TRANSPORTATION OPTIMIZATION MODEL, ANALYSIS FOR CEMENT DISTRIBUTION AND RISK REDUCTION

Daniel, Eneojo Emmanuel,[1*] Udeh, Promise Chukwuedozie[2] Ibrahim, Isah[1] Abubakar Alechenu, Benard[1] and **Danhausa, Ahmed Azi[1]**

[1]*Department of Mathematics/Statistics/Computer Science, Federal University Kashere, Nigeria*

[2]*Nigeria Maritime University, Okerenkoko, Delta State*

Email: emmytetra@yahoo.com

Abstract

The dangers associated with articulate truck driving has led to calls on the need to reduce risk exposure in cement haulage industry. This study utilized the transportation distance matrix model to propose an optimal distribution plan in Dangote Cement Company, Nigeria. The need to reduce haulage truck travel distance is necessitated by loss of concentration, stress, strains and other risk factors associated with incessant road crashes which results into loss of lives and properties. Transportation Optimization Model was adopted for Dangote Cement Distribution. Study was conducted in three industrial locations, namely; Ibese, Obajana and Benue plants and ten major distribution centers namely; Aba, Owerri, Benin, Ikeja, Ondo, Abeokuta, Enugu, Anambra, Kano and Maiduguri distribution centers. The study recommended that, using optimal cement distribution plan on existing truck capacity, product distribution from Ibese production plant to Ikeja, Ondo and Abeokuta, 2200, 332 and 1050 truck trips should be made respectively. From Obajana production plant, 1075, 1150, 1200, 768, 776, 1025 and 2500 truck trips should be made to Aba, Owerri, Benin, Ondo, Enugu, Anambra, and Kano distribution centers and finally from Gboko production plant, 424 and 2140 truck trips should be made to Enugu and Maiduguri. Using the transportation optimization model, with a 4635835km distance, a grand total of 37,795784km distance would be minimized. Minimized kilometer will lower risk exposure from source to destination, thereby ensuring efficient service delivery in Dangote Cement Company.

Keywords: *Risk Factors, Transportation, Optimization Model, Distance Matrix*

1. Introduction

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 factors. Therefore, 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 transport system is largely done by road. Despite the poor condition of Nigeria roads, the subsector accounts for 90 percent of transportation sector's contribution to national Gross Domestic Product (GDP) (Proshareng, n.d). The transportation of perishable and weighty goods such as cements is tied to industrial decisions that minimize transportation distances to the optimal level of meeting market demands.

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. Truck driving is one of the most dangerous and demanding occupation in the world. Their large size and weight constitute serious dangers to road users. Studies by Adejugbade, Fatiregun and Alonge (2015) and Udeh and Nwogwugwu (2020) found that, long distance articulate trucks drivers are major contributors to road traffic crashes in Nigeria Adejugbade et al (2015) revealed that in Ibadan, South West Nigeria, there was about 57% reported road crashes in one year with cases of permanent disability, loss of company goods and deaths in most cases. Several reports of road crashes involving Dangote Cement haulage trucks shows the dangers of the activities of long distance articulate drivers and the need for the adoption of a transportation model that best reduces drivers stress, accidents and optimize timely delivery of cement products. Toromade (2020) reported that in January, six persons lost their lives to the reckless driving of a Dangote Cement truck in Lagos State, Nigeria. Other instances involving Dangote haulage trucks includes, the deaths of two persons in Lokoja, Kogi State (Akinfehinwa, 2020), seven people along the Lagos-Abeokuta expressway (Dimeji, 2020), four family members in Gaida, kano State and twenty five people in Ihiala, Anambra State, five in Enugu State, six along the Lokoja-Abuja expressway amongst others (Abubakar, 2020). Causes of articulate trucks accidents include stress, poor concentration, bad road networks, inadequate training on road signs, distraction and lack of attention, reckless driving, low level of education and religious fatalism (Udeh and Nwogwugwu, 2020). To minimize these accidents 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, his use of the transportation distance matrix will be employed in solving the transportation problem of Dangote Cement Company.

2. Objectives of the study

The primary objective of this study is to:

1. Determine the unknown X_{ij} that will minimize the total transportation distance and invariably, eradicate risks associated with cement delivery.

4. Materials and Method

Industrial Locations, Production and Conveyance Capacities

The secondary data for the study was sourced from Dangote Cement Plc. The total current production capacities (in Million Metric Tonnes Per Annum (MMTPA)) from its three existing cement plants are Obajana (10.25MMTPA), Ibese (6.0MMTPA) and Gboko (4.0MMTPA). Due to the difficulty in getting published data for the demand at the various distribution centers, expert opinion for average truck trips per week to each distribution centers were sort and the demand at the various distribution centers were therefore given as follows: Aba (1075 truck trips), Owerri (1150 truck trips), Benin (1200 truck trips), Ikeja (2200 truck trips), Ondo (1100 truck trips), Abeokuta (1050 truck trips), Enugu (1200 truck trips), Anambra (1025 truck trips), Kano (2500truck trips) and Maiduguri (2140 truck trips). The full truck capacity was also ascertained as 600 bags. Since a bag of cement is 50kg, this was used alongside the 600 bag full truck capacity in converting each plant capacity in MMTPA to number of trips per week. Data on the distance from each source to each destination were sourced from the Nigerian Kilometer map/ distance calculator (Distance Calculator, 2015). Distance from three supply source i (1, 2, 3) to ten demand destination j (1, 2, 3, 4, 5, 6, 7, 8, 9, 10) as D_{ij} . While X_{ij} is the number of vehicle trips from source i to destination *j*. The amount of supply at source i is a_i and the amount of demand at destination j is b_j .

The Optimal Distribution Plan/Solution

According to Taha (1992), a solution (set of values for the decision variables) for which all of the constraints in the solver model are satisfied is called a feasible solution. An optimal solution is a feasible solution where the objective function reaches its maximum (or minimum) value. Effective and efficient movement of products or services from point of supply to points of demand is crucial for any business. Transporting finished products to the market at lowest possible cost leads to huge potential of cost saving and consequently maximizes company's profit (Mendel, 2004). Optimal transportation also minimizes human errors and risks associated with long distance haulage driving. As such, it is imperative for Dangote Cement Company to seek to optimize their cement distribution plan in relation to the distance of transportation and the safety of its workers/drivers. Improvement in the transportation plan has significant impact to a company's bottom-line as research shows that a five percent reduction in transportation cost has similar impact as a 30 percent increase in company sales (Reeb and Leaveengood, 2000).

Obtaining an Optimal Solution

To obtain an optimal solution, there is need to make successive improvements to the initial basic feasible solution until no further decrease in the transportation cost is possible. An optimal solution is one where there is no other set of transportation routes that will further reduce the total transportation cost and exposure to risk. Thus, we have to evaluate each unoccupied cell in the transportation table in terms of an opportunity of reducing total transportation cost. An unoccupied cell with the largest negative opportunity cost is selected to be included in the new set of transportation routes (allocations). This value indicates the per unit cost reduction that can be achieved by raising the shipment allocation in the unoccupied cell from its present level of zero. This is also known as an incoming cell (or variable). The outgoing cell (or variable) in the current solution is the occupied cell (basic variable) in the unique closed path (loop) whose allocation will become zero first as more units are allocated to the unoccupied cell with largest negative opportunity cost. That is, the current solution cannot be improved further. This is the optimal solution. The widely used methods for finding an optimal solution are the Stepping stone method and the Modified Distribution (MODI) method. Since the initial basic feasible solution obtained by the Vogel approximation method is either optimal or very close to the optimal solution.

5. Formulation of Dangote Transportation Problem

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 source i to destination j, the study adopts Abduljabaar (2013) transportation model in formulating the transportation problem of the Dangote cement distribution as a Linear Programming Problem. This is given below;

Minimize:

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

Subject to

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

(Supply Constraints)

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

(Demand Constraints)

Balanced Transportation Problem

If the total supply equals the total demand then, the problem is said to be a balanced transportation problem, that is

$$\sum_{i=1}^{m} a_i = \sum_{i=1}^{n} b_j$$

Unbalanced Transportation Problem

If the total supply does not equal the total demand then the problem is said to be an unbalanced transportation problem that is;

$$\sum_{i=1}^{m} a_i \neq \sum_{i=1}^{n} b_j$$

There are two cases;

Case I

$$\sum_{i=1}^{m} a_i > \sum_{i=1}^{n} b_j$$

Case II

$$\sum_{i=1}^{m} a_i < \sum_{i=1}^{n} b_j$$

We can balance the transportation problem by introducing a dummy point since shipment to dummy point is not realistic. They are assigned a cost of zero. That is;

$$\sum_{i=1}^{n} b_j - \sum_{i=1}^{m} a_i = O$$

(Taha, 1992)

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_j …	d_{10}	**Source Supply**
S_1 ↓	D_1 X_{11}	D_{12} X_{12}	…D.. … X_{1j}	D_{10} X_{110}	a_1
S_2	D_2 X_{21}	D_{22} X_{22}	…D_2.. … X_{2j}	D_{210} X_{210}	a_2
S_3	D_3 X_{31}	D_{32} X_{32}	…D_{3j} … X_{3j}	.. D_{310} X_{310}	a_2
Destination	b_1	b_2	…b_j …	b_{10}	

Vogel Approximation Method (VAM)

VAM is an improved version of the least-cost method that generally, but not always, produces better starting solutions. VAM is based upon the concept of minimizing opportunity (or penalty) costs. The opportunity cost for a given supply row or demand column is defined as the difference between the lowest cost and the next lowest cost alternative. The method is an iterative procedure for computing a basic feasible solution of a transportation problem. This method is preferred over the two methods discussed earlier, because the existing body of literature established that the initial basic feasible solution obtained by this method is either optimal or very close to the optimal solution. Thus, it was adopted for this work.

Steps in Vogel Approximation

i. Identify the boxes having minimum and next to minimum transportation cost in each row and write the difference (penalty) along the side of the table against the corresponding row.

ii. Identify the boxes having minimum and next to minimum cost in each column and write the difference (penalty) against the corresponding column.

iii. Identify the maximum penalty. If it is along the side of the table, make maximum allotment to the box having minimum cost of transportation in that column.

iv. If the penalties corresponding to two or more rows or columns are equal, you are at liberty to break the tie arbitrarily

v. Repeat the above steps until all restrictions are satisfied.

The Tora Optimization Software, (Taha, 1992) was used in the implementation of the Vogel Approximation method.

6. The Transportation Distance Matrix

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

Destina-tion / Source	Aba	Owerri	Benin	Ikeja	Ondo	Abeokuta	Enugu	Anambra	Kano	Maiduguri	Supply
Ibese	554	586	286	60	251	59	303	372	808	1605	3846
Obajana	415	337	203	398	224	381	173	182	505	1039	8494
Gboko	428	304	478	587	414	576	182	234	474	677	2564
Demand	1075	1150	1200	2200	1100	1050	1200	1025	2500	2140	

Table 3: Optimal Iteration Tableau using the Vogel Approximation Method

Destination / Source	Aba	Owerri	Benin	Ikeja	Ondo	Abeokuta	Enugu	Anambra	Kano	Maiduguri	Dummy	Supply
Ibese	554	586	286	60 **2200**	251 **331**	59 **1050**	303	372	808	1605	0 **264**	3755
Obajana	415 **1075**	337 **1150**	203 **1200**	398	224 **768**	381	173 **776**	182 **1025**	505 **2500**	1039		8330
Gboko	428	304	478	585	414	576	182 **424**	234	474	677 **2140**		2555
Demand	1075	1150	1200	2200	1100	1050	1200	1025	2500	2140	264	

Note: Figures in bold are the optimal numbers of truck trips.

Table 4: The optimal distribution plan for Dangote Cement

From Source	To Destination	Number of Truck Trips $(X)_{ij}$	Distance In Kilometer $(D)_{ij}$	$X_{ij} * D_{ij}$ (KM)
S1 :IBESE	D4:IKEJA	2200	60.00	132000.00
S1 :IBESE	D5:ONDO	332	251.00	83332.00
S1: IBESE	D6: ABEOKUTA	1050	59.00	61950.00
S2: OBAJANA	D1:ABA	1075	415.00	446125.00
S2: OBAJANA	D2:OWERRI	1150	337.00	387550.00
S2: OBAJANA	D3:BENIN	1200	203.00	243600.00
S2: OBAJANA	D5: ONDO	768	224.00	172032.00
S2: OBAJANA	D7:ENUGU	776	173.00	134248.00
S2: OBAJANA	D8:ANAMBRA	1025	182.00	186550.00
S2: OBAJANA	D9:KANO	2500	505.00	1262500.00
S3: GBOKO	D2:ENUGU	424	182.00	77168.00
S3: GBOKO	D10:MAIDUGURI	2140	677.00	1448780.00
S1: IBESE	D11: DUMMY	264	0.00	000000.00
	TOTAL			4635835.00

7. Discussion of Findings

Several studies support that an optimal transportation distance reduces driving risk exposure and maximizes company profitability. Transportation distance matrix in Figure 2 shows that, the longest distance (1,605km) of cement transportation is from Ibese to Maiduguri while the shortest distance (59km) is from Ibese to Abeokuta. 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 challenge of estimating the cost of transporting a bag of cement due to the unavailability of data.

In the absence of transportation optimization model, Ibese plant (1602 truck trips multiplied by 4884km = 7824168), Obajana plant (8494 truck trips multiplied by 3857km = 32761358km) and Gboko plant (424 truck trips multiplied by 4354km=1846096km) equaled 42,431,622km. Using the transportation optimization model, with 4635835km distance (see Table 4); a grand total of 37,795784km distance would be minimized. The study considered this model adequate since the total cost of transportation is proportional to the distance covered.

8. Conclusion

The study concludes that:

1. The problem of minimizing the total transportation cost of Dangote Cement has been modeled as a transportation problem.
2. An optimal distribution plan that will minimize the total transportation distance and by implication the total transportation cost can and has been determined for the current truck capacity of 600 bags, in the face of plant (capacity) and destination (demand) constraints.
3. The risk posed by Dangote long distance cement haulage drivers' can be overcome using transportation distance matrix.

10. Recommendations

1. From the study, Dangote cement industry is advised to adopt the optimal cement distribution plan as follows: From the Ibese factory 2,200, 332 and 1,050 truck trips of cement should be made to Ikeja, Ondo and Abeokuta distribution centres respectively. 264 truck trips would be left in the Ibese factory for individual and private lifting. From Obajana production plant, 1,075, 1150, 1,200, 768, 776, 1025 and 2,500 truck trips of cement should be made to Aba, Owerri, Benin, Ondo, Enugu, Anambra, and Kano distribution centers. The Gboko production plant should be solely saddled with the responsibility of making 424 and 2,140 truck trips of cement to Enugu and Maiduguri. See figure 3 for details. The implementation as earlier mentioned is on weekly basis. This result minimizes the total transportation distance.

2. With a computed reduced distance of 37,795,784km, it is also expected that transportation distance matrix will reduce stress and risk factors such as the constant road traffic crashes, loss of lives and company properties. If the challenge of obtaining data on transportation costs is removed, the transportation cost matrix should be used in a future research for comparative and validation purposes

References

Abduljabbar, W. K. (2013). Transportation optimization model of oil products, *Scientific Research and Essays,* 8(5): 211-219.

Abubakar, A. M. (2020). Dangote truck kills four family members in Kano. Retrieved from https://www.premiumtimesng.com/regional/nwest/380838-dangote-truck-kills-four-family-members-in-kano.html

Adejugbade, A. M., Fatiregun, A. R. and Alonge, T. (2015). Epidemiology of road traffic crashes among long distance drivers in Ibadan, Nigeria. *African Health Science,* 15(2):480-488. Doi: 10.4314/ahs.v15i2.22.

Agbonifoh, B., Ogwo, O. E., Nnolim, D. A., and Nkamnebe, D. A. (2007). *Marketing in Nigeria: Concepts, principles and decisions, 2nd ed*. Aba: Afrowater Books.

Akinfehinwa, j (2020). Kogi: Two burnt to death in accident involving Dangote trailer. Retrieved from *https://dailypost.ng/2020/01/13/kogi-two-burnt-to-death-in-accident-involving-dangote-trailer/*

Bashkim, C., Roberta, B., Robert, K., and Valentina, S. (2015). Transportation Cost Optimization. *Academic Journal of Interdisciplinary Studies*. 4(2): 42-47.

CompanyHomeWebPage (2014) retrieved from https://dangote.com/aboutus/awardsandaccolades.aspx

Dantizig, G. B. and Wolfe, P. (1961). The Decomposition algorithm for linear programs econometrica: *Journal of the Econometric Society*, 29(4): 767-778.

Dimeji, K. A. (2020). Seven dead in Dangote truck accident on Lagos-Abeokuta expressway. Retrieved from https://www.premiumtimesng.com/regional/south-west/377497-seven dead-in-dangote-truck-accident-on-lagos-abeokuta-expressway.html.

Distance Calculator (2015). Available at: www.distancefrom-to.net

Mojekwu, J. N., Idowu, A. and Sode, O. (2013). Analysis of the contribution of imported and locally manufactured cement to the growth of gross domestic product (GDP) of Nigeria (1986-2011). African Journal of Business Management. Vol 75. Pp360-371.

Ogwo, E. O. and Agwu, G. A. (2016). Transport infrastructure, manufacturing sector performance and growth of gross domestic production in Nigeria. (1999-2011). Journal of Business and African Economy. Vol 2.

Taha, H.A. (1992). Operations Research: An Introduction, 5th Edition, Macmilan, New York.

Toromade, S. (2020). Cement truck crushes 6 to death in Lagos after coronavirus lockdown. Retrieved from hhttps://www.google.com/amp/s/www.pulse.ng/news/local/dangote-truck-crushes-6-to-death-in-lagos-after-coronaviruslockdown/vcjpzbk.amp

Transpot Statistics (n.d). Retrieved from https://www.proshareng.com/news/nigeria-economy/transport-statistics/14363

Tzeng, G.H, Teodorovic, D, and Hwang, M.J. (1996).Fuzzy Multi-index transportation problems for coal allocation planning.*European Journal of Operational Research*, 95: 62-72.

Uba, A.A., Abubakar, D. A., Nurudeen, G. A. (2013).Transshipment Optimization of Potable Water to Some Rural Areas in Gombe State Using Equal Demand from Two Created Depots. *European Journal of Business and Management* 5(29): 108-115.

Udeh, P. C. and Nwogwugwu, J. C. (2020). Safety training and road accident: Opinion Survey of Petroleum Tanker Drivers in Awka South, Anambra state, Nigeria. Direct Research Journal of Social Science and Educational Studies. Vol 7 (5), pp. 62-69.