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Optimization of Shipping Cost of Cement for Selected Construction Projects of Julius Berger

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ABSTRACT

The Transportation modelling technique was adopted in solving the transportation problem of shipping cement from three supply locations (cement depots) to three demand locations (construction sites) for Julius Berger construction company in Port Harcourt. The research was carried out for standard 900 bag truck load of cement from the selected cement depots. Transportation costs of the cement were analysed and the initial feasible solutions obtained, using the North-West Corner, Least Cost, and Vogel's approximation methods. The Least Cost method resulted in the most feasible cost. Finally, the optimum shipping cost was attained, using the Stepping stone method, which resulted to an amount of $2,259 or (₦1,716,840 as at April 2023). Alternatively, Microsoft Excel solver was used on a computer in order to draw a comparison of the results. This gave exactly the same results.

Keywords—Cost of Cement, Optimization of Shipping Cost, Transportation Model

I. INTRODUCTION

The use of cement as a binder for Portland cement concrete, masonry, screeding, rendering, tiling, soil stabilization, rigid pavements and many more, has continually shown the relevance of the material in the construction and infrastructure industries. It is so important [1] that over 149kg/person [2] are being consumed in Nigeria. Cement is carried in 50kg bags for commercial use in Nigeria. These bags are loaded in 600 or 900 bag-trucks and transported across the country. They are stock in major cement depots and later transported according to the relevant demands. This process of shipping cement from one location to another is very important in the construction industry. However, studies such as [3] show that shipping of construction materials has not been thoroughly studied in a scholarly manner during risk assessment and procurement planning. Engineers, Construction practitioners and construction managers often find it difficult shipping materials, especially cement to their various site locations for construction. The cement depots in this research are referred to as the supply locations, while the site locations for construction are referred to as the demand locations. The process of transportation usually comes with management of transportation cost, time, personnel, cost of diesel, type of client, taxation, truck to be used, distance to demand location, traffic, demurrage, vendors, and local authorities. These are some of the numerous factors that contribute to the overall shipping costs of cement. This has now brought about the need to study and employ standard operational research techniques to optimise (minimize) the shipping cost of cement.

Several scholarly studies [4]–[11] have been conducted to management and transport construction materials and other items. [11] conducted a study on the management, control, planning, purchasing and handling of construction materials. In a bid to improve transportation of goods from one place to another, [6] developed a transportation model, using a modified generic algorithm for the vehicle fleet. Several others [4], [8]–[10] have since been conducted, but have been unable to address the problem of transportation of cement for construction purposes. However, a recent study by [12] utilised a transportation model technique that addressed a transportation problem for sand. None has been done for cement, so far.

This study is a continuation of [12], whereby, Julius Berger construction company of Nigeria was used as the case study. In the past eight years, Julius Berger construction company has been handling bridge construction, road construction, and building construction projects for the Government of Rivers state, in Nigeria. The company has the greatest number of construction projects awarded by the Rivers state government within the period under review (between years 2015 and 2023). The projects under review are only those sited in Port Harcourt, the capital city of Rivers state, and oil and gas hub of the nation, Nigeria. The city's high traffic volume, large population, and less road networks have created difficulties in the shipping of construction cement, usually transported in large trucks within the city and across the state. This study hopes to address the problem of

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transportation of cement from various supply locations to various demand locations, while reducing the number of trips, cost, social challenges, and emission of a methane gas from the trucks used for the transportation.

II. MATERIALS AND METHODS

The material used for this study was cement. Interviews were conducted on some site supervisors, site engineers, cement truck drivers, and project managers, of Julius Berger Construction Company. The cement depot managers were also interviewed. The trucks were those carrying 900 bags of cement per trip. The required number of trips per day and associated costs were estimated. The cost of transporting cement from three depots within Port Harcourt to three construction sites in Port Harcourt are shown in Table I. The amounts are in U.S Dollars, at the rate of ₦760 per US$ as at March 2023. The costs include cost of buying the cement, hiring a truck (when necessary), fuelling the truck, paying homages and taxes, and paying the driver's wages. The total cost was then divided by 30 tons to obtain the results shown below.

Table I: Transportation Distribution from Supply to Demand locations

min	Project Locations with transportation costs ($)			Availability or supply (trips of 900 bag trucks)
Cement depots	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)	
Dangote depot, PHC township (A)	131	145	135	7
Ibeto depot, PHC township (B)	138	144	141	5
Dangote depot, Onne (C)	213	222	200	3
Requirement or demand (trips of 900 bag trucks)	4	6	5	

a. The Simplex method of Solving a Transportation Problem

According to [13], the steps for solving a transportation problem are:

i. Formulate the problem and arrange the data in matrix form
ii. Obtain an initial feasible solution by the following three methods (choose the lowest result from these three):
- North-West Corner method
- Least Cost method (or inspection method)
- Vogel's approximation method (or penalty method, or opportunity cost method)

iii. Test the chosen feasible solution for optimality using either of the following two methods:
- Modified Distribution (MoDi) method
- Stepping stone method

iv. Update the solution and repeat the test until the optimal solution is reached.

The general form of a transportation model is:

$$Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \quad (1)$$

Subject to the constraints:
Supply constraint

$$\sum_{j=1}^{n} x_{ij} = a_i;\ i = 1,2,\dots,m \quad (2)$$

Demand constraint

$$\sum_{i=1}^{m} x_{ij} = b_j;\ j = 1,2,\dots,n \quad (3)$$

$x_{ij} \geq 0$; for all i and j

When $no.of\ allocations = m + n - 1$ (4)
it is a non-degenerate solution
However, when $no.of\ allocations < m + n - 1$ or $> m + n - 1$, (5)
then it is a degenerate solution.
For there to be a feasible solution,
$\sum Supply = \sum Demand$ (6)
This is referred to as the rim condition.

However, if $\sum Supply < \sum Demand$, a dummy row should be added, whose supply (availability) is $\sum Demand - \sum Supply$.

Similarly, if $\sum Supply > \sum Demand$, a dummy column should be added, whose demand (requirement) is $\sum Supply - \sum Demand$.

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For the given data,
m is 3, n is 3, and 3+3-1 is 5.
$\sum Supply = 15 \; and \; \sum Demand = 15$

Since supply and demand are equal, the rim condition is met.

III. RESULTS AND DISCUSSIONS

a. The North-West Corner method

This method was used to obtain an initial feasible solution as shown in Table II below.

Table II: Initial feasible solution by North-West Corner method

	X	Y	Z	s
A	131 4	145 3	135	7
B	138	144 3	141 2	5
C	213	222	200 3	3
d	4	6	5	

The total shipping cost = (4*131) + (3*145) + (3*144) + (2*141) + (3*200) = **$2,273**

b. The Least Cost method

This method was used to obtain an initial feasible solution as shown in Table III below.

Table III: Initial feasible solution by Least Cost method

	X	Y	Z	s
A	131 4	145	135 3	7
B	138	144 3	141 2	5
C	213	222 3	200	3
d	4	6	5	

The total shipping cost = (4*131) + (3*135) + (3*144) + (2*141) + (3*222) = **$2,309**

c. The Vogel's Approximation method

This method was used to obtain an initial feasible solution as shown in Table IV below.

Table IV: Initial feasible solution by Vogel's Approximation method

	X	Y	Z	s				
A	131	145 5	135 2	7	135-131 = 4	135-131 = 4	145-135 = **10**	145-145 = 0
B	138 4	144 1	141	5	141-138 = 3	141-138 = 3	450-446 = 3	450-446 = **3**
C	213	222	200 3	3	213-200 = **13**	N/A	N/A	N/A
d	4	6	5					
	135-131 = **7**	145-144 = 1	141-135 = 6					
	135-131 = **7**	145-144 = 1	141-135 = 6					
	N/A	145-144 = 1	141-135 = 6					
	N/A	145-144 = 1	N/A					

The total shipping cost = (5*145) + (2*135) + (4*138) + (1*144) + (3*200) = **$2,291**

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d. The Optimal solution

The method adopted to obtain the optimal feasible solution was the Stepping stone method as shown in Table VI below. From the three methods used above, the North-West corner method resulted in the minimum cost and most feasible solution. Hence, results from Table II were used here.

A positive sign was assigned to the first unoccupied cell. Next, a loop was created, linking the first unoccupied cell with the occupied cells, while alternating the sign conventions. The process was repeated for all the unoccupied cells as shown in Table V. The Values from each loop were summed up. The results show that the total values are not all positive, hence the solution is not yet optimal, further iteration would be required.

Table V: Determination of Constants for first iteration

		un						total
S/N		c						
1	11							
2	12							
3	13	135	-141	144	-145			-7
4	21	138	-144	145	-131			8
5	22							
6	23							
7	31	213	-200	141	-144	145	-131	24
8	32	222	-200	141	-144			19
9	33							

Table VI: Optimization solution using Stepping stone for first iteration

	X	Y	Z	s
A	131 4	145 3	135	7
B	138	144 3	141 2	5
C	213	222	200 3	3
d	4	6	5	

The total shipping cost = (4*131) + (3*145) + (3*144) + (2*141) + (3*200) = **$2,273**

The cell with the maximum negative total value was 1-3. Hence a loop was created with the lowest negative value as -2. This formed the basis of the second iteration.

Table VII: Determination of Constants for second iteration

		un						total
S/N		c						
1	11							
2	12							
3	13							
4	21	138	-144	145	-131			8
5	22							
6	23	141	-135	145	-144			7
7	31	213	-200	135	-131			17
8	32	222	-200	135	-145			12
9	33							

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The values in Table VII are all positive, hence the solution is optimal and there is no need for any further iteration.

Table VIII: Optimization solution using Stepping stone for second iteration

	X	Y	Z	s
A	131 / 4	145 / 1	135 / 2	7
B	138	144 / 5	141	5
C	213	222	200 / 3	3
d	4	6	5	

The optimum shipping cost = (4*131) + (1*145) + (2*135) + (5*144) + (3*200) = **$2,259**
In Table IX, Microsoft Excel solver was used as an alternative approach to obtain the optimum shipping cost.

Table IX: Optimal feasible solution using MS Excel

min	Project Locations with transportation costs ($)			Supply	Availability or supply (trips of 900 bag trucks)
Cement depots	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)		
Dangote depot, PHC township (A)	4	1	2	7	7
Ibeto depot, PHC township (B)	0	5	0	5	5
Dangote depot, Onne (C)	0	0	3	3	3
Demand	4	6	5		
Requirement or demand (trips of 900 bag trucks)	4	6	5		
Optimum shipping cost ($)	2,259				

The optimum shipping cost is **$2,259 (₦1,716,840)**. There were 5 allocations when the manual and computerised (MS excel) approaches of transportation modelling were used respectively. The optimum solution obtained turned out to be the same for both approaches.

IV. CONCLUSION

Cement loaded in 900bag-trucks was to be shipped from three depots (supply locations) to three construction sites (demand locations) in Port Harcourt respectively. The initial feasible solution was determined, using the North-West Corner, Least Cost, and Vogel's Approximation methods. These gave results of $2,273.00, $2,309.00, and $2,291.00 respectively. The North-West Corner method gave the lowest result, hence was selected for further analysis by the use of stepping stone method to obtain the optimal solution to the transportation problem. This was achieved after two consecutive iterations. This study has contributed to knowledge by applying Transportation modelling techniques to successfully address transportation of cement for construction purpose. Construction researchers, engineers, stakeholders, and construction practitioners can now adopt operational research approaches to better plan, manage, execute, and operate their construction projects as a result of the outcomes of this study.

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