SENSITIVITY ANALYSIS AND GREEDY HEURISTIC APPROACH TO TRANSSHIPMENT MODEL IN OUTBOUND SYSTEM

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Abstract - Managing outbound supply of manufacturing products in a multi-echelon systems is noticeably more complex than managing them in a single-echelon system. Unfortunately, engineering managers rely on local heuristics while making allocation decision. Rule of thumb strategies does not guarantee optimal solution. In this study, an algorithm for effective transshipment has been developed. The model was tested using information from a bottling plant in Nigeria. It was observed that the source distribute products to downstream location at a high cost, not meeting the demand at required outbound neighbourhood. At the end of the analysis, the results obtained showed that the developed model eliminated several deficiencies since all depots got a fraction of the products demanded at all destinations in a cost effective manner. It is concluded that the model is effective for reducing or minimizing distribution expenses while fulfilling demand at all destinations.

Keywords - Single-Echelon, Multi-Echelon, Heuristics, Algorithm, Transshipment

I. INTRODUCTION

It is the desire of every manufacturing industry to meet customers' service goals at specified service levels at the lowest possible cost [1]. Supply chain inventory management (SCIM) is an integrated approach to the planning and control of inventory throughout the entire network from the source of supply to the end user. SCIM goals are to improve customer service, increase product variety, and decrease costs [2]. In addition to these, greater demand is being placed on products and services quicker with greater added value, at correct quality, in the correct quantity, to the right place, at the right time, in the correct condition and packaging, at the right cost, to the right location and to the correct customer, so as to remain competitive in business. The key point to make an enterprise have international competence is to reduce operation cost and raise the satisfaction of customers [3].

Thus, this study addresses a case of distribution problem faced by a source which produces products to be supplied to various destinations so that product delivered can satisfy retailers' expectation. In this problem the demand of each customer as well as the distances (unit cost) among all network nodes is known in advance. The quantity of product that can be loaded in a vehicle from the source to various destinations cannot exceed the capacity of the vehicle. This is an outbound supply chain (the flow of goods from the point of production or manufacture to the point of consumption.) in a multi-echelon network system of source and destination. These challenges as aforementioned are ever posed on producers of manufacturing industries. Practical application of this study may arise in different settings as shown: Oil and gas sector; Bottling companies; Fruit juice companies; Food and Pharmaceutical industries where demand of products is required at various distribution centres. [4].

II. TRANSPORTATION AND TRANSHIPMENT MODELS

A transportation model is concerned with the transport of goods from several supply locations to several customer locations. The structure of a transportation problem involves a large number of shipping routes from several supply origins to several demand destinations [5]. Determining optimal routes to minimize costs associated with physical distribution management has been a serious challenge to managers. It is therefore necessary to formulate a transshipment model to be solved by transportation techniques. The transshipment problem thus assumes great importance in any manufacturing company. Transshipment is widely used in practice to reduce inventory costs and to improve the customer service level. It provides an effective mechanism for correcting discrepancies between the locations observed customer demands and their available inventories. [6]. [7] viewed transportation and transshipment problems as a special class of Linear Programming Problem which deals with the distribution of single commodity from various Sources of supply to various destination of demand in such manner that the total transportation cost is minimized. In his research he tested the strength of heuristics like

North- West Corner Method (NWCM), Least Cost Method (LCM), Vogel's Approximation Method (VAM), NMD Method and Zero suffix Method were used. He recommended decision makers to test all the solution methods and go for the optimal result.

For most manufacturing companies in Nigeria it is not financially viable to transport directly from the factory to the various demand destinations. This is due to a lack of a good road network in many cities. The high costs involved, together with the prevailing market conditions, force the decision maker to consider alternative channels of transporting the company's products. As bad roads make it difficult for companies to transport their products to their customers, they often employ third-party logistics that are involved with warehousing, transport or indirect transportation channels. The products are therefore transported through one or more intermediate stages before reaching the final customer (demand destination). This approach is adopted by many industries in Nigeria. For example, Manufacturers Distribution Services (MDS) Logistics providing warehousing and other transport companies take care of transporting their products. Companies such as PZ Cussons Plc., Nigerian Breweries, Guinness Breweries and LPG companies and depots. Many companies use the terms 'logistics' and 'supply chain' to describe a process in which internal and external units are merged to minimize cost and maximize profit in the transshipment performance to the consumer in terms of redistribution of their finished products [8].

The integrated network of the supply chain design promotes faster and more reliable business transactions for shipments of both raw materials and finished products [9]. [10] Presented a research with focus on transshipment problems in supply chain system using Juaben oil Mill Company limited as a case study to reduce the transportation problems at inbound and outbound level. The techniques employed in determining an optimal solution to transshipment problem is the same employed under direct transportation model. However certain modifications in sources and destination were made to counter the peculiarities of indirect transportation. A primal-dual approach was applied to solve the problem. With focus on minimizing the variable and fixed cost using Quantitative Methods for windows software to analyze the data. The model developed was able to cut cost of distribution to the barest minimal. [4] Discussed multi product, multi-destination supply chain in a single source where an algorithm for cost reduction was developed. [11] Discussed the significant effect of stock out on firm's profitability and the effectiveness of transhipment.

The objective of the study is to develop a methodology that involves mathematical models to support complex distribution tasks for minimizing cost of products to various locations using greedy heuristics, and then validate the models generated by applying it to real life problems in the bottling plant. The company, Nigeria Bottling Company (NBC) located at Asejire Nigeria has been considered as a case study in this research. NBC Asejire is a very large system with nine major depots located at strategic centres in different states to feed other subsystem at echelon-destinations. This study is necessary because of high operating cost associated with physical distribution of goods. Since managers often apply mental guess while making allocation, developing a valuable facility architecture or structural design for effective and efficient product flow will greatly help in reducing high operating costs in manufacturing systems.

Nomenclatures

I	Index identifying source/depots with i = 1,2…m
J	Index identifying destination/location centres j = 1, 2, 3, …n
K	Index identifying intermediate node with k = 1,2,..n
X_{ij}	Quantity of product i shipped to destination j (decision variable)
M	Total number of source/depots
N	Total number of Locations to receive products from the source /depots
c_{ij}	Unit cost of shipping product i to destination j
C	Total distribution cost
A	Product available at the source/depots
S	Source.
D	Destination.

Abbreviations

NBC	Nigerian Bottling Company
SC	Supply Chain
GH	Greedy Heuristic

III. MATERIALS AND METHODS

This section focus on the methods and techniques adopted for developing total cost models for supply chains. It involves: problem description, model development, data gathering method and model parameterization. Attempt was made to identify system parameters, variables, limitations, criteria so as to be able to define the distribution problem. This study was conducted using information from a bottling plant. A transshipment model for product delivery was

developed in this work. The transhipment matrix is shown in table 1-4.

Plant and Depots	Plant and Depots									
S_1	D_1	D_2	D_3	...	D_n	b_1	b_2	...	b_m	Total
S_2										
S_3										
⋮ S_m										
s_1										
s_2										
⋮ s_m										
Total										

Table I: Transshipment Matrix for Plant and Depots

Sources & Sinks	Source and Sinks							
X_1	X_1	X_2	X_3	X_4	X_5	..	X_{10}	Total
X_2								
X_3								
X_4								
X_5								
X_6								
..								
X_{10}								
Total								

Table II: Transshipment Matrix for Sources and Sinks

Sources & Sinks	Source and Sinks							
X_1	c_1	c_2	c_3	c_4	c_5	....	c_{10}	Total
X_2								
X_3								
X_4								
X_5								
X_6								
..								
X_{10}								
Total								

Table III: Cost matrix for Source and Sinks

Table 2 and 3 are now combined to give the matrix of quantities and costs associated to each transshipment node. This is shown as in Table 4.

Sources & Sinks	Sources & Sinks					
	D_1	D_2	D_3	....	D_8	Total
D_1	c_{11} x_{11}	c_{12} x_{12}	c_{13} x_{13}	....	$c_{1\,10}$ $x_{1\,10}$	
D_2	c_{21} x_{21}	c_{22} x_{22}	c_{23} x_{23}	....	$c_{2\,10}$ $x_{2\,10}$	
D_3	c_{31} x_{31}	c_{32} x_{32}	c_{33} x_{33}	....	$c_{3\,10}$ $x_{3\,10}$	
⋮				....		
D_{10}	$c_{10\,1}$ x_{81}	$c_{10\,2}$ x_{82}	$c_{10\,3}$ x_{83}	....	c_{1010} $x_{10\,10}$	
Total						

Table IV: Transhipment matrix for Distances and Costs

A. Mathematical Model for Transshipment Problems

Here, shipment may move through intermediate nodes before reaching a particular destination node.

Problem constraint

The problem constraints and equations describing them are:

Supply Constraint:

In this model, one of the systems of constraints is related to product availability. This explains the fact that everything going into transhipment point is less or equal to the total product i available at the source S_i.. This is shown in (1)

Supply $$\sum_{j=1}^{n} X_{ik} \le S_i$$

for all i =1,2,3…..m (1)

Policy on transshipment Constraint:

Every company has its own policy on distribution. In this research, the policy constraint requires that everything going into the transshipment point is equal to total product going out of transshipment point. This is shown in (2)

Transhipment $$\sum_{j=1}^{n} X_{ik} - \sum_{i=1}^{m} X_{kj} = 0$$

for each intermediate node (2)

Demand Constraint:

This constraint requires that total sum of product going out of transhipment point is less or equal to the demand at that end. This is represented in (3).

Demand $$\sum_{i=1}^{m} X_{kj} \le D_j$$

for all j = 1, 2 … n (3)

Non-negativity constraint:

There explains the fact that there is no negative distribution. This is represented in (4)

Non-negativity $X_{ik,;} X_{kj} \ge 0$

for all i = 1, 2 … m; j = 1, 2 … n (4)

B. Objective function of the transshipment model

The objective function of this transshipment model is to minimize the total distribution cost. Equation (5) depict mathematical statement to represent the objective function of the transshipment model.

Minimize

$$\sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik} X_{ik} + \sum_{k=1}^{n}\sum_{j=1}^{m} C_{kj} X_{kj} \qquad (5)$$

Summary of generalized Bottling Plant model

$$\sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik} X_{ik} + \sum_{k=1}^{n}\sum_{j=1}^{m} C_{kj} X_{kj}$$

Subject to the constraints:

Supply $$\sum_{j=1}^{n} X_{ik} \le S_i$$

for all i =1, 2, 3…..m

Demand $\sum_{i=1}^{m} X_{kj} \leq D_j$

for all j = 1, 2 … n

Policy $\sum_{j=1}^{n} X_{ik} - \sum_{i=1}^{m} X_{kj} = 0$

for each intermediate node k

$X_{ik}, X_{kj} \geq 0$

for all i = 1, 2 … m; j = 1, 2 … n

IV. DATA ANALYSIS

Nigerian Bottling Company have a massive plant located at Asejire, the boundary between Ibadan and Osun State. The industry is actually made up of two major manufacturing systems that, taken together, bring soft drinks to the market. These two systems fall into distinct categories: (1) Inbound (sourcing for flavouring syrup and concentrate) and (2) Outbound (soft drink manufacturing/distribution). The inbound is the driver for most outbound operations. The majority of the bottled soft drinks follow a similar product life cycle, moving from syrup sourcing, to bottler, to distributor, to merchant and finally to consumers. Once soft drinks are bottled and ready for distribution, a variety of distribution channels are leveraged to get the final product to the end consumer. The industry has 9 major depots located within south-west Nigeria respectively: Asejire (S1), Ado (D2), Ore (D3), Akure (D4), Abeokuta (D5), Ijebuode (D6), Ibadan (D7), Ondo (D8), Ife (D9) and Ilesha (D10). Periodic data collected from the source showing unit cost of distribution and product availability and demand at various location is shown in Appendix 1.

A. Formulation of transshipment model

A transshipment model must include Source (i.e. plants or factories where products are produced) and sink (i.e. destinations or depots where products are needed or demanded for). Strategic staff at every point in time is interested in productivity, profitability, efficiency and effectiveness. To achieve these objectives it is necessary to apply heuristics that will give an optimal or a near optimal solution. Following the parameters of the model developed in our methodology. In this transportation model, let m source (Asejire) be the supplier of the products to n sinks (Asejire (S1), Adoekiti(D2), Ore(D3), Akure (D4), Abeokuta (D5), Ijebu-ode (D6), Ibadan (D7), Ondo (D8), Ife (D9) and Ilesha (D10) (see Figure1, Appendix 1). Let the Source of supply i (i = 1, 2, 3,4……, m) produce Si units and the destination j (j = 1, 2, 3,….., n) require Dj units. The cost of transportation from factory i to warehouse j is cij. The decision variable of this problem will be xij, which is the amount of transportation from source i to sink j. To achieve an optimal or near optimal solution, It is necessary to adopt greedy heuristic approach by choosing the depots closer to the source as transhipment points (D7, D9 and D10) for onward distribution to the final destination. (See Figure 1).

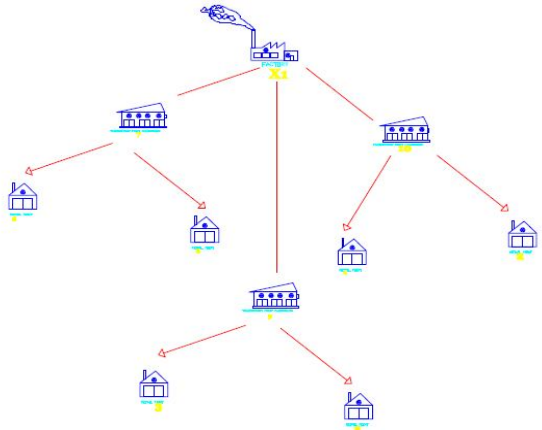


Fig I: Transshipment at Depot 7, Depot 9 and Depot 10

S/No	Source/Sink	Unit Cost from Source to Sink
1	Plant (Ai)	S_1 to S_1 = 0
2	Depot 2 (D_2)	S_1 to D_2 = 62
3	Depot 3 (D_3)	S_1 to D_3 = 62
4	Depot 4 (D_4)	S_1 to D_4 = 55
5	Depot 5 (D_5)	S_1 to D_5 = 50
6	Depot 6 (D_6)	S_1 to D_6 = 45
7	Depot 7 (D_7)	S_1 to D_7 = 35
8	Depot 8 (D_8)	S_1 to D_8 = 50
9	Depot 9 (D_9)	S_1 to D_9 = 35
10	Depot 10 (D_{10})	S_1 to D_{10} = 42

Table V: Unit Cost from Source to Sink

S/N	Source/Sink	Product Availability/Demand
1	Source 1/Depot 1	135,255 (A)
2	Depot 2	11,215 (D)
3	Depot 3	20,125 (D)
4	Depot 4	18,540 (D)
5	Depot 5	21,869 (D)
6	Depot 6	11,986 (D)
7	Depot 7	31,500 (D)
8	Depot 8	8,348 (D)
9	Depot 9	7,126 (D)
10	Depot 10	4,546 (D)

TABLE VI: Product Availability (S) and Demand (D) at Sources and Sinks

RESULTS AND DISCUSSIONS

The analysis was done using Tora Software version 2.0. Greedy heuristic approach was adopted and it gave

a satisfactory result. Least cost and Vogel approximation gave equal feasible and near optimal solution. The solution Min. Objective from source to transshipment points =N4,974,032, using greedy heuristic approach. The solution Min. Objective from transshipment points to final destinations using greedy heuristic approach =N2, 961,885. The solution Min. Objective from source to transshipment points using Vogel approximation method = N4, 974,032. Also the solution Min. Objective for from transshipment points to final destinations using Vogel approximation =N2, 961,885. (See Appendix). The solution Min. Objective from source to transshipment points using NWC method =N4, 974,032. Finally, the solution Min. Objective for from transshipment points to final destinations using NWC method =N5,743, 010. This is illustrated in Appendix .

In summary:

Total Cost of distribution from source to transshipment point and from transshipment point to final destination using LCM and VAM gives:

$$= \sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik} X_{ik} + \sum_{k=1}^{n}\sum_{j=1}^{m} C_{kj} X_{kj}$$

$$4{,}974{,}403 + 2{,}961{,}885 = N7{,}936{,}288$$

Total Cost of distribution from source to transshipment point and from transshipment point to final destination using NWCM gives:

$$= \sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik} X_{ik} + \sum_{k=1}^{n}\sum_{j=1}^{m} C_{kj} X_{kj}$$

$$4{,}974{,}403 + 5{,}743{,}010 = N10{,}717{,}413$$

In conclusion, the solution obtained from VAM and Vogel approximation outperforms the solution NWC method and the companys rule of thumb.

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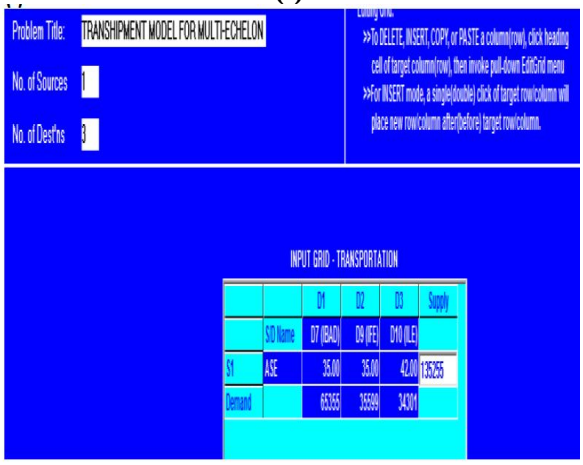
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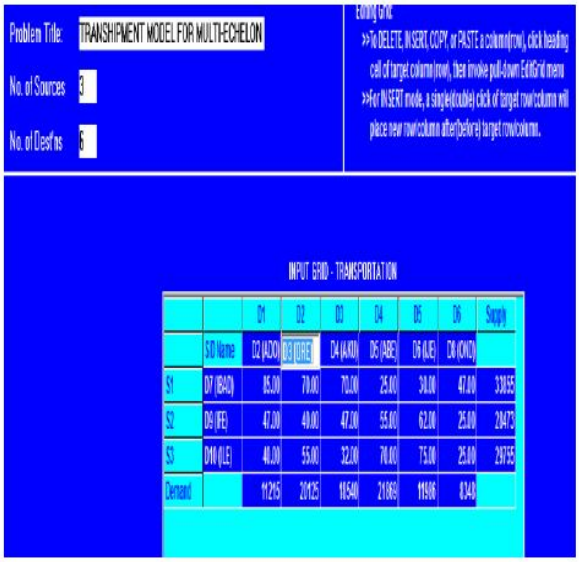
APPENDIX I

Input Grid For Product Flow From (I) Source To Transhipment Points (Ii) Transhipment Point To Final Destination

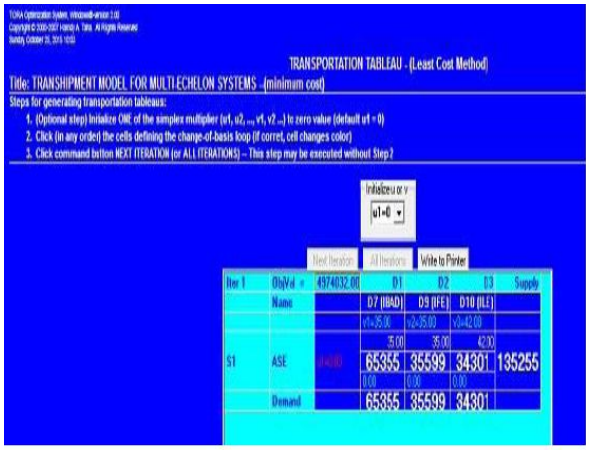
(I)



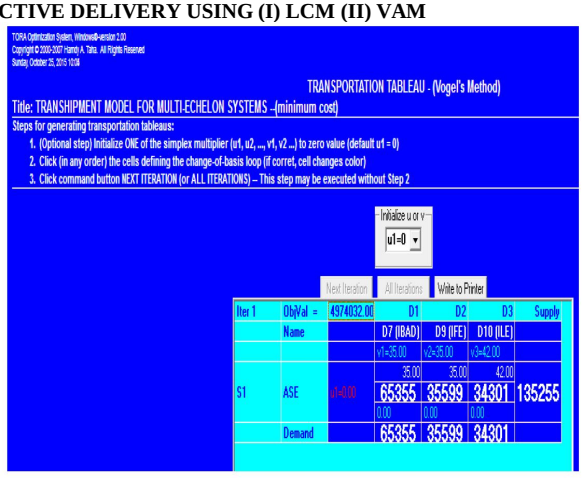
(II)



APPENDIX II OUTPUT RESULT FOR EFFECTIVE DELIVERY USING (I) LCM (II) VAM



(I)



(II)

★★★