KASU JOURNAL OF MATHEMATICAL SCIENCES (KJMS) VOL. 5, ISSUE 1, JUNE 2024
ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

KASU JOURNAL OF MATHEMATICAL SCIENCES

Transportation Optimization Model of Risk Reduction for Flour Distribution Plan in Dangote Flour Plants

Abdullahi, I.[1,*] , Usman, S. [2] , Yusuf O. O.[3] , Agaie, B. G.[4] Dauda, B. I[5].

[1,2,3,4,5]Federal University Dutse (FUD), P.M.B 7156 Dutse, Jigawa State, Nigeria

[*]Email: iabdullahi94@gmail.com, ibrahim.abdullahi@fud.edu.ng

Abstract

Reduced risk exposure in Dangote Flour haulage industry has been on calls due the dangers posed by articulate truck driving in Nigeria. In this paper, the transportation distance matrix model was used to propose an optimal distribution plan for Dangote Flour Company in Nigeria. The calls to reduce haulage truck travel distance is warranted by daily stress, strains, fatigue, loss of concentration and other related factors that usually lead to unnecessary road crashes thereby, resulted to loss of precious lives and properties. Transportation optimization was adopted for Dangote Flour Distribution to reduce the truck distance travel and enhanced the distribution of flours to the various destinations and thereby, reduce loss of lives and properties which in returned increased the profit maximization. The study conducted involved four Dangote flour industrial locations in the country (Ilorin, Apapa, Calabar, and Kano plants) and eight major distribution centers were considered (Sokoto, Ibadan, Ogun, Osun, Ebonyi, Kogi, Ekiti and Lagos distribution centers) for the purpose of this research. The data collected was used to obtained optimal flour distribution plan on existing truck capacity, product distribution from Ilorin production plant to Osun and Ekiti where 9,000 and 3,167 truck trips of flour should be made respectively to reduce risk and maximizing profit. From Apapa production plant to Lagos with 12,167 truck trips. From Calabar production plant to Ogun, Ebonyi, Kogi and Ekiti with 417, 7,000, 6,000, and 4,833 truck trips of flour respectively. Finally, from kano production plant, 6083 truck trips of flour should be send to Sokoto. The actual kilometers for these eight distribution centers from the four production plants is 18,510km, however, with application of transportation optimization model, the distance to be covered is 2,838km. This translates to a grant total of 15,672KM distance would be minimized and this would translate to lower risk exposure from production plants to destination centers, thereby, reduces loss of lives and properties and enhanced service delivery by Dangote Flour Company and thereby increase profits.

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

1. Introduction

The movement of goods from production sites to actual location of demands is key in the industrialization and development. In 1781 A French mathematician named Monge first formalized the transportation problem. However, it was not until the Second World War that Leonid Kontorovich, a Soviet/Russian mathematician, and economist, made significant advances

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

in the field. As a result, the problem is now sometimes referred to as the Monge-Kontorovich transportation problem. In 1942, Kontorovich released a paper on the continuous version of the problem. Later, Kantorovich and Gavurin (1949) adapted their research to the subject of capacitated transportation, Numerous scientific disciplines, such as operation research, economics, engineering, geographic information science, and geography, have contributed to the analysis of the transportation problem. Ogwo and Agwu (2016) opined that product distribution from the site of production to the destination should be within the appropriate time, maintaining standard quality and quantity and get the right customers. Transportation factors are key to industrial viability or otherwise. Transport-related factors have an impact on the cost, the state of the goods, business profitability, and customer happiness. As a result, efficient transportation boosts the economic value of goods by generating time and place utility and spreading possession utility, as explained by (Hitchcock., 1941, Abdullahi et.al. 2021). Hitchcock (1941) outlined the basis of the transportation issue and research titled "The Distribution of Product from Several Source to Destination”. The goal of the transportation problem is to find the shipment schedule that minimizes the overall shipping cost while satisfying supply and demand constraints (Abdullahi et.al. 2022). Nigeria’s increasing population and concomitant demand for wheat products in Nigeria which includes bread flour, confectionary flour, pasta semolina and bran (wheat offal). Dangote flour Mills is a subsidiary of Dangote group of industries limited which is one of Nigeria’s largest and fastest growing conglomerates meeting Nigerians flour needs and beyond. The location of raw materials, epileptic power, startup capital for the construction of the company and transportation are major obstacles in meeting the market demand of the flour (Abduljabar, 2013). Therefore, shortening the distance between the source of flour production plants and the actual destinations will reduce these impediments especially the transportation and loss lives and properties due to incessant accidents resulted from truck driving. Minimization of distance coverage during movement of flours to actual destinations is informed by need to reduce delays delivery of goods due to long distance covered and to reduce to the minimum possible the risks associated with truck driving which sometimes led to loss of lives and properties. Truck driving is one of the demanding and risky occupation one finds because of the might size and weight of the trucks which intimidate other road users and therefore, needs attention it deserves to drive them successfully. Alechenu & Danhausa (2021) and Udeh and Nwogwugwu (2020) are of the viewed that truck drivers covering long distance journeys are major contributors and road traffic and crashes in highways in Nigeria. It was revealed by them that in Ibadan, Southwest about 57% road crashes in one year which resulted to fatalities, permanent disabilities and loss of both company, public and individual properties occurred due to truck driving. Accidents involving articulated trucks can be caused by stress, poor concentration, poor road systems, a lack of road sign training, distraction and inattentiveness, irresponsible driving, and lack of education (Udeh and Nwogwugwu, 2020). The need for the adoption of a transportation model that best reduces drivers stress, accidents and optimize timely delivery of cement products cannot be overemphasized.

Toromade (2020) reported that in January, six persons lost their lives to the reckless driving of a Dangote truck in Lagos State, Nigeria. Death of two persons reported in Lokoja, Kogi State

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

(Akinfehinwa, 2020). Seven reported dead along the Lagos-Abeokuta expressway because of accident involving Dangote truck (Dimeji, 2020). Five persons in Ihiala, Anambra State, five persons in Enugu State, four people in Gaidan, Kano State, six persons reported dead along the Lokoja-Abuja expressway among others (Dimeji, 2020). Barely two days after some Dangote trucks were set on fire by some angry bobs for killing two persons, another Dangote truck caused multiple accidents in Ogun State where ten persons were reported killed as a result of brake failure (Oludare 2020). Traffic compliance and enforcement corps (TRACE) reported that a mob of secondary school students set ablaze a truck of Dangote group after killing a student on Friday (Babatunde 2021). As a result of excessive speeding, a truck of Dangote group fell into Ososa river in Ogun State and one corpse was recovered (Oludare 2021). Three lives were lost to a truck belonging to Dangote group when it rammed into a shop in Ogun State (Oludare 2023). Fifteen persons died while seven people sustained degrees of injuries along Bauchi-Jos Road, Bauchi State involving Dangote truck and other vehicles (Armstrong, 2023). Four killed, nine injured as two trucks crash in Plateau (James, 2024). On the premise of these incessant crashes, Dangote articulated truck driving school reported that 50 trainees who passed through a specially designed educational curriculum graduated. The school located at Obajana in Kogi State, Nigeria is the first accredited truck driving school (Armstrong, 2023). The result of Abduljabbar (2013) best refinery–to-depots assignments that minimized total transportation distance as well as the total transportation cost, i.e, the transportation distance matrix will be employed in solving the transportation problem of Dangote Flour Mills Company. The main objectives of this research are to Determine the unknown X_{ij} that will minimize the total transportation distance which by implication reduce the transportation and invariably, minimized risks associated with Flour delivery.

2. Materials and Method

Industrial Locations, Production and Conveyance Capacities. For the sake of this research data were sourced from Dangote Flour Mills plc for the three selected production plants namely: Apapa (Lagos State), Calabar (Cross River State), Ilorin (Kwara State) and Kano (Kano Sate). Dangote Flour mills Limited started operations in 1999 as a subsidiary of Dangote industries Ltd, one of Nigeria’s largest growing conglomerates. From an initial installed capacity of 500 metric tonne (MT) per day at its Apapa mill, it expanded very rapidly by adding three other flour mills in Calabar, Ilorin and Kano in the years 2000, 2005 and 2007 respectively. Each of the mills started with an installed capacity of 500 MT per day but three of were expanded resulting in a total of 4000MT per day distributed as follows: Apapa 1000 MT, Calabar 1500MT, Ilorin 1000 MT, and Kano 500 MT all per day. These expansions were in response to a growing National demand for flour and flour-based products and likewise company’s drive for increased market share. The total current production capacities (in Million Metric Tonnes Per Annum (MMTPA) from its four production plants are Apapa (0.365 MMTPA), Calabar (0.5475 MMTPA), Ilorin (0.365MMTPA), and Kano (0.1825 MMTPA). The data obtained summarized as follows; Dangote flour Ilorin (Kwara State) supplied 12167 trucks loads of 50k Flour at a full capacity of 600 bags annually.

KASU JOURNAL OF MATHEMATICAL SCIENCES (KJMS) VOL. 5, ISSUE 1, JUNE 2024
ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

Apapa (Lagos State) supplied 12167 trucks loads of 50kg Flour at a full capacity of 600 bags annually. Calabar (Cross River State) shipped 18250 trucks of loads of 50kg Flour at a full capacity of 600 bags each on annual basis, and Kano (Kano State) supplied 6,083 trucks loads of 50kg Flour at a full capacity of 600 bags every year. Due to the difficulty in getting published data for the demand at the various distribution centers, expert opinion for average truck trips per annum to each distribution centers were sort and the demand at the various distribution centers were therefore given as follows: Sokoto (12,000 truck trips), Ibadan (10,000 truck trips), Ogun (8000 truck trips), Osun (9000 truck trips), Ebonyi (7000 truck trips), Kogi (6000 truck trips), Ekiti (8000 truck trips), and Lagos (140000 truck trips). The full truck capacity was also ascertained as 600 bags. Since a bag of Flour is 50kg, this was used alongside the 600 bag full truck capacity in converting each plant capacity in MMTPA to number of trips per annum. Data on the distance from each source to each destination were sourced from the Google Map. Distance from three supply source i (1, 2, 3,4) to ten demand destination j (1, 2, 3, 4, 5, 6, 7, 8) 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

Taha (1992) defined a feasible solution as a solution (set of values for the decision variables) for which all the constraints in the solver model are satisfied. When the objective function reaches its maximum (or least) value, a solution is said to be optimum. Any business must be able to move goods or services effectively and efficiently from supply locations to demand points. Getting finished goods to market as cheaply as feasible has a significant potential for cost savings, which increases business profit (Novák and Popesko , 2014). Human errors and risks associated with long-distance haulage driving are also reduced by optimal transportation. As a result, Dangote Flour Company must strive to optimize their flour distribution plan in terms of transportation distance and worker/driver safety.

Obtaining an Optimal Solution

To obtain an optimal solution, successive improvements to the initial basic feasible solution must be made until no further reduction in transportation costs is possible. An optimal solution is one in which no other set of transportation routes can be used to reduce total transportation costs and risk. As a result, we must assess each unoccupied cell in the transportation table in terms of the possibility of lowering total transportation costs. To be included in the new set of transportation routes, an unoccupied cell with the highest negative opportunity cost is chosen (allocations). This value represents the per unit cost savings that can be obtained by increasing the shipment allocation in the unoccupied cell from its current level of zero. Another name for this is an incoming cell (or variable). The occupied cell (basic variable) in the one and only closed path (loop) that will become zero first as more units are assigned to the unoccupied cell with the biggest negative opportunity cost is the outgoing cell (or variable) in the current solution. In other words, the current solution cannot be further enhanced. This is the optimal solution. The Modified Distribution (MODI)

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

method and the Steppingstone method are frequently employed techniques for locating an ideal answer. As a result of the original basic viable solution being either ideal or extremely close to the optimal solution as found by the Vogel approximation approach.

3. 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 Abduljabar (2013) transportation model in formulating the transportation problem of the Dangote Flour distribution as a Linear Programming Problem. This is given below;

Minimize:

$Z = \sum_{i=1}^{4} \sum_{j=1}^{8} d_{ij} X_{ij}$ (1)

Subject to

V =∑_(j=1)^8, X_ij=a_i, i=1,2,3,4,…,8 (2)

(Supply Constraints)

V =∑_(i=j)^4, X_ij=b_j, j=1,2,3,4,…,8 (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

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

KASU JOURNAL OF MATHEMATICAL SCIENCES (KJMS) VOL. 5, ISSUE 1, JUNE 2024
ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

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;

$$\sum_{i=1}^{n} b_j - \sum_{i=1}^{m} a_i = 0$$

(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_i) 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_8	Source Supply
S_1	D_{11} X_{11}	D_{12} X_{12}	…	D_{18} X_{18}	a_1
S_2	D_{21} X_{21}	D_{22} X_{22}	…	D_{28} X_{18}	a_2
S_3	D_{31} X_{31}	D_{32} X_{32}	…	D_{38} X_{38}	a_3
S_4	D_{41} X_{41}	D_{42} X_{42}	…	D_{48} X_{48}	a_4
Destination	b_1	b_2	…	b_8	

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

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 Transportation Distance Matrix

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

Source (Google map)

It is observed that Demand is not equal to supply, this signify that it is an unbalanced problem. Here Total demand = 74000 is greater than Total Supply = 48667. Therefore, introduction of dummy supply constraint with 0-unit distance and with allocation of 25333. Now, the modified table is

KASU JOURNAL OF MATHEMATICAL SCIENCES (KJMS) VOL. 5, ISSUE 1, JUNE 2024
ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

DESTINATION / SOURCE	SOKOTO	IBADAN	OGUN	OSUN	EBONYI	KOGI	EKITI	LAGOS	SUPPLY
ILORIN	921	219	223	192	586	368	189	352	12167
APAPA	959	203	84	207	643	590	374	11	12167
CALABAR	1348	634	630	641	214	496	624	737	18250
KANO	482	867	871	790	736	593	652	2074	6083
S_{dummy}	0	0	0	0	0	0	0	0	25333
DEMAND	12,000	10,000	8000	9000	7000	6000	8000	14,000	

Table 3: Modified table after is make balanced.

Table 4: Initial Feasible solution using the Vogel Approximation Method

Initial feasible solution is

<table>
<tr><th></th><th>Sokoto</th><th>Ibadan</th><th>Ogun</th><th>Osun</th><th>Ebonyi</th><th>Kogi</th><th>Ekiti</th><th>Logas</th><th>Supply</th><th>Row Penalty</th></tr>
<tr><td>Ilorin</td><td>921</td><td>219</td><td>223</td><td>192(9000)</td><td>586</td><td>368</td><td>189(3167)</td><td>352</td><td>12167</td><td>3 | 3 | 3 | 3 | 3 | 3 | 30 | -- | -- | -- | -- | -- |</td></tr>
<tr><td>Apapa</td><td>959</td><td>203</td><td>84</td><td>207</td><td>643</td><td>590</td><td>374</td><td>11(12167)</td><td>12167</td><td>73 | 73 | 73 | 73 | 73 | -- | -- | -- | -- | -- | -- | -- |</td></tr>
<tr><td>Calabar</td><td>1348</td><td>634(1417)</td><td>630(8000)</td><td>641</td><td>214(7000)</td><td>496</td><td>624</td><td>737(1833)</td><td>18250</td><td>282 | 282 | 410 | 6 | 6 | 6 | 6 | 6 | 6 | 10 | -- | -- |</td></tr>
<tr><td>Kano</td><td>482</td><td>867(1250)</td><td>871</td><td>790</td><td>736</td><td>593</td><td>652(4833)</td><td>2074</td><td>6083</td><td>111 | 59 | 84 | 138 | 138 | 138 | 215 | 215 | 215 | 215 | 215 | 652 |</td></tr>
<tr><td>S_{dummy}</td><td>0(12000)</td><td>0(7333)</td><td>0</td><td>0</td><td>0</td><td>0(6000)</td><td>0</td><td>0</td><td>25333</td><td>0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- | -- |</td></tr>
<tr><td>Demand</td><td>12000</td><td>10000</td><td>8000</td><td>9000</td><td>7000</td><td>6000</td><td>8000</td><td>14000</td><td></td><td></td></tr>
<tr><td>Column Penalty</td><td>482
--
--
--
--
--
--
--
--
--
--
--</td><td>203
203
203
203
16
415
415
233
233
233
867
--</td><td>84
84
84
84
139
407
407
241
241
--
--
--</td><td>192
192
192
192
15
449
--
--
--
--
--
--</td><td>214
214
214
--
--
--
--
--
--
--
--
--</td><td>368
368
--
--
--
--
--
--
--
--
--
--</td><td>189
189
189
189
185
435
435
28
28
28
652
652</td><td>11
11
11
11
341
385
385
1337
--
--
--
--</td><td></td><td></td></tr>
</table>

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

Table 5. The Initial Feasible solution for distribution plan of Dangote Flours

FROM SOURCE	TO DESTINATION	NUMBER OF ALLOCATION X_{ij}	DISTANCE IN KILOMETER D_{ij}	$X_{ij} * D_{ij}$ KM
S1:Ilorin	D4: Osun	9000	192	1728000.00
S1: Ilorin	D7: Ekiti	3167	189	598563.00
S2: Apapa	D8: Lagos	12167	11	133837.00
S3: Calabar	D2:Ibadan	1417	634	898378.00
S3: Calabar	D3: Ogun	8000	630	5040000.00
S3: Calabar	D5:Kogi	7000	214	1498000.00
S3: Calabar	D8:Lagos	1833	737	1350921.00
S4: Kano	D2: Ibadan	1250	867	1083750.00
S4: Kano	D7:Ekiti	4833	652	3151116.00
S5: Sdummy	D1: Sokoto	12000	0	0.00
S5: Sdummy	D2:Ibadan	7333	0	0.00
S5: Sdummy	D6: Kogi	6000	0	0.00
	TOTAL		**4126KM**	**15482565.00**

Here the number of allocated cells = 12 is equal to $m + n - 1 = 5 + 8 - 1 = 12$. Therefore, the solution is non-degenerate.

The Optimality Test Using Modi Method.

After obtained the initial feasible solution using Vogel Approximation Method, we now further use MODI method for optimality test. The allocation table is

Table 6. The Initial Feasible solution using VAM

Optimality test using modi method...
Allocation Table is

	Sokoto	Ibadan	Ogun	Osun	Ebonyi	Kogi	Ekiti	Logas	Supply
Ilorin	921	219	223	192 (9000)	586	368	189 (3167)	352	12167
Apapa	959	203	84	207	643	590	374	11 (12167)	12167
Calabar	1348	634 (1417)	630 (8000)	641	214 (7000)	496	624	737 (1833)	18250
Kano	482	867 (1250)	871	790	736	593	652 (4833)	2074	6083
S_{dummy}	0 (12000)	0 (7333)	0	0	0	0 (6000)	0	0	25333
Demand	12000	10000	8000	9000	7000	6000	8000	14000	

KASU JOURNAL OF MATHEMATICAL SCIENCES (KJMS) VOL. 5, ISSUE 1, JUNE 2024
ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

The following steps are carried out.

1. Find u_i and v_j for all occupied cells (ij), where $c_{ij} = u_i + v_j$.
2. Find d_{ij} for all unoccupied cells (ij) where $d_{ij} = c_{ij} - (u_i + v_j)$,
3. Choose the minimum negative value from all d_{ij} (opportunity cost) and a draw a closed path,
4. Minimum allocated value among all negative position (-) on closed path, subtract from all (-) and add to all (+)
5. Repeat the step 1 to 4, until an optima solution is obtained.

Table 7. Final table of iteration

	Sokoto	Ibadan	Ogun	Osun	Ebonyi	Kogi	Ekiti	Logas	Supply	u_i
Ilorin	921 [726]	219 [24]	223 [28]	192 **(9000)**	586 [807]	368 [307]	189 **(3167)**	352 [157]	12167	u_1 = - 435
Apapa	959 [948]	203 [192]	84 [73]	207 [199]	643 [1048]	590 [713]	374 [369]	11 **(12167)**	12167	u_2 = - 619
Calabar	1348 [718]	634 [4]	630 **(417)**	641 [14]	214 **(7000)**	496 **(6000)**	624 **(4833)**	737 [107]	18250	u_3 = 0
Kano	482 **(6083)**	867 [385]	871 [389]	790 [311]	736 [670]	593 [245]	652 [176]	2074 [1592]	6083	u_4 = - 148
S_{dummy}	0 **(5917)**	0 **(10000)**	0 **(7583)**	0 [3]	0 [416]	0 [134]	0 [6]	0 **(1833)**	25333	u_5 = - 630
Demand	12000	10000	8000	9000	7000	6000	8000	14000		
v_j	v_1 = 630	v_2 = 630	v_3 = 630	v_4 = 627	v_5 = 214	v_6 = 496	v_7 = 624	v_8 = 630		

Since all $d_{ij\geq 0}$

Table 8. Optimal solution using MODI

So final optimal solution is arrived.

	Sokoto	Ibadan	Ogun	Osun	Ebonyi	Kogi	Ekiti	Logas	Supply
Ilorin	921	219	223	192 (9000)	586	368	189 (3167)	352	12167
Apapa	959	203	84	207	643	590	374	11 (12167)	12167
Calabar	1348	634	630 (417)	641	214 (7000)	496 (6000)	624 (4833)	737	18250
Kano	482 (6083)	867	871	790	736	593	652	2074	6083
S_{dummy}	0 (5917)	0 (10000)	0 (7583)	0	0	0	0	0 (1833)	25333
Demand	12000	10000	8000	9000	7000	6000	8000	14000	

ISSN 2734-3839 (Print), ISSN 2735-962X (E-Copy)
http://www.journal.kasu.edu.ng/index.php/kjms DOI/10.5281/zenodo.12647069.svg

Table 10. Optimal solution for Distribution plan

From Source	To Destination	Number Allocated X_{ij}	Distance in Kilometer D_{ij}	$X_{ij} * D_{ij}$
S1:Ilorin	D4: Osun	9000	192	1728000.00
S1:Ilorin	D7: Ekiti	3167	189	598563.00
S2:Apapa	D8: Lagos	12167	11	133837.00
S3:Calabar	D3: Ogun	417	630	262710.00
S3:Calabar	D5: Ebonyi	7000	214	1498000.00
S3:Calabar	D6: Kogi	6000	496	2976000.00
S3:Calabar	D7: Ekiti	4833	624	3015792.00
S4:Kano	D1: Sokoto	6083	482	2932006.00
S5:Sdummy	D1: Sokoto	5917	0	0.00
S5:Sdummy	D2: Ibadan	10000	0	0.00
S5:Sdummy	D3: Ogun	7583	0	0.00
S5:Sdummy	D8: Lagos	1833	0	0.00
	TOTAL		**2838KM**	**13144908.00**

5. Discussion of Findings

Studies have shown that an optimal transportation distance model reduces exposure to long distance health related problems such as fatigue, accidents among others. Therefore, increase the profits make by companies. The transportation distance matrix in Table 2 shows that longest transportation route for transportation of Flour is from Kano to Lagos (2074km) while the shortest distance is Apapa to Logas (11km). The distance matrix is the actual road mileage in kilometers from each plant to the location of interest. The distance matrix is used instead of the usual cost matrix in the transportation model due to unavailability of the cost data to transport each bag which lead to usual estimation. Without considering the optimization model, direct distribution from plants. From Distance matrix and production capacity in trucks in Table 2, Ilorin plant (3050KM), Apapa plant (3071KM) , Calabar plant (5324KM) and Kano plant (7065KM), summing up to 18,510KM. However, with the transportation optimization model (see Table 5); 4,126KM distance is to be covered to distribute the Flour trucks to their various destinations using VAM. Therefore, a grant total of **14,384KM** distance would be minimized. Furthermore, when optimality test using MODI method was employed, the distance to be covered is **2,838KM** which is an improved solution of initial feasible solution using VAM. With MODI method a further distance of **1,288KM** distance would be minimized. This translates to a grant total of **15,672KM** distance would be minimized.

Conclusion

The study concludes the challenge of reducing the overall cost of moving Dangote flour has been modeled as a transportation problem. Optimal distribution plan obtained from the solution using VAM and later enhanced it through MODI method will reduce the overall transportation distance to be cover and consequently minimized the transportation cost. The transportation cost has been determined for the existing trucks capacity of 600 bags putting into consideration plant capacity and demand (destination) constraints. Finally, the transportation distance matrix can be used to some extent reduce the risk posed by Dangote long distance Flour haulage drivers.

Recommendations

From the study, Dangote flour plants are advised to adopt the optimal flour distribution plan as follows: From the Ilorin plant, 9,000 and 3167 truck trips of flour should be made to Osun and Ekiti distribution centers respectively. From Apapa production plant, the entire 12167 truck trips of flour should be made to Lagos distribution center. The Calabar production plant should be solely saddled with the responsibility of making 417, 7000, 6000 and 4833 truck trips of flour to Ogun, Ebonyi, Kogi and Ekiti. And lastly, from Kano plant, 6083 truck trips of flour should be made to Sokoto distribution center. This implementation is on annual basis. This result minimizes the total transportation distance. It is further recommended that Sokoto, Ibadan, Ogun and Lagos should source for 5,917, 10,000, 7,583 and 1,833 truck trips respectively to their distributions since Dangote Flour plants could not meet their entire demand due plants capacity. From the initial table, it was observed that demand (destination) is higher than supply (plant capacities) and this led to introduction of dummy row to balance the transportation model. The shortages can be source from nearby Flour factories.

With a grand reduced distance of 15,672KM, it is expected that transportation distance matrix will reduce stress and risk factors such as the constant road traffics, crashes, loss of lives, driver's fatigue (such as back pain, pile and so on) and company properties. In future research, this approach could be adopted by other similar companies involved in transportation. It can be used for validation purposes.

References

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

Abdullahi, I., Usman, S., Kabir, G. I., Mustapha A., Yusuf, H. B. , Agaie, B. G. and Yisa, E. Optimal Allocation of Buses to Routes Using Linear Programming as a Tool in a Transport Service Authority: A Case Study of Kano State Transport Authority, Nigeria. (2022). Dutse Journal of Pure and Applied Sciences (DUJOPAS), 8(4b) 43-56.

Abdullahi, I., Usman, S., Aliyu, S. I., Yusuf, H. B., Kabir, G. I., & Agaie, B. G. (2021). Linear Programming Application in optimal allocation of Buses to Inter and Intra State Routes from Katsina State Transport Authority Service, Nigeria. *Dutse Journal of Pure and Applied Sciences (DUJOPAS), 7 (4a)*, 155-166.

Alechenu, B., & Danhausa, A. A. (2021). Transportation Optimization Model, Analysis for Cement Distribution and Risk Reduction. *Abacus (Mathematics Science Series)*, *48*(2).

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/*

Armstrong B. (2023). FRSC blames speeding as 15 die in Bauchi crash. Retrieved from https://punchng.com/frsc-blames-speeding-as-15-die-in-bauchi-crash/

Babatunde A. (2021). Mob sets Dangote truck ablaze for killing students. Retrieved from https://www.premiumtimesng.com/regional/ssouth-west/470037-again-mob-sets-dangote-truck-ablaze-for-killing-student.html?tztc=1

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

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*.

Hitchcock, F. L. (1941). The distribution of a product from several sources to numerous localities. *Journal of mathematics and physics*, *20*(1-4), 224-230.

James A. (2024). Four killed, nine injured as two trucks crash in Plateau. Retrieved from https://punchng.com/four-killed-nine-injured-as-two-trucks-crash-in-plateau/

Kantorovich, L. V. (1942). On the transfer of masses, Dokl. Akad. Nauk. SSSR, 37, 227-229.

Kantorovich, L. V., & Gavurin, M. K. (1949). Application of mathematical methods to problems of analysis of freight flows. *Problems of raising the efficiency of transport performance*, 110-138.

Novák, P., & Popesko, B. (2014). Cost variability and cost behaviour in manufacturing enterprises. *Economics and Sociology*.

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.

Oludare O. (2020). Dangote truck involved in another terrible road crash in Ogun. Retrieved from https://dailypost.ng/2020/01/02/dangote-truck-involved-in-another-terrible-road-crash-in-ogun/

Oludare O. (2021). Dangote cement truck plunges into river, one corpse recovered. Retrieved from https://dailypost.ng/2021/11/22/dangote-cement-truck-plunges-into-river-one-corpse-recovered/

Oludare o. (2023). Three traders killed as Dangote truck rams into shop in Ogun. Retrieved from https://dailypost.ng/2023/03/15/three-traders-killed-as-dangote-truck-rams-into-shop-in-ogun/

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

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