Original Research Article

Optimization of Transportation Cost of Steel Reinforcement for some Construction Projects of Julius Berger

ABSTRACT

The Transportation modelling approach was employed in solving the transportation problem of shipping steel reinforcement from three supply locations (steel depots) to three demand locations (construction sites) for Julius Berger construction company in Port Harcourt. The study was done for 100-ton truck load of steel reinforcement bars with standard 12m lengths and diameters 8mm to 40mm. This was from the three selected steel depots in Port Harcourt. The costs of transporting the steel reinforcement bars 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 lowest cost. Finally, the optimum shipping cost was obtained, using the Stepping stone method after three consecutive iterations, which amounted to $3,813 or (₦2,897,880 as at March 2023). The Microsoft Excel solver was later used on a computer to obtain the optimal solution as well as form a basis for a comparison with the analytical results. The results were found to be the same.

Keywords: Cost of Reinforcement, Julius Berger, Optimization of Shipping Cost, Transportation model.

1. INTRODUCTION

Steel is widely used globally in several industries for different purposes. The construction, and oil and gas industries have so far been the most beneficiaries of steel. Steel is mostly used as reinforcement and structural steel in columns, foundations, beams, slabs, stairs, girders, and other structural members in construction. The case is very much the same in Nigeria as most buildings are made of reinforced concrete. In [1] Nigeria's estimated annual steel consumption as at 2020 was 150kg/capital. This huge amount of steel and even more, are transported across the country for various construction works. Transportation of steel reinforcement is the process of shipping steel reinforcement from one location to another, and this is very critical in the Nigerian construction industry. Some studies such as [2] however, posit that shipping of construction materials has not been given much academic and scholarly intervention while considering the procurement planning and risk assessment for construction purposes. This is why Engineers, construction managers, and construction practitioners are regularly faced with difficulty in the management of shipping construction materials, especially reinforcing steel to their various construction sites. The reinforcement steel bars of varying diameters are of standard 12m lengths that are shipped from depots herein referred to as the supply locations, to construction sites herein referred to as the demand locations. The transportation process often entails management of transportation cost, personnel, time, cost of diesel, taxations, type of client, truck to be used, traffic, distance to demand location, demurrage, local authorities, and vendors. These are some of the many factors that affect the overall shipping costs of steel reinforcement for construction. There is therefore a need to explore standard operations research techniques to optimise (minimize) the shipping cost of steel reinforcement.

In the past, studies by [3], [4], [5], [6], [7], [8], [9], [10] were done to manage and transport construction materials and other items. An article by [10] on the management, planning, control, purchasing and handling of construction materials was successfully published. In a bid to improve transportation of goods from one place to another, [5] formulated a transportation model, using a modified generic algorithm for the vehicle fleet. Several others similar studies [3], [7], [8], [9] have since been conducted, but have been unable to address the problem of transportation of steel reinforcement for construction purposes. However, a recent study by [11] utilised a transportation model technique that addressed a transportation problem for sand. This means that, no such scholarly article has been published for steel reinforcement, so far.

This study is a continuation of a series of research from [11], whereby, Julius Berger construction company of Nigeria was the case study. In the past eight years, Julius Berger construction company had been executing various road construction, bridge construction, and building construction projects for the Government of Rivers state, in Nigeria. Within the period under review (between years 2015 and 2023) Julius Berger construction company owned the greatest number of construction projects awarded by the Rivers state government. However, only projects sited in Port Harcourt, the capital city of Rivers state, and oil and gas hub of the nation, were the projects in the scope of this research. Port Harcourt's large population, high traffic volume, and less road networks have made transportation of steel reinforcement, and construction materials in general, more difficult. This study aims at addressing the problem of transportation of steel reinforcement from various supply locations to various demand sites in a sustainable manner, while reducing the cost, number of trips, social issues, and emission of greenhouse gases from the trucks used for the shipping.

2. RESEARCH METHODOLOGY

The material used for this study was steel. Interviews were conducted on some truck drivers, site supervisors, project managers, site engineers, and vendors of Julius Berger Construction Company. Some sellers of steel reinforcement at the three supply locations were also interviewed. The trucks were those carrying a maximum of 100 tons load of steel reinforcements of standard 12m length, and diameters ranging from 8mm to 40mm. The required number of trips per day and associated costs were calculated with the information gathered from the interviews. The cost of shipping steel reinforcement from three locations within Port Harcourt to three construction sites in Port Harcourt are shown in Table 1. The amounts have been converted to U.S Dollars, at ₦760 per US$ as at March 2023. The costs include cost of hiring a truck (when necessary), buying the steel reinforcement, fuelling the truck, paying the driver's wages, and paying homages and taxes for every 100 tons of steel transported. These are shown in Table 1 below.

Table 1.Ttransportation Distribution from Supply to Demand sites

minimization	Project Locations with transportation costs ($)			Availability or supply (trips of 100 tons trucks)
Steel depots	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)	
Kala (A)	100	197	88	9
Mile 3 (B)	132	201	112	4
Iriebe steel village (C)	238	93	206	20
Requirement or demand (trips of 100 tons trucks)	11	15	7	

2.1. The Simplex method of solving a Transportation problem

The steps for solving a transportation problem were outlined in [12] 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:

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

S ,

Supply constraint

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

Demand constraint

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

$x_{ij} \geq 0;$ 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.

$\sum Supply = 33\ and\ \sum Demand = 33$

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

3. RESULTS AND DISCUSSION

3.1. The North-West corner method

This method was used to obtain an initial feasible solution. The first allocation was made to the cell at the top left or North-West corner such that the smaller of the supply or demand was satisfied. The process was repeated in a step-wise manner until all appropriate allocations were made. This is shown in Table 2.

Table 2.Initial feasible solution by North-West Corner method

	X	Y	Z	s
A	100 9	197	88	9
B	132 2	201 2	112	4
C	238	93 13	206 7	20
d	11	15	7	

The initial shipping cost = (9*100) + (2*132) + (2*201) + (13*93) + (7*206) = **$4,217**

3.2. The Least Cost method

This method was used to obtain an initial feasible solution. The first allocation was to the least or lowest value in Table 3. This was done such that the smaller of the supply or demand was satisfied. The process was repeated until all appropriate allocations were made.

Table 3.Initial feasible solution by Least Cost method

	X	Y	Z	s
A	100 2	197	88 7	9
B	132 4	201	112	4
C	238 5	93 15	206	20
d	11	15	7	

The initial shipping cost = (2*100) + (7*88) + (4*132) + (5*238) + (15*93) = **$3,929**

3.3. The Vogel's Approximation method

Table 4 shows the results from this method in obtaining an initial feasible solution. On the first row, the difference between the least value and the second to least value was determined. This was also done on the first column. The highest of all the results was chosen as the position for the first allocation to be made such that the smaller of the supply or demand was satisfied. This process was repeated until all appropriate allocations were made.

Table 4.Initial feasible solution by Vogel's Approximation method

	X	Y	Z	s				
A	100 7	197 2	88	9	100-88 = 12	100-97 = 97	100-97 = **97**	100-100 = 0
B	132 4	201	112	4	132-112 = 20	132-201 = 69	132-201 = 69	132-132 = 0
C	238	93 13	206 7	20	206-93 = **113**	238-93 = **145**	N/A	N/A
d	11	15	7					
	132-100 = 32	197-93 = 104	112-88 = 24					
	132-100 = 32	197-93 = 104	N/A					
	132-100 = 32	201-197 = 4	N/A					
	132-100 = **32**	N/A	N/A					

The initial shipping cost = (7*100) + (2*197) + (4*132) + (13*93) + (7*206) = **$4,273**

3.4. The Optimal solution

The stepping stone method was adopted to obtain the optimal feasible solution as shown in Tables 5 to 10 below. From the three methods used to determine the initial feasible solution, the Least cost method resulted in the most feasible solution and lowest cost. This means the results obtained from Table 3 will be used for the first iteration to obtain the optimal shipping cost.

A positive sign was assigned to the first unoccupied cell. A loop was later created, to link the first unoccupied cell with the occupied cells within that loop, with alternating sign conventions. This process was repeated for all the unoccupied cells as shown in Table 5. The summation of all the values from each loop was obtained. The results indicate that there is a negative sign convention., hence the solution is not yet optimal, and there would be further iteration.

Table 5.Determination of constants for first iteration

		un						total
S/N		c						
1	11							
2	12	197	-93	238	-100			242
3	13							
4	21							
5	22	201	-93	238	-132			214
6	23	112	-132	100	-88			-8
7	31							
8	32							
9	33	206	-238	100	-88			-20

Table 6.Optimization solution using stepping stone for first iteration

	X	Y	Z	s
A	100 2	197	88 7	9
B	132 4	201	112	4
C	238 5	93 15	206	20
d	11	15	7	

The total shipping cost = (2*100) + (7*88) + (4*132) + (5*238) + (15*93) = **$3,929**

The cell that has the maximum negative total value from Table 5 is 3-3. Hence a loop was created with the lowest negative value as -5. This formed the basis of the second iteration as 5 is subtracted and added within the loop according to the assigned sign convention.

Table 7.Determination of constants for second iteration

		un						total
S/N		c						
1	11							
2	12	197	-93	206	-88			222
3	13							
4	21							
5	22	201	-132	100	-88	206	-93	194
6	23	112	-132	100	-88			-8
7	31	238	-206	88	-100			20
8	32							
9	33							

Table 8.Optimization solution using stepping stone for second iteration

X Y Z s

A	100 7	197	88 2	9
B	132 4	201	112	4
C	238	93 15	206 5	20
d	11	15	7	

The total shipping cost = (7*100) + (2*88) + (4*132) + (15*93) + (5*206) = **$3,829**

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

Table 9.Determination of constants for third iteration

S/N		un c						total
1	11							
2	12	197	-93	206	-112			198
3	13	88	-100	132	-112			8
4	21							
5	22	201	93	-206	112			200
6	23							
7	31	238	-206	112	-132			12
8	32							
9	33							

Since all the values in Table 9 are positive, the solution is therefore optimal, and there will be no more iteration.

Table 10.Optimization solution using stepping stone for third iteration

	X	Y	Z	s
A	100 9	197	88	9
B	132 2	201	112 2	4
C	238	93 15	206 5	20
d	11	15	7	

The optimum shipping cost = (9*100) + (2*132) + (2*112) + (15*93) + (5*206) = **$3,813**

In Table 11, Microsoft Excel solver was used as a comparison, to obtain the optimum shipping cost.

Table 11.Optimal feasible solution using MS Excel

min	Project Locations with transportation costs ($)			Supply	Availability or supply (trips of 100 tons trucks)
Steel depots	N.T.A flyover (X)	Rumukwurusi flyover (Y)	Rumuokuta flyover (Z)		

Kala (A)	9	0	0	9	9
Mile 3 market (B)	2	0	2	4	4
Iriebe steel village (C)	0	15	5	20	20
Demand	11	15	7		
Requirement or demand (trips of 100 tons trucks)	11	15	7		
Optimum shipping cost ($)	**3,813**				

The optimum shipping cost is **$3,813 (₦2,897,880)**. This was obtained from 5 allocations exactly the same way as the result from the computer, using MS excel solver.

4. CONCLUSION

The steel reinforcement bars loaded in 100tons-trucks to be shipped from three steel depots (supply locations) to three construction sites (demand locations) in Port Harcourt have been successfully allocated using the transportation modelling technique. The initial feasible solution was determined. This was done by the use of the North-West Corner, Least Cost, and Vogel's Approximation methods. The results obtained were $4,217.00, $3,929.00, and $4,223.00 respectively. This indicates that the Least Cost Corner method gave the lowest result, hence was selected and subjected to test for optimality, using of stepping stone method. The optimal solution was achieved after three consecutive iterations with an optimum shipping cost of $3,929.00. This study has contributed to knowledge by applying Transportation modelling techniques to successfully address transportation of steel reinforcement for construction purposes. Construction stakeholders, engineers, researchers, and practitioners can now adopt operations research techniques to better organise, manage, plan, execute, and operate their construction projects as recommended by this study.

CONSENT (WHEREEVER APPLICABLE)

No written consent note of any sort is required for this manuscript.

ETHICAL APPROVAL (WHEREEVER APPLICABLE)

No ethical approval of any sort is required for this manuscript.

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