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TRANSPORTATION OPTIMIZATION MODEL USING THE DISTANCE MATRIX: A CASE OF CEMENT SUPPLY IN EBONYI STATE

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ABSTRACT
Ascertaining an optimal cement distribution plan for cement companies in Nigeria has remained a challenge. The absence or fluctuation of data for estimating the cost of transporting cement from each source to each distribution center is a big stumbling block whenever modeling attempts are being made via transportation algorithms. This work has succeeded in removing these challenges by providing a Transportation Optimization Model for cement distribution using transportation Distance Matrix instead of transportation Cost Matrix. This research seeks to improve supply in the Nigerian cement industry. Three selected factories (Gboko, Port-Harcourt and Calabar) and four major distribution centers (Abakaliki, Onueke, Ohaozara and Afikpo) in Ebonyi state were considered for this work. The result of the findings using the Vogel Approximation Method, minimized the total transportation distance and by implication the total transportation costs.

Keywords: Transportation, Optimization Model, Distance Matrix, Supply and Demand

INTRODUCTION

For any business to be successful there is a need to acknowledge the crucial importance of organized logistics. Implementing a smooth logistics is a key element in keeping pace with customer's demand and outpacing competitors. Manufacturing companies that furnish their products from various factories to their respective destinations try to evolve transportation innovations as a method that would reduce the price of transportation (Nwekpa, 2015). According to Bowersox (2007), logistics is engaged in a wide range of important activities for the transfer of goods, services and related information. Modern industries rely on the movement of goods from areas of production to locations of demand. Ogwo and Agwu (2016) stressed the importance of the transportation sector to industrial viability when they asserted that product distribution from point of production to target market must fall within the right time, appropriate quality, expected quantity and right customers. Price, conditions of goods, company profit and customer satisfaction is influenced by transportation factor hence, an effective transportation increases economic value of products through the creation of time and place utility, and propagation of possession utility (Agbonifoh, Ogwo, Nnolim and Nkamnebe, 2007).

Nigeria's increasing population and concomitant demand for residential housing have increased demands for cement since the end of the Nigerian civil war. More so, availability and location of raw materials, unstable power supply, unfavorable government policies on production and importation, high set up capital and transportation cost are major impediments in meeting market needs of the cement industry (Mojekwu, Idowu and Sode, 2013). To reduce these challenges, there is need to lessen the distance between source of cement production and destination. Minimization of coverage distance in the movement of cement is informed by need to reduce delays in product delivery and eliminate several risks associated with long haul trucks. To minimize transportation cost and coverage distance, there is need for an optimal distribution plan that ensures timely delivery of cement products to delivery points using transportation optimization model. Abduljabbar (2013) formulated a transportation optimization model for oil products. The result of Abduljabbar (2013) treatise is the best refinery–to-depots assignments that minimized total transportation distance as well as the total transportation cost. The aim of this work is to determine an optimal distribution plan for cement from the three plants to the four distribution centers. The specific objectives include to: model the distribution of cement as a transportation problem using the transportation distance matrix, minimize the total transportation distance and recommending to the company the optimal distribution plan for cement transportation.

MATERIALS AND METHODS

For the purpose of this study, data were obtained from the selected three cements producing companies consisting of Dangote Cement (Benue State), Ibeto Holdings (Rivers State) and Unicen Cement Company (Cross River State) as well as their respective distribution centers in Ebonyi State namely; Abakaliki, Afikpo, Onueke and Oha-ozara. The data obtained were summarized as follows; Dangote Cement (Benue state) shipped 300 trailer loads of cements at full capacity of 800 bags each which gives a total supply of 240,000 bags of cement, Ibeto Holdings (River State) supplied 80 trailer loads of cement at full capacity of 700 bags each amounting to 56,000 bags, and Unicem (Cross River) supplied 150 trailer loads of cement at full capacity of 700 bags each to a total of 105,000 bags supplied. The shipment is done on a monthly basis (Nwekpa, 2015).

As earlier mentioned in this work that obtaining data on cost of transporting cement from each source to each distribution has become a challenge due to fluctuations in prices of diesel, spare parts and other levies, the option left to the researcher was only to make use of transportation distance matrix since cost of transportation can be ascertained to be proportional to the distance covered. This follows the thinking of Abduljabbar (2013).

In the light of the above, data on the distance from each source to each destination were sourced from the Nigerian Kilometer map/ distance calculator (Distance Calculator, 2021). The transportation distance matrix was obtained as the actual distance in kilometers of transporting cement from plant (source) to each destination (distribution centers). This is shown in Table 2.

Using the transportation distance (D_{ij}), the total demand and total supply constraints $\sum b_j$ and $\sum a_i$ respectively, capacity of the truck (V) as well as the number of vehicle trips (X_{ij}) from plant i to distribution center j, we adopted the transportation model of Abduljabaar (2013) in formulating the transportation problem of the Dangote cement distribution as a Linear Programming Problem. This is given below:

Minimize:

$$\mathbf{Z} = \sum_{i=1}^{3}\sum_{j=1}^{10} dij\, X_{ij} \dots \dots \dots \dots \dots \dots . (1)$$

Subject to

$$\mathbf{V}\sum_{J=1}^{10} X_{ij} = a_i, i = 1,2,3, \dots \dots \dots \dots . . (2)$$

(Supply Constraints)

$$V\sum_{i=j}^{3} X_{ij} = b_j, j = 1,2,3,4, \dots ,10 \dots \dots \dots (3)$$

(Demand Constraints)

Transportation Tableau

Each cell represents a shipping route. Supply availability (a_i) at each source is shown in the far right column and the destination requirements (b_j) are shown in the bottom row. The transportation distance (D_{ij}) is shown in the upper right corner of the cell, the number of vehicle trips(X_{ij}) is shown below the D_{ij}'s in each cell.

Table 1: The Transportation Tableau

Destination → Source ↓	d_1	d_2	d_3	d_4	**Source Supply**
S_1	D_{11} X_{11}	D_{12} X_{12}	D_{13} X_{13}	D_{14} X_{14}	a_1
S_2	D_{21} X_{21}	D_{22} X_{22}	D_{23} X_{23}	D_{24} X_{24}	a_2
S_3	D_{31} X_{31}	D_{32} X_{32}	D_{33} X_{33}	D_{34} X_{34}	a_2
Destination	b_1	b_2	b_3	b_4	

Vogel Approximation Method (VAM)

VAM is an enhance form of the least-cost method that usually, but not often, yields better initial results. VAM is established on the notion of reducing opportunity (or penalty) costs. The opportunity cost for a specified supply row or demand column is defined as the difference between the lowest cost and the next lowest cost alternative. The technique is an iterative process for calculating a basic feasible solution of a transportation problem. According to Taha (1992), this method is favored over the two methods discussed earlier, because the standing body of literature recognized that the initial basic feasible solution gotten by this method is either optimal or close to the optimal solution. Thus, it was adopted for this work. The Tora Optimization Software was used in the implementation of the Vogel Approximation method.

RESULTS

Table 2: Actual distance in kilometers of transporting cement from plant (source) to each destination (distribution centers).

DESTINATION SOURCE	ABAKALIKI	AFIKPO	ONUEKE	OHAOZARA	SUPPLY
DANGOTE (GBOKO)	148	199	167	194	240,000
IBETO (RIVERS)	211	160	191	166	56,000
UNICEM (CROSSRIVER)	154	112	138	132	105,000
DEMAND	220,000	100,000	38,000	43,000	

Table 3: Optimal Iteration Tableau using the Vogel Approximation Method

DESTINATION SOURCE	ABAKALIKI	AFIKPO	ONUEKE	OHAOZARA	SUPPLY
DANGOTE (BENUE)	148 **220000**	199	167 **38000**	194	240000
IBETO (RIVERS)	211	160	191	166 **38000**	56000
UNICEM (CROSSRIVER)	154	112 **100000**	138	132 **5000**	105000
DEMAND	220000	100000	38000	43000	

Note: Figures in bold are the optimal numbers of bags of cement.

Table 4. The optimal distribution plan for Dangote Cement

FROM SOURCE	TO DESTINATION	NUMBER OF BAGS X_{ij}	DISTANCE IN KILOMETER D_{ij}	$X_{ij} * D_{ij}$ (KM)
S1 :	D1:ABAKALIKI	220000	148	32560000
S1 :	D3: ONUEKE	38000	167	6346000
S2:	D4: OHAOZARA	38000	166	6308000
S3:	D2: AFIKPO	100000	112	11200000
S3:	D4: OHAOZARA	5000	132	660000
	TOTAL			**57074000**

DISCUSSION OF FINDINGS

The transportation distance matrix in Table 2 shows the actual distance of cement transportation from each plant to each destination. It also captures the demand and supply constraints of cement for the plants and destinations respectively. The longest distance (211km) of cement transportation is from Rivers to Abakaliki while the shortest distance (112km) is from Cross River to Afikpo. The distance matrix contains the actual kilometers by road from each plant to the various destinations. This matrix is used to replace the usual cost matrix employed in transportation problem of this nature. This as earlier stated was done to eliminate the challenges of estimating the cost of transporting a bag of cement due to numerous factors that can cause fluctuation in determining the cost of transporting cement. The researcher considered this replacement adequate since the total cost of transportation is proportional to the distance covered.

From the study, the cement companies are advised to adopt the optimal cement distribution plan as follows: From the Gboko factory 220,000 and 38,000 bags of cement should be made to Abakaliki and Onueke distribution centres respectively. From Unicem production plant, 100,000 and 5000 bags should be shipped to Afikpo and Ohaozara distribution centers respectively. The Ibeto production plant should be solely saddled with the responsibility of making 38,000 bags shipment to Ohaozara. See Table 3 for details.

This result minimizes the total transportation distance and by implication the total transportation costs. Comparing our work with the baseline research, we observed that the Gboko factory also shipped to Abakaliki and Onueke. The Unicem production plant was saddled with servicing Abakaliki center while the Ibeto factory is responsible for Afikpo and Ohaozara distribution centers respectively. It was clearly observed that both models gave an accurate optimal distribution plan.

CONCLUSION

The problem of minimizing the total transportation cost of Cement has been modeled as a transportation problem. An optimal distribution plan that will minimize the total transportation distance and by implication the total transportation cost can and has been determined in the face of plant (capacity) and destination (demand) constraints. Also, the challenge posed by lack of data on transportation costs from sources to destinations has been overcome by the use of the transportation distance matrix.

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