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On The Application of Transportation Methods for the Distribution of Crude Oil in Delta State, Nigeria

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Abstract: *Methods for solving transportation problems are of great importance in every manufacturing or production industries such as oil companies, power stations, ministry of water resources and even in military. As part of important and real life applicability of mathematics to the world and every day activities of human existence, it a known fact that mathematics is one of the factors to achieve sustainable goal. This paper basically examined the practical application of North West Corner Rule, Least Cost Method and Vogel Approximation Method to obtain initial solution while Stepping Stone Method and Modified Distribution Method for optimal solution of distribution of crude oil in Delta State, Nigeria, with a view to advise government which of the methods suitable for even distribution of crude oil among the communities that will minimize cost and maximize profit*

Keywords: *Transportation Problems, Modeling, Optimality, Initial Solution, Sustainable Development Goals, Demand and Supply, Crude oil*

INTRODUCTION

Olaosebikan *et al.* (2022), tremendously analyzed how these methods can be used to achieve goal 2 and 12 of sustainable development goals as approved by United Nation (UN) for 2030 agenda. Koopman, (1947), presented a study titled "Optimum Utilization of the transportation system" which assisted in the development with involvement of a number of transporting source (Origin) and a number of distribution (end point or final consumer). During world war II, Agbadudu, (1996), discovered proper activities of operation research which a group of scientist gathered to solve problems of allocating resources that were scarce to military operation. Charles and Cooper, 1953, developed stepping stone method, (SSM), with the purpose of using the algorithm developed to solve transportation problem which was subsequently improved upon and led to the computational easier modified distribution method in 1955. This paper examined and applied the ideas and techniques developed by these researchers to the distribution of crude oil in Delta State, Nigeria, in other to suggest which method is suitable to minimize cost and as well maximize profit.

Transportation Model either for Maximization or Minimization Problem

Usually, maximization or minimization form of transportation model is designed to either minimize total cost of shipment or transporting inventories or maximizing profit of shipment or transporting inventories. It also involves structuring of a large number of shipping routes from several supply origins to several destinations with the aid of variables, parameters and mathematical operators. It is a linear programming devise basically designed to illustrate the total minimum cost of moving, distributing or allocating commodities, especially inventories of either materials or finished goods from known number of origin or supply points to a given number of demand points or final consumers' considering the capacities of the origin or supply points with demand requirements. In 2004, Jensen opined that transportation model is designed to create a sort of solution that will be feasible in such a way that successive likely revisions of this solution with the use of quantitative analysis will directly lead to optimal solution required.at the lowest likely total cost.

Solving Problem of Initial Solution using Distribution of Crude Oil

The cost of transporting 1,000barrel of a certain component of crude oil from Warri refinery to filling station is as shown below (all in Naira)

Filling Stations/ Refineries	F_1	F_2	F_3

R_1	20	30	20
R_2	10	10	30
R_3	30	20	25

The quantities available at the refineries are $6, 8$ and 5 million barrels of a certain crude oil respectively, while at the filling stations $5, 6$ and 8 million barrels of a certain crude oil such as kerosene, petrol etc. respectively are demanded.

Model Formulation

In other to formulate the transportation problem as a linear programming to minimize the total transportation cost using the initial and optimal solution methods. The transportation table is as follows:

	F_1	F_2	F_3	**Availability**
R_1	20	30	20	6
R_2	10	10	30	8
R_3	30	20	25	5
Demand	5	6	8	

It is aimed to formulate the table above as a linear programming model to minimize the total transportation cost.

Let X_{ij} be the number of units of the component of crude oil to be transported from refinery $i(i = 1, 2, 3)$ to a filling stations $j(j = 1, 2, 3)$. The transportation problem can be formulated as linear programming models as:

$$Min(TC) = 20x_{11} + 30x_{12} + 20x_{13} + 10x_{21} + 10x_{22} + 30x_{23} + 30x_{31} + 20x_{32} + 25x_{33}$$

Subject to the constraints

$$20x_{11} + 30x_{12} + 20x_{13} = 6$$
$$10x_{21} + 10x_{22} + 30x_{23} = 8$$
$$30x_{31} + 20x_{32} + 25x_{33} = 5$$
$$20x_{11} + 10x_{21} + 30x_{31} = 5$$
$$30x_{12} + 10x_{22} + 20x_{32} = 6$$
$$20x_{13} + 30x_{23} + 25x_{33} = 8$$

$$X_{ij} \geq 0 \;\forall\; i, j(i = 1, 2, 3 \; and \; j = 1, 2, 3)$$

Generalized Mathematical Model Formulation for the Problem

Let m be the source of supply $S_1, S_2, S_3, \dots, S_m$ having $a_i(i = 1, 2, \dots, m)$ units of supply to be transported among n destinations $D_1, D_2, D_3, \dots, D_m$ with $b_j(j = 1, 2, \dots, n)$. Let C_{ij} be the cost of transporting one unit of the commodity from source i to destination j for each route. X_{ij} represents the numbers of units of commodities being transported per route from source i to destination j for each route. The aim is to determine the transportation schedule so as to minimize transportation cost satisfying the demand and supply constraints. This can be translated mathematically as:

Minimize (TC): $\sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$

Subject to the Constraints:

(Supply Constraints) $\sum_{j=1}^{n} X_{ij} = a_i, i = 1, 2, 3, \dots, m$

(Demand Constraints) $\sum_{j=1}^{m} X_{ij} = b_i, i = 1, 2, 3, \dots, n$

(Decision Variables) $X_{ij} \geq 0 \;\forall\; i, j$

Total Supply = Total Demand, so: $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$

MATHEMATICAL METHODS

Suggested mathematical methods for the mathematical model formulation are summarized as follows:

Step 1: Formulate the problem and set up in the matrix form: the formulation of the transportation problem is similar to the linear programming problem formulation. Here the objective function is the total transportation cost and the constraints are the supply and demand available at each source and destination respectively.

Step 2: Obtain an initial basic feasible solution: there are three different methods to obtain an initial solution

which are:

- Northwest Corner Rule
- Least Cost Method
- Vogel's Approximation Method
- The initial solution obtained by any of the three methods must satisfy the following condition:
- The solution must be feasible
- The number of positive allocation must be equal to $m + n - 1$, where m is the number of rows and n is the number of columns.

Step 3: Test the initial solution for optimality: to test the optimality of the solution obtained in step 2 using the Modified Distribution Method. If the current solution is optimal, then stop, otherwise, determine a new improved solution.

Step 4: Updating the solution: Repeat step 3, until an optimal solution is reached.

Method of Generating Initial Solution

There are three methods of finding initial solution as stated in Step 2 above, which are: Northwest Corner Method, Least Cost Method and Vogel Approximation Method yield the best starting basic solution.

Northwest Corner Method (NWCM)

The method starts at the Northwest Corner cell (route) of the table. It is a simple and efficient method to obtain an initial solution.

Characteristics features of NWCM

- It involves least computation

- It does not take cost into consideration
- It is simple and efficient
- It is a quick and easy method
- The solution obtain is always to form optimal

Algorithm of NWCM

Step1: Allocate as much as possible to the selected cell, and adjust the associated amounts of supply and demand by subtracting the allocation amount.

Step2: Cross out the row or column with zero supply or demand to indicate that no further assignments can be made in that row or column. If both a row and column net to zero simultaneously cross out row (column).

Step3: If exactly one row or column is left uncrossed out, stop, otherwise, move to the cell to the right of a column has just been crossed out or below if a row has been crossed out. Go to Step 1.

Least Cost Method (LCM)

The LCM finds a better starting solution by concentrating on the cheapest routes. This method starts by assigning as much as possible calls with the smallest unit cost (ties are broken arbitrarily).

Characteristics Features of LCM

- It concentrated on the cheapest routes
- It is consider to be the better method of finding starting solution
- It is a simple and efficient method
- It starts by assigning or allocating to possible cells with the smallest unit cost

Algorithm of LCM

Step 1: Select the cell with the lowest unit cost in the entire transportation tableau and allocate as much as possible to this cell and eliminate that row or column in which either supply or demand is exhausted. If a row and column are satisfied simultaneously, only one way is to cross out. In case the smallest unit cost is not unique then select the cell where maximum allocation can be made.

Step 2: After adjusting the supply and demand for all uncrossed out rows and column, repeat the procedure with the next lowest unit cost among the remaining rows and columns of the transportation tableau and allocate as much as possible to the cell and eliminate that row or column in which either supply or demand is exhausted.

Step 3: Repeat the possible until the entire available supply at various sources and demand at various destinations are satisfied.

Vogel Approximation Method (VAM)

VAM is a heuristic method and preferred to the other two methods described above in this method, each allocation is made on the basis of the opportunity cost that would have been incurred if allocations in certain cells with minimum unit transportation cost were missed. In this method, allocations are made so that the penalty cost is minimized. The advantage of this method is that it gives an initial solution which is nearer to an optimal solution itself.

Characteristics Features of VAM

- The solution obtain by VAM is always nearer to the optimal solution
- It is relatively easy to implement by hand
- It is sometimes referred to as an optimal
- It takes cost into account. i.e. into consideration in relative way
- It yield the best starting basic solution

Algorithm of VAM

Step 1: Calculate the difference between the two lowest distribution cost for each row and column.

Step 2: Select the row or column with the great differences and circle the value. In case of tie, select the row or column allowing the greatest movement of units.

Step 3: Assign the largest possible allocation within the restrictions of a row or column to the lowest cost cell for the row or column selected.

Step 4: Cross out any row or column satisfied by the assignment made in Step 3

Step 5: Repeat Step 1 to 4 except for rows and columns that have been crossed out until all the assignment have been made.

Methods for Generating Optimal Solution

The three methods studied above cannot necessarily guarantee optimal solution, even though they give feasible solution. Hence, they are referred to as initial solution methods. Optimal solution therefore starts where initial solution stops. To check for optimality, the following methods are used.

- Stepping Stone Method (SSM)
- Modified Distribution Method (MODI)

Stepping Stone Method (SSM)

The SSM is one of the methods for generating optimal solution that involves allocation of limit to the unoccupied cells in the initial basic solution so as to minimize transportation cost. It utilize unoccupied cells with negative sign allocation in the change and in a situation where two cells have allocation (tie) the first allocation goes to the specific one with highest allocation.

Characteristics Features of SSM

- It utilizes unoccupied cells with negative sign

- It is one of the method used in generating an optimal solution
- It first allocation goes to the specific one with highest negative cell or sign.
- It makes use of the final solution .i.e. final tableau of these methods: NWCM, LCM and VAM.

Algorithm of SSM

Step 1: Start with initial basic solution of the three methods discussed and confirm that the final tableau form initial method satisfies $m + n - 1$ cells where m and n are columns and rows respectively.

Step 2: Identify the occupied and unoccupied cells and for unoccupied cell, compute the net change

Step 3: If the net change is negative, allocate minimum unit to the value otherwise no need for allocation.

Step 4: If two unoccupied cells have the same negative sign, start with one with highest unit or make arbitrary choice

Step 5: Update your optimality and checkmate your result if the unoccupied cells are positive.

Step 6: If they are positive, stop, otherwise, go to step 2.

Modified Distribution Method (MDM)

The modified distribution method of ascertaining optimal solution in transportation problems is an efficient technique, which helps in comparing the relative advantage of alternative allocations for all the unoccupied cells simultaneously. The advantage of this method is that, it provides a flat form of minimizing transportation cost associated with transporting goods from production facilities to requirement facilities. If function with the aid of any of the three basic solutions discussed previously. For a given basic feasible solution we associate numbers U_i and V_i with row $i = 1(1)m$, and column $j = 1(1)n$ of the transportation table respectively they, U_i and V_i must satisfy the equations:

$U_i + V_j = C_{ij}$ (Occupied Cells)

$e_{ij} = C_{ij} - U_i - V_j$ (Unoccupied Cells)

The preceding computations are usually done directly on the transportation tableaus, meaning that, it is not necessary to write the equations explicitly, instead, we start by setting $U_i = 0$. Then, we can compute V_j values of all the columns that have been determined, we can evaluate the non basic X_{ij}

Algorithm for MDM

Step 1: For an initial basic feasible solution with $m + n - 1$ occupied cells, calculate U_i and V_j for rows and columns. The initial solution can be obtained by any of the three methods discussed. To start with, any one of U_i's and V_j's assign zero for a particular U_i or V_j where there are maximum number of allocation in a row or column respectively as it will reduce arithmetic work considerably. The complete the calculation of U_i's and V_j's for other rows and columns by using the relation $U_i + V_j = C_{ij}$ fo all occupied cells (ij)

Step 2: For unoccupied cells, calculate opportunity cost by using the relation

$$e_{ij} = C_{ij} - U_i - V_j$$

Step 3: Examine sign of each stage in Step 2.i.e

- If $e_{ij} > 0$, then current basic solution is optimal
- If $e_{ij} = 0$, then current basic solution will remain unaffected but an alternate solution exist
- If one or more $e_{ij} < 0$, then an improved solution can be obtained by entering unoccupied cell (C_{ij}) in the basis.

Step 4: Construct a closed path for the unoccupied cell with largest negative opportunity cost. Start the close path with selected unoccupied cell and mark a plus $(+)$ in the cell, trace a path along the row or column to an occupied cell, mark the corner with a minus sign $(-)$ and continue down the column (row) to an occupied cell and mark the corner with plus sign $(+)$ and minus sign $(-)$ alternatively. Then, back to the selected unoccupied cell.

Step 5: Select the smallest quality among the cells marked with minus sign on the corners of closed path. Allocate value to the selected unoccupied cell and add it to occupied cell marked with plus and subtract it from the occupied cell marked with signs.

Step 6: Obtain a new improved solution by allocating units to the unoccupied cell to step and calculate the new transportation cost.

Step 7: Test the revised solution further for optimality. The procedure terminate when all $e_{ij} > 0$ for unoccupied cells.

RESULT DISCUSSIONS

Finding the Initial Solution of the problem, the results are: $NWCM = \#395$, $LCM = \#310$, $MODI = \#395$. In other to generate the optimal solution of the problem, we make use of any of the final tableau of the initial solution methods and the results are as follows: $VAM = \#325$, using NWCM. While $SSM = \#340$.

Conclusively, comparing all the methods discussed so far, one can advise government which method to adopt in other to minimize transportation cost and maximize profit.

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CONCLUSION

Transportation problem is very interesting and helpful topic in operation research which is useful in all aspects of establishments (mankind), a need to move goods and services from origin (source) to destination. We can therefore analyze the scope and result of this work dealt with transportation problem. The initial solution i.e. the Northwest Corner Method. But Vogel Approximation method and least cost method are very close to optimal solution. The other two methods used the initial solution method to arrive at optimal solution and they are: Stepping Stone and Modified Distribution Methods. In breaking ties arbitrarily where they exist, one should be careful because the wrong choice can lead to the problem of degeneracy. The modified distribution method is an algebraic version of the stepping stone method.

It is aimed to suggest some mathematical methods which will be used to solve some real life problems in relation to SDGs 2 and 12 in particular. Clearly, this paper has been able to show some methods both for initial solution and optimal solution as proposed. In the subsequence research, focus shall be on practical aspect of these suggested methods in comparism with existing methods for solving the said problems.

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