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APPLICATION OF TRANSPORTATION MODEL FOR OPTIMAL PRODUCT DISTRIBUTION CHAIN MANAGEMENT

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ABSTRACT

Many business organizations are operating at an unacceptable high distribution chain costs even as industrial competition continues to pose as a major challenge to business success. Linear programming devices can help organizations achieve efficiency. This research aims at establishing the impact of Transportation algorithm in optimal product distribution and scheduling of business organizations. In a field study of NOWAS Oil and Gas, data was significantly secondary sourced, resulting from indepth analysis of existing documented content materials on the subject. Practical application of the least cost method scheduling and North West Corner Rule method of an initial basic feasible solution was imminent. Revising that solution using the stepping stone method translated to an optimal distribution schedule and a minimum cost profit in yearly distribution schedule of Nowas Oil and Gas, Enugu. It is recommended that business organizations carryout careful analysis of their supply and demand constraints in materials and products distribution for cost minimization and overall resource optimization.

Keywords: Application, Transportation Model, Basic Feasible Solution, Optimality, Distribution Chain, Management.

INTRODUCTION

Background of the Study

Modern Business organizations are continuously confronted with the challenges of effective and prudent decision making in the face of ever increasing competition, globalization and innovation. Comprehensive response to these challenges can only be demonstrated in resource optimization strategies that ultimately maximize benefits (profits, turnover, market share, etc) and minimize losses and unsought consequences (Koontz, et al 1980).

Organizations command leverage and competitive advantage over others as a result of careful, systematic and programmed efforts in the choice of products technology, market and innovative strategies to continuously sustain their leadership positions. Success in business results from an objective response to identifiable business problem. Taylor (1911) notes that intuitiveness and the rule of thumb have since been replaced by an organized scientific and integrated approach that avails of quantitative analysis in tackling the monster of cost and optimizing benefits.

Linear programming has afforded business organizations the template to achieve resource optimization. It proceeds from the formulation of an objective function, which usually would either be to minimize cost or maximize benefits. This is realizable within a feasible manipulation of a set of resource structural constraints.

Accordingly, organization must visualize a range of opportunities available to them and comprehensively undertake proper assessments of their strengths and weakness in terms of resources and constraints available. The extent to which strategic operations are programmed and informed decisions taken will determine the level of success achieved in the industry.

Statement of the Problem

Organizations are operating at unacceptable increasing distribution chain costs. Often times, decisions on products and material distribution, supplies and transport are made without critical and quantitative analysis of detailed cost implications. Business organizations are also facing the challenges of changes in economic conditions that necessitate continuous distribution/delivery schedules. So there is a dire need to evaluate the circumstances and extent to which transportation as a linear programming device can be applied in the scheduling and analysis in products distribution in order to achieve efficiency in business operations.

Objectives of the Study

The cardinal focus of the study is to examine the impact of Transportation algorithm in attaining optimal product distribution chain management in Business firms. Specific objectives include to:

i) Assess the extent to which Least Cost Method scheduling can result in total distribution cost minimization.
ii) Ascertain the extent to which North West Corner rule method scheduling can result in total distribution cost minimization.

Research Questions

(i) To what extent does Least Cost Method scheduling result to minimization of Total distribution cost?
(ii) To what extent does North West Corner rule method scheduling result to minimization of total distribution cost?

LITERATURE REVIEW

The Transportation Model

This is a linear programming devise principally designed to establish the total minimum cost of transporting, distributing or allocating products, especially inventories of either materials and finished goods from a known number of sources (origins or supply points) to a given number of destinations (demand points) in consideration of source capacities and destination requirements. Jensen (2004) notes that a transportation model is designed to establish a solution that is basic feasible. Successive possible revisions of this solution using quantitative analysis will ultimately lead to the optimal solution. At the optimal solution, a combined mix of optimal product allocations are possible from variety of sources to destinations at the lowest possible total cost.

Relevance to Distribution Chain

Inventory has been defined as the stored accumulation of material resources in a transformation process. This process entails every stage of transformation (material input → output state). In effect, inventory (stock) includes: raw materials, work in progress, finished parts/components, and finished goods (Ani, 2002).

Typically a transportation model is applicable to material resource management in two broad spheres within the origin and destination structural constraints. Accordingly, raw material inventory may be transported from original sources to factories (destinations) and in another situation, finished goods inventory may be transported from factories (origin) to warehouse/markets (destinations). So in essence, origins refer to original raw material sources or finished good sources (factories) while destination may be a reference to factory for production (raw material destination) or the warehouse/market (finished good destination).

The Critical Components of a Transportation Model

The model exhibits the general nature of a linear programming device which is predicated on three obvious situations.

1. The objective function: This is usually focused on the minimization of total cost of distribution/allocation of materials, or inventory from all known origins to all known destinations.
2. Structural constraints: Each source/origin has a given capacity which cannot be exceeded. For example, a factory as source cannot produce beyond a stated maximum volume units of its products. On the corollary each destination has a given maximum requirement, for example, a storage silo cannot absorb beyond the maximum inventory units designated to it.
3. Non-negativity constraints: All products/inventories to be distributed/ transported must have a value that is equal or usually greater than zero, that is a positive and not negative value.

The Structural Balance of Constraints

It is emphasized that the transportation model is not a square matrix that is, need not have equal number of sources (rows) and destination (columns). What is of significance is that the total inventory supplied by aggregated number of sources must equal the total inventory quantity/units required by all destinations (Frazelle, 2002).

In order words, total source capacities must equal total destination requirements for a transportation problem to be on balance.

Accordingly, source capacities are presented in rows while destination requirements are shown in columns in the formulation of initial transportation table, initial basic feasible solution and subsequent revisions, in the search for optimality.

Balancing an Unbalanced Problem

In a situation where total source capacities exceed total destination requirements or vice versa, an unbalanced problem has arisen. The solution is to create a dummy cell to absorb the excess capacity or to provide for excess requirements respectively. The delivery cost associated with a dummy cell is assumed to be zero.

Systematic Solutions in a Transportation Model

In tackling a transportation problem, the programmer must identify the variables in the solution.

These must exist, a clear isolation of the objective function and the structural constraints. Subsequently, Mahmud (2017) shared systematic steps in transportation scheduling.

1. **Setting up the initial transportation table**

This involves the setting up of the columns and rows with identification symbols and inventory delivery cost schedules per unit. Source capacities are identified horizontally (in rows) while destination requirements are identified vertically (in columns). At this stage, all the existing cells are empty (unoccupied). All inventories originating from all sources and same being absorbed in all demand points are summed up separately for a balance. A dummy cell earlier emphasized could be created here to rectify an imbalance if the situation arose.

2. **Developing an Initial Basic Feasible Solution**

   Two conventional approaches that are utilized here are:

   i. The North-West corner rule and

   ii. The least cost method.

i. The North – West Corner Rule

Here, inventory allocation to cells start from the top left hand corner (geographical locations of northeast). Maximum allocation is made subject to source and destination constraints. A corollary condition exists here: The rim requirement of each column must be satisfied before moving to the next column (rightwards). The source capacity of each row must be satisfied before moving to the next row (downwards). When all rim capacities and requirements have been met, the total cost is obtained.

For a solution to be basic feasible the number of occupied cells (cells with inventory allocations) must be equal to the total number of rows (m) and columns (n) less one, i.e. No of occupied cells = (m+n)-1.

ii. The Least Cost Method

The emphasis here is on making the first allocation to the cell that has the least transportation cost per unit of inventory. The least cost cell is allocated maximum quantity subject to the origin capacity of its row and destination requirement of its column. Then, the next least cost cell is similarly attended. This pattern continues till all rim capacities and requirements have been satisfied.

Usually, the total cost obtained in the initial basic feasible solution using the least cost method is lesser than that obtained using the North West corner rule for obvious reasons. Emphasis was given to least cost cells in the inventory transportation. In most cases, the initial basic feasible solution using least cost method cannot be improved upon i.e. is also the optimal solution least cost implications.

3. **Testing for Optimality**

There are two well known procedures for this:

i. The steeping stone method

ii. Modified distribution method.

According to Henry (2012), optimality test is an attempt to explore the accomplishment of the objection function.

I. The Stepping Stone (SS)

Testing for optimality involves the one by one evaluation of all the empty cells/unused squares in the present solution. The process involves tracing a closed path or loop for each empty square by moving horizontally and vertically; and starting from the empty cell being evaluated, assign (+) or (-) alternatively at each corner square of the closed path. For each empty cell, only one closed path exists. The path may skip over stone and all empty cells. In this regard, only the most direct route is used.

The +ve or –ve signs indicate the addition or subtraction of one inventory unit to the cell. Accordingly, the net changes in total cost, resulting from the changes made in inventory unit additions or subtractions is obtained. This is resultant from summing the unit cost in each square with a +ve sign and minimizing the unit cost in each square with a –ve sign. The different in value is the improvement index for the empty cell.

In other words, an improvement index shows by how much total cost will increase or decrease, if one inventory unit is allocated to that empty cell in a new solution. All the empty cells are to be evaluated similarly and improvement index obtained. In the stepping stone method; if the indices are all ≥ O (greater or equal to O), an optimal solution has been found. Otherwise, an improved solution is possible,.

II. The Modified Distribution (MODI) Method

In this approach, the test for optimality is done by the utilization of dual variables. The actual cost for each stone cell (basic variable) is determined. Then the implied cost and the opportunity cost is derived for each empty cell (non-basic variable). The cell with the highest positive opportunity cost is chosen as the most favourable empty cell. At this point, a closed path or loop is drawn for the empty cell in order to obtain a new basic feasible solution (incoming variable). When a new solution is developed, the same testing for optimality procedure is administered (after total cost table has been obtained). At the point in which opportunity cost for the empty cells are all ≤ O (less or equal to zero), the optimal solution is obtained, otherwise the solution can be improved upon.

4. **Deriving the Optimal Solution**

The goal of the transportation technique is to establish the minimum total cost of transporting products/inventories from all known sources to all known destinations. This is realizable only at the optimal solution. Thus, the optimal solution is the final destination of any linear programming model. At this level, the solution can no longer be improved upon. Inventory allocations are finally made availing of optimal routes. In this way, organizations achieve prudence and efficiency in resource/inventory allocation and utilization. This is true because Baron (2005) defines the optimal solution as either the most profitable or the least costly solution that simultaneously satisfies all the constraints of a linear programming problem. In a typical problem, the search for this solution starts from the basic feasible solution and finally it is located at the boundary of the feasible region, that is at one of the corner points of the region. When the least cost method is applied in arriving at the initial basic feasible (IBFS) solution, that in many cases is optimal or very close to optimal. But, the North West corner rule (NWCR) method usually makes subsequent revision (s) imperative. Whether the stepping stone or modified distribution is applied in the search for optimality, the most direct route is applied in drawing a closed path (loop) for the incoming variable.

The incoming variable is the empty cell with the largest negative value in improvement index (stepping stone method) or the one with the largest positive opportunity cost (modified distribution method). The closed path is drawn and isolated. It is important to reemphasis that each negative value in the improvement index shows by how much total cost will reduce if one inventory unit is transported to that cell. In the same way, each positive value in the opportunity cost indicates how much of the foregone benefit in total cost reduction if one unit is not allocated to an empty cell.

So, tracing the closed path with the largest negative value (SS) or largest positive value (MODI) as the case may be, the isolated closed path is manipulated by determining maximum inventory quantity that will be allocated or assigned to the incoming variable. This will be obtained by locating the smallest quantity of the present solution in a negative position. This is added to every cell with plus sign and deduct same form every cell with minus sign and obtain new results. A new transportation table is re-constructed and if the rim requirements have not been satisfied, allocations on the table is concluded with preference to least cost cells. Total cost of the new solution is obtained, and optimality test re-applied.

It is important to stress that until the solution becomes optimal, the same processes already stated for solution revisions will be repeated.

Transportation Model for Maximizing

In usual cases, the transportation model is designed to minimize total cost of shipment or transporting inventories. However, the objective function could sometimes be to maximize benefits: Profits, turnover, market share, demand etc. When such a situation arises, the problem undergoes one unique transformation. All profit values are subtracted from the highest profit value to obtain relative costs. The problem is solved as a minimization case. The relative costs are used as the basis to determine initial basic feasible solution and subsequently the optimal solution. When the optimal solution is achieved, the original values (profit) are inserted to determine total profit volume or the value of the objective function.

Maximum inventory/product allocation pattern synchronizes with profit contribution profile of demand areas. However, in an academic research study by Lee (1997), the trade off in the transportation model is the unsatisfied or unfulfilled demand area or market share which will in turn affect customer satisfaction level. The current practice by strategic cement, Malaysia reveals that the company is supplying to certain demand locations/destinations despite lower profit margin as compared to the empirical result generated by the transportation model.

This is attributable to other business exigencies like customer service, market share and long term business relationship in addition to the core factor-profit. The sensitivity analysis from the same research reveals that 1% change of the variable and demand has direct effect on the profit margin and transporation schedule for the company.

Case of Multiple Optimal Solutions

An optimal solution in a given transportation problem is not always a unique solution. The presence of an improvement index or opportunity cost of zero (0) in the optimal programme affords the manager the flexibility of revising the solution and bringing in the zero opportunity cost cell. This does not affect the value of the objective function. Bruce and Carl (1983) note that the realization that alternative optimal routes exists serves as a boost to managerial confidence, a vital factor for organizational effectiveness.

According to the authors, the manager is excited at the prospects of alternative solutions without any additional risks nor benefits. The total cost of profits contribution remains unaffected.

METHODOLOGY

The researcher undertook a comprehensive analysis of existing documented theoretical contents on the subject.

For project data, the researcher applied the transportation schedule (Product supply and demand constraints as well as Unit Cost) of Nowas Oil and Gas Ltd, Enugu to derive the optimal solution.

Nowas Oil and Gas is an independent petroleum marketing company with a total workforce of 120 employees. It sources its petroleum products from two of Nigeria's major refineries in Port-Harcourt, Warri and from the Lagos private jetty. It markets same in the Enugu, Benin and Lagos areas respectively. Least cost method and North West Corner rule method of distribution scheduling were applied in data processing and analysis.

Subsequently, there was simple interpretation of the optimal solution in the applied transportation programming.

DATA PRESENTATION AND ANALYSES

The yearly petroleum (Premium Motor Spirit) availabilities (quota) from the three sources (Port-Harcourt Refinery, Warri Refinery, and Lagos Private Jetty) and the maximum market demand in the three market zones (Enugu, Benin, and Lagos) relating to Nowas Oil and Gas in an initial transportation model arrangement with naira unit cost schedule (sourcing and distribution per litre) are presented below:

INITIAL TRANSPORTATION TABLE

FROM \ TO	MA	MB	MC	TC
SA	45	70	60	5
SB	70	40	50	7
SC	60	65	50	9
TR	6	9	6	21 \ 21

Total capacity (TC) and Total requirement (TR) constraints in million of litres.

Establishing the initial basic feasible solution using the North West Corner rule reveals:

BASIC FEASIBLE SOLUTION FOR NORTH WEST

FROM \ TO	MA	MB	MC	TC
SA	45 5	70	60	5
SB	70 1	40 6	50	7
SC	60	65 3	50 6	9
TR	6	9	6	21 / 21

Key: TC = Total Capacity
TR = Total requirements

TOTAL COST

				₦
SA – MA	=	5 x 45	=	225
SB → MA	=	1 x 70	=	70
SB → MB	=	6 x 40	=	240
SC → MB	=	3 x 65	=	195
SC → MC	=	6 x 50	=	300

Total cost ₦1,030 (million)

Applying stepping stone method in evaluating empty cells, the result is

SAMB = SAMB – SAMA + SBMA = SBMB
70 - 45 + 70 - 40 = 55

SAMC = SAMC – SAMA + SBMA = SCMB - SCMC
60 - 45 + 70 - 40 + 65 - 50 = 55

SBMC = SBMC – SBMB + SCMB = SCMC
50 - 40 + 65 - 50 = 25

SCMA = SCMA – SCMB + SBMB - SBMA
60 - 65 + 40 - 70 = -35

The solution above is not optimal because of the presence of negative improvement index for cell SCMA -35 SCMA will be brought into a new solution. The closed path for SCMA is reproduced here.

SBMA SBMB

1-1 = (0)	6 + 1 = (7)
0 + 1 = (1)	3 – 1 = (2)

SCMA SCMB

IMPROVED SOLUTION FOR NORTH WEST AND BASIC FEASIBLE SOLUTION FOR LEAST COST

TO / FROM	MA	MB	MC	TC
SA	5 [45]	[70]	[60]	5
SB	[70]	7 [40]	[50]	7
SC	1 [60]	2 [65]	6 [50]	9
TR	6	9	6	21 / 21

TOTAL COST

			₦
SA – MA	=	5 x 45 =	225
SB → MB	=	7 x 40 =	280
SC → MA	=	1 x 60 =	60
SC → MB	=	2 x 65 =	130
SC → MC	=	6 x 50 =	300

Total cost ₦995 (million)

Deriving the improvement indices for empty cells as follows:

SAMB = SAMB – SAMA + SCMA = SCMB
70 - 45 + 60 - 65 = 20

SAMC = SAMC – SAMA + SCMA - SCMC
60 - 45 + 60 - 50 = 25

SBMA = SBMA – SBMB + SCMB - SCMA

70 - 40 + 65 - 60 = 35

SBMC = SBMB – SBMB + SCMB - SCMC
50 - 40 + 65 - 50 = 25

Since al the improvement indices ≥ O, the solution is optimal.

Resulting from the optimal solution above, the optimal routes/schedules for Nowa Oil and Gas are as follows:

Source		Market		Quantity (Ltrs) in million	C.P.U. (₦)		Total cost (₦) in million
P.H.Refinery	→	Enugu zone		5	45		225
Warri refinery	→	Benin zone		7	40		280
Lagos Jetty	→	Enugu zone		1	60		60
Lagos Jetty	→	Benin zone		2	65		130
Lagos Jetty	→	Lagos Area		6	50		300
TOTAL				21			995

Summary of Research Findings

1. Transportation algorithm is most applicable in the objective function of cost minimization, but can also be applied in maximizing benefits.
2. Total cost reduction was significant in the systematic manipulations of an initial basic feasible solution with a total cost of N1,030 (million) in NOWAS Oil and Gas. The optimal solution of same problem revealed a total cost of N995 (million), showing a reduction by N35 (million) in the company.
3. The initial Basic Feasible solution, Least cost scheduling translated to an optimal solution. The initial basic feasible solution, North West Corner rule was improved upon to obtain on optimal solution.

CONCLUSIONS

Transportation algorithm has remained an essential tool of linear programming analysis which has availed modern organizations with quality scientific and objective decision making especially in product and inventory shipment. Most transportation problems are concerned with minimization of total cost. In few cases, the objective function could be to maximize profit and other benefits.

A typical solution to a transportation problem proceeds from the determination of an initial basic feasible solution, systematically progresses through successive improved revisions and terminates at the optimal solution.

Ani (2002) notes that practical application of transportation models have been visible in the areas of distribution and supply chain management, e.g. of inventories of raw-materials or finished products or parts from sources to demand points. It is also most applicable in demand and profit contribution management decisions. According to the author, it is essentially distribution, logistics and supply tool.

A balanced transportation algorithm which satisfies the rim requirement for a basic feasible solution ultimately culminates in an optimal solution. Thus, the number of occupied cells in a basic feasible solution equals the sum of the total number of rows (m) and columns (n), minus one (i.e. $m + n – 1$),

Efficient resource utilization is the bedrock of successful modern business organizations. Linear programming is the hallmark of operations research which guides effective business decisions. Effective inventory management must carefully reflect cost considerations in both procurement, supply, distribution and consumption. Decisions which minimizes costs and maximizes benefits, while simultaneously satisfying all constraints of the linear programming problem is imperative (Baron 2005).

Recommendations

1. Organizations should facilitate effective products and materials planning, scheduling and distribution by availing of the systematic programming which the transportation technique affords.
2. Effective application of the transportation algorithm will significantly minimize total cost/maximize total benefits as the case may be, thus outweighing system costs incurred in the programming.

3. Re-programming should be done at regular intervals and as situations dictate, for example on occasions of significant inflations or statutory/regulatory tariff adjustments.

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