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Optimization of Shipping Cost of Granite Chippings for Selected Construction Projects of Julius Berger

Kenneth Miebaka Oba
Department of Civil Engineering, Rivers State University, Port Harcourt, NIGERIA

Corresponding Author: kenneth.oba@ust.edu.ng

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ABSTRACT

Transportation modelling was employed to solve the transportation problem of shipping or transporting granite chippings from three supply locations (quarries) to three demand locations (construction sites) for Julius Berger construction company in Port Harcourt. The research was carried for standard 30tons tandem axle loads of granite from the various quarries. Transportation costs of the materials were analysed and the initial feasible solutions determined, 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 Modified Distribution method, which resulted to an amount of $14,875 or (₦11,305,000 as at March 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 Granite Chippings, Optimization of Shipping Cost, Transportation Model

I. INTRODUCTION

The use of granite as coarse aggregate for the batching and manufacture of Portland cement concrete, bituminous concrete, tiles, soil stabilization, base, paving and many more, has emphasized the great importance of granite chippings in the construction sector. Granite is gotten from igneous rocks disintegrated in a quarry to different grain sizes. It is then transported (or shipped) from the quarries to various locations of intended use. This process of shipping construction materials from one location to another is very critical in the construction industry. However, research shows that shipping of construction materials has not been given much attention during risk assessment and procurement planning [1]. Construction managers and practitioners often encounter difficulties shipping materials, especially granite chippings to their various intended locations for use. The quarries in this study are referred to as the supply locations, while the intended places of use are referred to as the demand locations. The transportation process often comes with management of transportation cost, personnel, time, cost of diesel, taxation, type of client, vehicle to be used, distance to demand location, vendors, traffic, and local authorities. These and many other factors contribute to the overall shipping or transportation cost of granite chippings. This calls for need to study and employ standard management techniques to optimise (minimize) the shipping cost of granite chippings.

Several scholarly researches [2]–[9] have taken place in order to management and transport construction materials and other items. [9] conducted a study on the control, management, planning, purchasing and handling of materials. In trying to find ways of improving transportation of commodities from one place to another, [4] developed a transportation model, using a modified generic algorithm for the vehicle fleet. Several other models and researches [2], [6]–[8] have since been carried out, but have been unable to address the problem of transportation of sand for construction purposes. However, a recent study by [10] came up with a model that addresses a transportation problem, not for granite, but for sand.

This study is a continuation of [10], whereby, Julius Berger, a leading construction company in Nigeria and Africa was the case study. In the past eight years, the company has been on several bridge construction, road construction, and building construction projects for the Government of Rivers state, Nigeria. The company has the greatest number of construction projects being executed by a single company within the period of this study (between years 2015 and 2023) in Rivers State. 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 large population, high traffic and few road networks have created difficulties in the transportation of construction materials, such as granite chippings, usually transported in large trucks within the city and across the state. This study will address the problem of transportation of granite from various supply locations to various demand locations, while reducing the cost, number of trips, and emission of a methane gas from the trucks used for the transportation.

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II. MATERIALS AND METHODS

The material used for this study was granite chippings. Some site engineers, project managers, dumper truck drivers, and site supervisors of Julius Berger Construction Company were interviewed. The required number of trips per day and associated costs, were cumulated. The cost of transporting granite chippings from three quarries outside Rivers state to three project locations in Port Harcourt are shown in Table I. The amounts are in U.S Dollars, as converted from Nigerian Naira at ₦760 per US$ as at March 2023. The costs include cost of buying the granite chippings, hiring a truck, fuelling the truck, paying the driver's wage, and paying homages and taxes. The total cost was then divided by 30 tons to obtain the results shown below.

Table I: Transportation Distribution from Supply to Demand locations

	Project Locations with transportation costs ($)			Availability or supply (30tons trip)
Quarries	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)	
Isiagwu (A)	450	435	461	12
Akamkpa (B)	446	453	450	14
Isialangua (C)	418	435	423	8
Requirement or demand (30tons trip)	10	11	13	

a. The Simplex Approach of Solving Transportation Problem

According to [11], the steps for solving a transportation problem are as follows:

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

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

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 $\sum Supply - \sum Demand$.

For the given data,

m is 3, n is 3, and 3+3-1 is 5.

$\sum Supply = 34\ and\ \sum Demand = 34$

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.

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

	X	Y	Z	s
A	450 / 10	435 / 2	461	12
B	446	453 / 9	450 / 5	14
C	418	435	423 / 8	8
d	10	11	13	

The total shipping cost = (10*450) + (2*435) + (9*453) + (5*450) + (8*423) = **$15,081**

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	450	435 / 11	461 / 1	12
B	446 / 2	453	450 / 12	14
C	418 / 8	435	423	8
d	10	11	13	

The total shipping cost = (11*435) + (1*461) + (2*446) + (12*450) + (8*418) = **$14,882**

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	450	435	461 / 12	12	450-435 = 15	450-435 = 15	450-435 = **15**	N/A
B	446 / 2	453 / 11	450 / 1	14	450-446 = 4	450-446 = 4	450-446 = 4	450-446 = 4
C	418 / 8	435	423	8	423-418 = 5	N/A	N/A	N/A
d	10	11	13					
	446-418 = **28**	435-435 = 0	450-425 = 27					
	450-446 = 4	453-435 = **18**	461-450 = 11					
	450-446 = 4	N/A	461-450 = 11					
	446-446 = 0	N/A	450-450 = 0					

The total shipping cost = (12*461) + (2*446) + (11*453) + (1*450) + (8*418) = **$15,201**

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d. The Optimal Solution

The method adopted to obtain the optimal feasible solution was the Modified Distribution (MoDi) method as shown in Table 6 below.

For occupied cells,

$$C_{ij} = u_i + v_i \quad (7)$$

and for unoccupied cells,

$$X_{ij} = u_i + v_i - C_{ij} \quad (8)$$

Where C_{ij} is the transportation cost for each cell, u, v, and X are constants. Note, the respective C_{ij} for occupied and unoccupied cells are to be used distinctly in Eqs. (7) and (8). The constant, u_1 is always equal to zero. From the three methods used above, the least cost method resulted in the minimum cost and most feasible solution. Hence, the results from Table 3 were used for the development of the optimal solution.

Table V: Determination of Constants for first iteration

					oc	un	
S/N			u	v	C	C_{un}	X_{un}
1	11					450	7
2	12	1	0	457	435		
3	13				461		
4	21				446		
5	22	2	-11	435		453	-29
6	23				450		
7	31				418		
8	32	3	-39	461		435	-39
9	33					423	-1

The X values are not all negative, hence the solution is not yet optimal, further iteration will be required.

Table VI: Optimization solution using MoDi for first iteration

			X	Y	Z	s
u_1=	0	A	450	435 11	461 1	12
u_2=	-11	B	446 2	453	450 12	14
u_3=	-39	C	418 8	435	423	8
		d	10	11	13	
			v_1= 457	v_2= 435	v_3= 461	

The total shipping cost = (11*435) + (1*461) + (2*446) + (12*450) + (8*418) = **$14,882**

Table VII: Determination of Constants for second iteration

					oc	un	
S/N			u	v	C	C_{un}	X_{un}
1	11				450		
2	12	1	0	450	435		
3	13					461	-7
4	21				446		
5	22	2	-4	435		453	-22
6	23				450		
7	31				418		
8	32	3	-32	454		435	-32
9	33					423	-1

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

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Table VIII: Optimization solution using MoDi for second iteration

			X	Y	Z	s
u_1=	0	A	450 1	435 11	461	12
u_2=	-4	B	446 1	453	450 13	14
u_3=	-32	C	418 8	435	423	8
		d	10	11	13	
			v_1= 450	v_2= 435	v_3= 454	

The optimum shipping cost = (1*450) + (11*435) + (1*446) + (13*450) + (8*418) = **$14,875**
In Table IX, Microsoft Excel solver was used as another alternative to obtain the optimum shipping cost.

Table IX: Optimal feasible solution using MS Excel

min	Project Locations with transportation costs ($)			Supply	Availability or supply (30tons trip)
Quarries	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)		
Isiagwu (A)	1	11	0	12	12
Akamkpa (B)	1	0	13	14	14
Isialangua (C)	8	0	0	8	8
Demand	10	11	13		
Requirement or demand (30tons trip)	10	11	13		
Optimum shipping cost ($)	14,875				

The optimum shipping cost in Naira is **₦11,305,000**. There were 5 allocations when the manual and MS excel approaches of transportation modelling were used respectively. The optimum results obtained were the same for both approaches.

IV. CONCLUSION

Granite chippings were to be transported from three quarries (supply locations) to three construction sites (demand locations). The initial feasible solution was obtained using the North-West Corner, Least Cost, and Vogel's Approximation methods. These resulted to $15,081.00, $14,882.00, and $15,201.00 respectively. The Least Cost method gave the lowest value, hence was chosen for further analysis by the use of Modified Distribution method to obtain the optimal solution to the transportation problem. This occurred after two consecutive iterations. This research has given transportation of granite chippings for construction purpose, a more standard approach by adopting Transportation modelling. Construction stakeholders, researchers and construction practitioners can now have better and more effective means of managing, planning, and executing their construction projects as a result of the knowledge added from this research.

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