allocate the supply to it. If the supply gets exhausted, we ignore the entire row. If the demand gets exhausted, we ignore the entire column. We then move to the next north west corner cell for allocation. Repeat the process until all allocations are made and demand and supply get exhausted.

TABLE V
Allocations According to
NWCM

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	136	63	62	=	261
JOS	-	-	155	=	155
MAIDUGURI	-	-	72	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

According to Table V. we see that for a cost of 349 dollars- 1,36,000 litres, 429 dollars- 63,000 litres, 46 dollars- 62,000 litres, 109 dollars- 1,55,000 and for 400 dollars- 72,000 litres have been allocated.

Hence, the cost obtained with NWCM is: **$12,30,38,000**

C. *Vogel's Approximation Method (VAM)*

We first find the row as well as column penalties by subtracting the lowest costs in the rows and columns respectively. We then find the maximum penalty. If it is a row penalty, we select the cell in that row which has the lowest cost. /If it is a column penalty, we select the cell in that column which has the lowest cost. Allocate supply to that selected cell. If the supply gets exhausted then we ignore the entire row. If the demand gets exhausted, we ignore the entire column. We again find the row as well as column penalties and go on until demand and supply get exhausted.

TABLE VI
Allocations According to
VAM

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY
MAKURDI	-	-	261	=	261
JOS	64	63	28	=	155
MAIDUGURI	72	-	-	=	72
CONSTRAINTS	=	=	=		
DEMAND	136	63	289		

According to Table VI. we see that for a cost of 46 dollars- 2,61,000 litres, 193 dollars- 64,000 litres, 195 dollars- 63,000 litres, 109 dollars- 28,000 litres, and for 282 dollars- 72,000 litres have been allocated.

Hence the obtained cost with VAM is: **$5,99,99,000**

After this, we proceeded for an optimality check.

TABLE VII
Optimality Check on VAM Solution

	KANO	MAIDUGURI	LAFIA	CONSTRAINTS	SUPPLY	u_i
MAKURDI	[219]	[297]	261	=	261	u_1=-63
JOS	64	63	28	=	155	u_2=0
MAIDUGURI	72	[116]	[202]	=	72	u_3=89
CONSTRAINTS	=	=	=			
DEMAND	136	63	289			
v_j	v_1=193	v_2=195	v_3=109			

In Table VII, all underlined values are the Δ_{ij} values where $\Delta_{ij} = c_{ij}-(u_i+v_j)$, c_{ij} being cost of that cell. This is the optimal solution as all Δ_{ij} values are greater than zero.
Hence the cost obtained with VAM is: **$5,99,99,000**
Fig 2. shows distribution of petroleum after optimality check on VAM solution

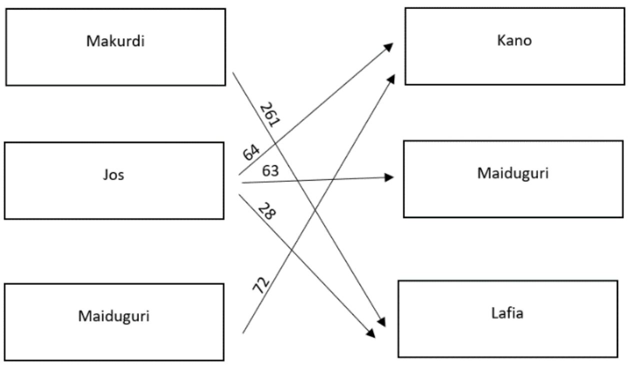
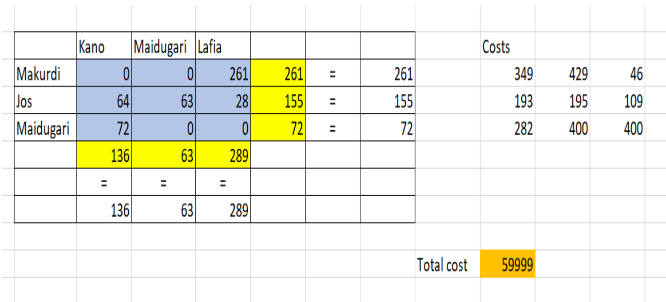


Fig. 2. Allocations according to VAM after optimality check

This solution was also verified by using MS Excel.



	Kano	Maidugari	Lafia					Costs		
Makurdi	0	0	261	261	=	261		349	429	46
Jos	64	63	28	155	=	155		193	195	109
Maidugari	72	0	0	72	=	72		282	400	400
	136	63	289							
	=	=	=							
	136	63	289							
							Total cost	59999		

Fig. 3. Verification of VAM allocation on MS Excel

In Fig 3. the blue cells are the variable cells, where the optimal distribution according to the VAM method is represented. The yellow cell represents the constraints applied to that supply or demand source, and the orange cell shows the total optimal cost for the assignment in the blue matrix. We can observe that the total cost for the manual and Excel calculations are the same, hence confirms that solution is optimal.

V. CONCLUSION

To conclude, Costs by various methods are:

1. LCM - $6,73,07,000
2. NWCM - $12,30,38,000
3. VAM - $5,99,99,000

By this, it is evident that VAM is the most optimal method to obtain the objective i.e., minimum cost of distribution. Thus, VAM is 10.85% better than the LCM and 51.23% than the NWCM.
The above study confirms our problem statement that VAM was the most optimal. The Python code developed can be used for further study of such transportation problems. For a larger matrix, users require an understanding of Python to make necessary modifications. The primary objective of the study was to find ways to reduce the expense of transporting petroleum products between locations inside Nigeria, both as sources and as destinations. The current finding shows potential for the company to reduce the costs, and hence increase their profits. In every enterprise, generating higher revenue remains one of the most essential objectives. If codes for such methods are made universally available, enterprises would benefit highly. It could open multiple transportation avenues, helping the companies to grow further. Furthermore, consumer needs will also be satisfied in optimal ways. Use of transportation problems for optimal solutions have great potential, if one has knowledge about them.

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