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Transportation Model : Review of Its Practical Application in Kogi State, Nigeria

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ABSTRACT

The transportation model is a linear programming model targeting at minimization of transportation cost for any firm. However, it is critical to examine how effective it can be applied to enable firms pursue its immediate and strategic objectives. This study on transportation model is carried out to examine the practical application of transportation model in Otebu Investment limited Idah, Kogi State. The study was induced by the curiosity to ascertain the extent in which the transportation model as a branch of linear programming model is being applied by the firm and how this model has been able to enhance the performance through cost minimization. The study empirically reached both the Management, senior and junior employees of the enterprise through field descriptive survey research and finding revealed that the application of transportation model of linear programming have been able to enhance the performance of the firm hence considering the fact that there is a link between cost minimization and revenue drive of the Firms this model should be consistently adopted so as to be able to continuously minimize transportation cost.

INTRODUCTION

Transportation model was first formulated as a special procedure for finding the minimum cost for the distribution of homogenous units of a product from several points of supply (sources) to a number of points of demand (destination) (Hilda,2009, Srivastava etal, 2011 Igbomereho, 2013, Edokpia, Amiolemhen, 2016 ; Dharmendra, Saurabh, 2017).

The objective of transportation model is to schedule shipments from sources to destinations in such a way as to reduce the total cost of transportation. The earliest formulation of this basic transportation problem was stated by F.I. Hitch cook in 1941 and later expanded by T.C. Koopman. The linear programming formulation was first given by G.B. Dantzig in 1953, W.W. Cooper and Charnes, A. developed the special stepping – stone method, a special purpose algorithm for solving the transportation problem. Subsequent improvements led to the computations of easier modified distribution (MOD I) method in 1955 (Barde, 2013, Nazma, et al, 2014, Umar, Ibrahim, 2016, Lakhveer, et al, 2018, Monye, Eruteya, 2018). This study therefore examines how transportation model is practically applied by Firms in Kogi state with a particular reference to Otebu Investment Limited Idah, Kogi State.

Otebu Investment limited specializes in the production of fish in Idah Local Government Area of Kogi State. The enterprise has several depots located in strategic areas where the product is produced before shipment to their customers located within and outside the environs. Considering the fact that the cooperative has strive over the years in terms of producing quality fishes for household and industrial consumption it has attracted patronage over the years. The business has its depots located in Idah, Onyedega, and Ogbogbo where it ships products to customers across other locations such as Ajaokuta, Itobe, Ochadamu and Anyigba. The enterprise has membership ranging between two hundred to three hundred spanning across the local government area. The business has management committee charged with the responsibility of running the day to day business activities targeted at meeting its member's welfare drive as well as meeting the economic and social objective of its members cum other stakeholders such as the customers, suppliers, society and the government. In achieving this objective, the enterprise ensures that it meet up with adequate economic returns on its investment as well as making sure that cost(s) especially transportation cost is minimized.

METHODOLOGY

The methods of solving transportation model are:

1. The north west corner rule
2. The least cost method
3. Vogels approximation method

More so, to obtain optimal solution the following approach can be applied.

i. The stepping stone method
ii. The modified distribution (MODI) method

Though from my interaction with Management of the Firm it was revealed that they adopt the Vogels' approximation method, this illustration will demonstrate other transportation methods to justify the choice of this method.

RESEARCH RESULT AND DISCUSSION

The researcher approach the management of the factories at their respective locations and they were engaged in discussions which borders on production costs, cost of raw materials, logistics/communication, profit after tax. This is to enable me deduced the transportation costs of the product from each factories to respective locations.

The period covered in conducting this exercise is two weeks. This is to enable me ascertain the accuracy of information obtained. The data generated is shown thus:

Idah factory produces 480 cartons every 2 weeks and the cost of shipping one carton is obtained as:

Cost of raw materials	₦3920
Logistics/communications	₦1500
Maintenance of premises	₦300
Tax	₦200
Selling price	₦7500
Profit after tax	₦1500

To get transportation cost we add all the cost and also add the profit after tax less from selling price

(a) Hence, Idah to Ajaokuta

= ₦3,920 + ₦1500 + ₦300 + ₦200 + ₦1500 = ₦7420

:Selling price – ₦7420

= ₦7500 – ₦7420 = ₦80

(b) From Idah to Itobe

We have the following breakdown;

Cost of raw material	₦3920
Logistics/ communication	₦1500
Maintenance of premises	₦300
Tax	₦200
Selling price	₦7500
Profit after tax	₦1470

Total accumulated expenses ; ₦3920 + ₦1500 + ₦300 + ₦200 + ₦1470 = ₦7390

Transportation cost = ₦7500 – ₦7390 = ₦110

(c) For Idah to Ochadamu

We have the following breakdown

Cost of raw material	₦3920
Logistics/communications	₦1500
Maintenance of premises	₦300
Tax	₦200

Selling price ₦7500
Profit after tax ₦1490
Total accumulated expenses, ₦3920 + ₦1500 + ₦300 + ₦200 + ₦1490 = ₦7410
Transportation cost = ₦7500 – ₦7410 = ₦90

(d) From Idah to Anyigba
We have the following breakdown;

Cost of raw materials		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1520
=	₦7440	
Selling price	₦7440	
Total accumulated expenses =		₦60

(e) For Onyedega to Ajaokuta
We have the following breakdown;

Cost of raw material		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1510
=	₦7430	
Selling price	₦7430	

= ₦7500 – ₦7430 = ₦70

(f) For Onyedega to Itobe
We have the following breakdown;

Cost of raw materials		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1530
Total =	₦7450	

Transportation cost = ₦7500 – ₦7450 = ₦50

(g) For Onyedega to Ochadamu
We have the following breakdown

Cost of raw material		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1480
Total accumulated expenses =		₦7400

Transportation cost = ₦7500 – ₦7400 = ₦100

(h) Hence, Onyedega to Anyigba

We have the following breakdown

Cost of raw material		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1540

Total accumulated expenses = ₦5920 + profit after tax ₦1540 = ₦7460

Transportation cost = ₦7500 – ₦7460 = ₦40

= ₦3,920 + ₦1500 + ₦300 + ₦200 + ₦1500 = ₦7420

:. Selling price – ₦7420

= ₦7500 – ₦7420 = ₦80

(i) For Ogbogbo to Ajaokuta

We have the following breakdown

Cost of raw material		₦3920
Logistics/communications	₦1500	
Maintenance of premises	₦300	
Tax	₦200	
Selling price	₦7500	
Profit after tax		₦1540

Total accumulated expenses = ₦5920 + profit after tax ₦1540 = ₦7460

Transportation cost = ₦7500 – ₦7460 = ₦40

(j) For Ogbogbo to Itobe

We have the following breakdown;

Cost of raw material			₦3920
Logistics/communications		₦1500	
Maintenance of premises		₦300	
Tax		₦200	
Selling price		₦7500	
Profit after tax			₦1510
	=	₦7430	
Selling price		₦7430	

= ₦7500 – ₦7430 = ₦70

(k) From Ogbogbo to Ochadamu

We have the following breakdown;

Cost of raw materials			₦3920
Logistics/communications		₦1500	
Maintenance of premises		₦300	
Tax		₦200	
Selling price		₦7500	
Profit after tax			₦1520
	=	₦7440	
Selling price		₦7440	
	=	₦60	

(l) For Ogbogbo to Anyigba

We have the following breakdown

Cost of raw material	₦3920
Logistics/communications	₦1500
Maintenance of premises	₦300
Tax	₦200
Selling price	₦7500
Profit after tax	₦1490

Hence, ₦3920 + ₦1500 + ₦300 + ₦200 + ₦1490 = ₦7410

Transportation cost = ₦7500 – ₦7410 = ₦90

Illustration: Otebu investment limited moves it products between three depots and four destinations. Ajaokuta requires 300 products, Itobe requires 300, Ocahdamu requires 360 while Anyigba requires 540. The depots located in Idah, Onyedega and Ogbogbo can supply 480, 600 and 420 respectively. The following gives cost information regarding shipment of the products from sources to destinations.

Table 1. Cost Information Regarding Shipment of the Products From Sources to Destinations

To / From	Ajaokuta	Itobe	Ochadamu	Anyigaba
Idah	N80	N110	N90	N60
Onyedega	N70	N50	N100	N80
Ogbogbo	N40	N70	N60	N90

Your are required to:

i. Set up the transportation table

ii. Determine an initial basic feasible solution using
   a. The North west corner rule
   b. The least cost method
   c. Vogels approximation method

iii. Obtain the optimal solution using:
   a. The stepping stone method
   b. The MODI method

Solutions

1. Setting up the transportation table

To / From	Ajaokuta	Itobe	Ochadamu	Anyigba	Total Capacity
Idah	80	110	90	60	480
Onyedega	70	50	100	80	600
Ogbogbo	40	70	60	90	420
Total requirements	300	300	360	540	1500 / 1500

From the above table we can deduced that each square is called a cell while the total number of rows and columns in this situation, it is 3 rows and 4 columns is referred to as RIM requirements which is 3 + 4 = 7.

Next we develop an initial basic solution using the North west corner rule.

The method requires you to start at the upper left hand corner (North west corner) of the table, allocate supply optimally before moving to the next row and column respectively. This implies that each row must be supplied before moving to the next square. The moment allocations are completed verify to ensure that all the RIM requirements have been satisfied then calculate the total cost of this initial allocation.

Table 2: North West Corner Rule

To From	Ajaokuta	Itobe	Ochadamu	Anyigba	Total Capacity
Idah	80 +	110	90	60 _480	480
Onyedega	70	50 300	100 240-	80 +60	600
Ogbogbo	- 40 300	70	60 +120	90	420
Total requirements	300	300	360	540	1500 1500

The total cost of this initial solution is given thus:

Idah to Ajaokuta = N80 x 300 = N24,000
Idah to Itobe = N110 x 180 = 19,800
Onyedega to Itobe = N50 X 120 = N18,000
Onyedega to Ochadamu = N100 x 360 = N36,000
Onyedega to Anyigba = N80 x 120 = N9,600
Ogbogo to Anyigba = N90 x 420 = 37,800
Total = N145,200

Note that for a solution to be termed feasible all rim requirements must be satisfied. This means that for any basic feasible solution the number of used squares must be equal to the total Rim requirements minus one. That is, if M = number of rows, n = number of columns, Rim requirements = m + n – 1

b. The least cost method.

The least cost method requires an allocation to be made to the cell whose transport cost per unit is the lowest. However, in a situation where there is tie in cost, there will be need to applied personal judgment in making an allocation. Example is given below:

Table 3: The least Cost Method

To / From	Ajaokuta	Itobe	Ochadamu	Anyigba	Total Capacity
Idah	80	110	90	60 480	480
Onyedega	70	50 300	100 240	80 60	600
Ogbogbo	40 300	70	60 120	90	420
Total requirements	300	300	360	540	1500 1500

Total cost of this solution:
Idah to Anyigba = N60 x 480 = N28,800
Onyedega to Itobe = N50 x 300 =N15,000
Onyedega to Ochadamu = N100 x 240 = N24,000
Onyedega to Anyigba = N80 x 60 = N4,800
Ogbogbo to Ajaokuta = N40 x 300 = N12,000
Ogbogbo to Ochadamu = N60 x 120 = N7,200
Total = **N91,800**

From the least cost method it shown that the rim requirements have now been satisfied and the initial solution shows a lower cost as compared to the North-west corner rule method because in North-west corner rule allocations are made without considering price. The number of occupied cells is six which conforms with the rim requirement of m + n – 1 which fulfilled a feasible solution.

c. The vogels approximation method (VAM)

This method is like the least cost method because in making allocation the least costs are considered but it provides an initial solution that is very often the optimal solution. Note that the firms adopt this method hence this shall be our focus.

Steps in Determining an Initial VAM Solution are Given thus:

1. Consider each row of the transportation table and find the difference between the two lowest cost cells. You are also required to repeat same processes for the columns. The new values represent the difference between the transportation costs on the best route.

2. Identify the row or column with the largest difference in cost.
3. Allocate as many units as possible to the cell with the minimum cost in the row or column selected paying attention to the demand availability corresponding to the cell.
4. Erase the column or column that has been completely satisfied by allocation by crossing out each appropriate square with on x.
5. Recompute the cost difference for the transportation table avoiding any row or column crossed out in the previous step.
6. Return to step 2 and repeat the steps until all the supplies have been exhausted and the requirements satisfied.

Total cost for this solution		
Idah to Anyigaba = N60 x 480	=	N28,800
Onyedega to Ajaokuta = N70 x 240	=	N16,800
Onyedega to Itobe = N50 x 300	=	N15,000
Onyedega to Anyigba = N80 x 60	=	N4,800
Ogbogbo to Ajaokuta = N40 x 60	=	N2,400
Ogbogbo to Ocahdamu = N40 x 360	=	N21,600
Total cost	**=**	**N89,400**

Note that in calculating the cost in each iteration the two least costs are subtracted for both rows and columns respectively and the highest costs within the rows and columns are considered by taking the lowest cost from either before making allocation. The process continues until all allocation are exhausted.

Test of Optimality for Initial Solutions

The two procedures for testing optimality are given thus;

a. The stepping stone method
b. The Modified Distribution (MODI) method
c.

The Stepping Stone Method

The stepping stone method entails evaluating the unused square through the following technique.

i. Choose the unused square to be evaluated
ii. Starting with the unused square selected, trace a closed loop, (moving horizontally or vertically only) from that square through stone square back to the original unused square.
iii. Allocate plus and minus signs alternatively at each corner square of the closed path beginning with a plus sign at the unused square being evaluated.
iv. Determine the net changes in cost resulting from changes made when tracing the closed loop. The net increase in cost is obtained by summing the unit cost in each square with a positive sign while the net decrease in cost is accomplished by summing the unit cost in each square with a negative sign.

v. Repeat steps (i) to (iv) for each unused square till the improvement indices for all unused squares have been determined. If the indices are greater than or equal zero then it can be said that an optimal solution has been accomplished.

To From	Ajaokuta	Itobe	Ochadamu	Anyigba	Total Capacity
Idah	80 +	110	90	60 _480	480
Onyedega	70	50 300	100 240-	80 +60	600
Ogbogbo	- 40 300	70	60 +120	90	420
Total requirements	300	300	360	540	1500 1500

The unused cells are Idah-Ajaokuta, Idah-Itobe, Idah-Ochadamu, Onyedega-Ajokuta, Ogbog-Itobe and Ogbogbo-Anyigba

Unused cell index	Closed loop	Improvement
Idah - Ajaokuta	IA – OA + OO – OO^b + DA^b – IA^b 80 – 40 + 60 – 100 + 80 – 60 = 20	
Idah - Itobe	II – OI + OA – IA 110 – 50 + 80 – 60 = 80	
Idah - Onyedega	IO – OO + OI – II 90 – 100 + 80 – 60 = 10	
Onyedega - Ajaokuta	OA – OA + OO – OI 70 – 40 + 60 – 100 = -10	
Ogbogbo - Itobe	OI – OI + OO – OO 70 – 50 + 100 – 60 = 60	
Ogbogbo - Anyigba	OA – OA + OO – OO 90 – 80 + 100 – 60 = 50	

The improvement indices for all the unused squares have been found. They are not all ≥ cell OA has an improvement index of -10. If several cells had a negative improvement index, we shall select the entire cell (route) with the largest negative improvement index.

Developing an improved solution using the stepping stone method. From the calculation it has been discovered that cell Onyedega to Ajaokuta (OA) as one which will reduce total cost transportation cost further. Hence, we are then faced with the problem of finding out how many items can be assigned to the cells meaning from source Onyedega to source Ajaokuta without violating the rim requirement. Therefore, there is need to reconstruct the closed path traced when evaluating Onyedega-Ajaokuta (OA)

OA 70 +	OI 50	OO 100 240 -
OA 40 - 300	OI 70	OO 60 120 +

To find the maximum we can transport from Onyedega to Ajaokuta, we determine the smallest quantity in a negative corner on the closed loop. This occurs at the cell OO which has an allocation of 240. To ascertain our new allocation, we add 240 items to all the squares on the closed loop with a plus sign and subtract 240 from all the squares on the loop with a minus sign therefore we have:

OA 70 0+240 +	OI 50	OO 240 - 240 0 -
OA 40 300 - 240- 60	OI 70	OO 120 + 240 60 360 +

Note that OO that was a stone square in the initial solution now ceases to exist while OA which was empty now enters into the solution. Thus, we construct new transportation table, we obtain the total cost of the new situation while ensuring that the total number of stone squares equals m + n – 1(4 + 3 – 1) = 6.

The particular problem must have six stone squares in every iteration otherwise it degenerate

To From	Ajaokuta	Itobe	Ochadamu	Anyigba	Total Capacity
Idah	80 +	110	90	60 480-	480
Onyedega	70 - 240	50 300	100	80 +60	600
Ogbogbo	- 40 60	70	60 360	90	420
Total requirements	300	300	360	540	1500 1500

Total cost of this solution

I to A = N60 x 480	=	N28,800
O to A = N70 X 240	=	N16,800
O to I = N50 x 300	=	N 15,000
O to A = N80 x 60	=	N4,800
O to A = N40 x 60	=	N2,400
O to O = N60 x 360	=	N21,600
Total	**=**	**N89,400**

Note that this total amount of N89,400 is less than the total cost of the initial transportation using least cost method which was N91,800. It is also less than the initial transportation cost when the stepping stone method was used to arrive at the initial solution N145,200.

We now go back to test the solution for improvement by calculating the improvement indices for all the unused squares.

Unused cells	closed loop improvement index
IA =	IA – OA + OA-IA
	80 – 70 + 80 – 60 = 30
II =	II – OI + OA – IA
	110 – 50 + 80 – 60 = 80
IO =	IO – IA + OA – OA +OA - OO
	90 – 60 + 80 – 70 + 40 – 60 = 20
OO =	OO – OA + OA – OO
	100 – 70 + 40- 60 = 10
OI =	OI – OI + OA – OA
	70 – 50 + 70 – 40 = 50
OA =	OA – OA + OA – OA
	90 – 80 + 70 – 40 = 40

There are no more negative improvement indices in this second solution so it is the optimal solution. Note that we have this allocation and cost with when the vogels approximation method (VAM) to obtain an initial solution.

Thus, the optimal solution to the transportation cost is given thus:

I to A = 480
O to A = 240
O to I = 300
O to A = 60
O to A = 60
O to O = 360

The total cost of this solution is N89,400. From this we can see that one source can supply more than one destination and one destination can be supplied by more than one source. The modified distribution (MODI) method of testing for optimality. The modi method involves test for optimal solution by utilizing dual variables without drawing closed paths for each empty cell.

For example

	D V_1 = 6	E V^2 =9	F V_3	Supply
A V = 0 1 = 0	150 6	50 9	16	200
B ½ = 1	11	150 10	50 7	200
C V_3 = 4	16	12	200 10	200
	150	200	250	600

Using the improved solution by calculating the indices = using the occupied cells
C = V +_ U
C is constant
6 = V + O
$V_1 = 6$
$V_2 = 9 + 0 = 9$
$10 = 9 + V_2$
$V_2 = 1$
$7 = V_3 + 1$
$V_3 = 7 - 1 = 6$
$10 = 6 + V_3$
= 10 – 6 = 4
Evaluate the unoccupied cells
E = C – V – U
Cell A to E = 16 – 6 – 0 = 10
Cell B to D = 11 – 6 – 1 = 4
Cell C to D = 16 – 6 – 4 = 6
Cell C to F = 12 – 9 – 4 = -1
Z min = 0

	D	E	F	
A	6 150	9 50	16	200
B	11	10 -150	7 200	200
C	16	12 +150	10 150	200
	150	200	250	600

ZQ = ∑(X Q) = 6 x 150 + 9 x 50 = N5050
Compare to the initial solution which was N5200 hence the sum of N150 have been saved.

CONCLUSIONS AND RECOMMENDATIONS

From the empirical evidence of the application of transportation model, it is evident that the effective application of transportation model by Otebu investment limited helps in minimization of transportation cost thereby enhances its revenue drive. This implies that the application of transportation model play a critical role to the attainment of both the immediate and strategic objectives of the enterprise hence it should be sustained.

From the empirical evidences emanating from this research, it is clear that application of transportation model has significant roles on the performance of both profit and non-profit firms.

The study recommends that there should be a careful study of the best transportation technique to apply particularly to ensuring that such fit into the economic and social reality of the business climate at any point in time. This would provide an avenue towards meeting the immediate and strategic objectives of organizations.

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