



A CASE STUDY FOR OPTIMIZING COST IN THE METAL INDUSTRY

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ABSTRACT The metal industry lies unexplored by researchers and in terms of Operations research and has a lot of scope in terms of data availability for determination of transportation problem, assignment problem, and other methods of arriving at the optimality of processes. This paper highlights the transportation costs of the metal keeping for Amee Metals Private Company as the basis for the data. The main operations of the company are based in Panvel, Mumbai and the majority of demand and supply centres are located in the state of Maharashtra. To arrive at the feasible and optimum costs, Solver tool of Excel has been used. Furthermore, sensitivity analysis has been conducted. A new method of evaluating costs, which is the ASM method is used.

KEYWORDS : Transportation Problem, ASM Method, Optimality, Metal industry

INTRODUCTION

Constant infrastructural development and automotive production are driving growth in the Metals and mining sector in India. In India, the second largest non-ferrous metals market is Copper in terms of production.

With the Government's 'Make in India' and 'Smart City' initiatives, the demand for non-ferrous metals like copper is going to increase, but on the other hand the industry is also facing challenges to decrease costs and support technological innovation.

India constitutes for only 2% of the world reserves of copper. Hence, the supply of raw materials are limited from very few locations and costs involved are high.

The company Amee Metals Pvt. Ltd. was founded in 1983. The company has three manufacturing plants located in Panvel, Ahmedabad and Bikaner. The company has 15 skilled, experienced staff and labour force of 70 workmen. The company is recognised as a well – known manufacturer and exporter in the field of copper tubes, brass tubes, copper tube fittings, seamless copper tube and a wide range of copper alloy tube. We intend to bring optimality by reducing the transportation costs and maximise profits. The paper focuses on optimization of transportation cost for the supply of raw materials from source to destination for the Raipur Steel and Thermal power plant. Data was collected manually by analysing data cost sheets of the plant for 30 days. It was used to prepare the Transportation Model using various softwares namely, TORA, LINGO and What's Best Solver. The the plant can save a total of Rs. 11589.46 in 30 days which can be utilized for increasing the production capacity by 1.37%.

The paper aims to find a new method for finding an optimal solution for solving a wide range of transportation problems, directly. The method is named the ASM Method and is found to be very lucrative for those decision makers who are dealing with logistics and supply chain related issues. We plan to use the above method for solving our transportation problem along with other methods to check the efficiency of the same. (Quddoos and Javaid, 2012).

METHODOLOGY

Mathematically, a transportation problem is nothing but a special linear programming problem in which the objective function is to minimize the cost of transportation subjected to the demand and supply constraints.

The transportation problem applies to situations where a single commodity is to be transported from various sources of supply (**origins**) to various demands (**destinations**). Let there be m sources of supply s_1, s_2, \dots, s_m having a_i ($i = 1, 2, \dots, m$) units of supplies respectively to be transported among n destinations d_1, d_2, \dots, d_n with b_j ($j = 1, 2, \dots, n$) units of requirements respectively.

Let c_{ij} be the cost for shipping one unit of the commodity from source i , to destination j for each route. If x_{ij} represents the units shipped per route from source i , to destination j , then the problem is to determine the transportation schedule which minimizes the total

transportation cost of satisfying supply and demand conditions.

Source: <https://www.wisdomjobs.com/e-university/quantitative-techniques-for-management-tutorial-297/mathematical-formulation-9881.html>

The basic elements in any transportation problem are:
I. Balanced and Unbalanced Problem:

- If in the problem the total supply = Total demand, then the problem is said to be a balanced Transportation problem.
- If in the problem the Total supply is not equal to the total demand, then the problem is said to be an unbalanced Transportation problem and a dummy column or row is added in order to convert the problem into a balanced problem.

II. Origin

It is the location from which shipments are dispatched.

III. Destination

It is the location to which shipments are transported.

IV. Unit Transportation Cost

It is the cost of transporting one unit of the consignment from an origin to a destination.

V. Feasible Solution

A feasible solution of $(m \times n)$ transportation problem is said to be a best feasible solution, when the total number of allocations is equal to $(m + n - 1)$.

VI. Optimal Solution

A feasible solution is said to be optimal solution when the total transportation cost will be the minimum cost.

Primary data was collected was a known source in the company. Along with the unit costs, routes and current allocation of the resources, it was found that Panvel, Ahmedabad and Bikaner were Demand destinations and Umargao, Baroda and Rabale are the supply Origins.

The cost of transportation has been collected through a primary source and is hence subject to bias and manipulation. However, the authors find it to be a limitation and have taken necessary assumptions to continue with their study.

Table 1: Per unit of cost of transportation and total demand and supply

LOCATION	PANVEL	AHMEDABAD	PUNE	DUMMY	SUPPLY
UMARGAM	2.75	6.125	3.5	0	4000
BARODA	3.625	0.95	4.375	0	4000
RABALE	1	18	4.25	0	2000
DEMAND	3500	2400	3100	1000	10000

The demand and supply of respective locations have been indicated against their names and the dummy column has been added in order to satisfy the condition of a transportation problem that the demand and supply must fully tally since the problem was unbalanced in raw form.

Using solver tool in excel, the allocations optimum to the problem have been achieved. In this case, some centres do not supply to particular locations in order to save cost.

Table 2: Optimum allocations (kg of metal); achieved using Solver

LOCATION	PANVEL	AHMEDABAD	PUNE	DUMMY	SUPPLY
UMARGAM	1500.00	0.00	2500.00	0.00	4000
BARODA	0.00	2400.00	600.00	1000.00	4000
RABALE	2000.00	0.00	0.00	0.00	2000
DEMAND	3500	2400	3100	1000	10000
TOTAL COST	19780				

The rim condition for any transportation problem is calculated using the following formula:
 Rim condition = m+n-1 where;
 m=Number of columns
 n= Number of rows

The rim condition is satisfied if the number of allocations is equal to the rim condition.

For our transportation problem, the number of allocations is 6 which satisfy the rim condition. This implies that the solution obtained is non-degenerate.

The Optimal Transportation Cost as obtained using Solver for Amee Metals Private Limited is Rs. 19,780.

Sensitivity Analysis is a method used for determining how a change in independent variable values will impact the dependent variable under a given set of assumptions.

SENSITIVITY ANALYSIS

Variable Cells						
Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
SCS10	UMARGAM PANVEL	900	0	2.75	0.875	0
SDS10	UMARGAM AHMEDABAD	0	6.05	6.125	1E+30	6.05
SES10	UMARGAM PUNE	3100	0	3.5	0	1E+30
SFS10	UMARGAM DUMMY	0	0.875	0	1E+30	0.875
SCS11	BARODA PANVEL	600	0	3.625	0	0.875
SDS11	BARODA AHMEDABAD	2400	0	0.95	6.05	1E+30
SES11	BARODA PUNE	0	0	4.375	1E+30	0
SFS11	BARODA DUMMY	1000	0	0	0.875	1E+30
SCS12	RABALE PANVEL	2000	0	1	2.5	1E+30
SDS12	RABALE AHMEDABAD	0	19.675	18	1E+30	19.675
SES12	RABALE PUNE	0	2.5	4.25	1E+30	2.5
SFS12	RABALE DUMMY	0	2.625	0	1E+30	2.625

Constraints						
Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
SCS13	PANVEL	3500	3.625	3500	0	600
SDS13	AHMEDABAD	2400	0.95	2400	0	2400
SES13	PUNE	3100	4.375	3100	0	600
SFS13	DUMMY	1000	0	1000	0	1000
SGS10	UMARGAM SUPPLY	4000	-0.875	4000	600	0
SGS11	BARODA SUPPLY	4000	0	4000	1E+30	0
SGS12	RABALE SUPPLY	2000	-2.625	2000	600	0

Figure 1: Sensitivity Report

The top half of the sensitivity report depicts the **Range of optimality** for the problem.

Final value: It represents the optimal solution obtained for the problem.

Reduced Cost: Reduced cost indicates how much the cost would increase if an additional unit over the final value is deployed.

Objective coefficient: It depicts the cost coefficient for each route used for transportation.

Allowable Increase/ Decrease: The values represent how much the objective coefficient can change before which the optimal solution changes. The following table also shows the Upper limit and lower limit for the objective coefficient.

Variable Cells								
Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease	Upper Limit	Lower Limit
SCS10	UMARGAM PANVEL	900	0	2.75	0.875	0	3.625	2.75
SDS10	UMARGAM AHMEDABAD	0	6.05	6.125	1E+30	6.05	∞	0.075
SES10	UMARGAM PUNE	3100	0	3.5	0	1E+30	3.5	∞
SFS10	UMARGAM DUMMY	0	0.875	0	1E+30	0.875	∞	∞
SCS11	BARODA PANVEL	600	0	3.625	0	0.875	3.625	2.75
SDS11	BARODA AHMEDABAD	2400	0	0.95	6.05	1E+30	7	∞
SES11	BARODA PUNE	0	0	4.375	1E+30	0	∞	4.375
SFS11	BARODA DUMMY	1000	0	0	0.875	1E+30	0.875	∞
SCS12	RABALE PANVEL	2000	0	1	2.5	1E+30	3.5	∞
SDS12	RABALE AHMEDABAD	0	19.675	18	1E+30	19.675	∞	∞
SES12	RABALE PUNE	0	2.5	4.25	1E+30	2.5	∞	1.75
SFS12	RABALE DUMMY	0	2.625	0	1E+30	2.625	∞	∞

Figure 2: Upper and Lower limit of the objective coefficient

If after the change in in the objective coefficient, the value falls within the range calculated, the Optimal solution will not change.

The bottom half of the Sensitivity report depicts the **Range of Feasibility**.

Shadow Price: Shadow price refers to amount of change in the optimal objective function value per unit increase in the right hand side of a constraint.

Constraint R.H. Side: It depicts the total demand/supply for each destination.

Allowable Increase/Decrease: It represents the range for the Right hand side constraints where the same calculated Shadow price would apply. The following table also shows the upper limit and the lower limit for the Right hand side constraint.

Constraints								
Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease	Upper Limit	Lower Limit
SCS13	PANVEL	3500	3.625	3500	0	600	3500	2900
SDS13	AHMEDABAD	2400	0.95	2400	0	2400	2400	0
SES13	PUNE	3100	4.375	3100	0	600	3100	2500
SFS13	DUMMY	1000	0	1000	0	1000	1000	0
SGS10	UMARGAM SUPPLY	4000	-0.875	4000	600	0	4600	4000
SGS11	BARODA SUPPLY	4000	0	4000	1E+30	0	∞	4000
SGS12	RABALE SUPPLY	2000	-2.625	2000	600	0	2600	2000

Figure 3: Upper and Lower Limit of RHS constraint

As long as the right hand side constraints are within the upper limit and lower limit the same shadow price applies. If the value goes beyond the limits, the model has to be resolved.

Using the ASM Method, founded by research from literature cited, the costs of transportation have been arrived at.

Table 3: Step 1 - Creating the cost matrix

Location	Panvel	Ahemdabad	Pune	Dummy
Umargam	2.75	6.125	3.5	0
Baroda	3.625	0.95	4.375	0
Rabale	1	18	4.25	0

Table 4: Step 2 - Row Minimization

Location	Panvel	Ahemdabad	Pune	Dummy
Umargam	2.75	6.125	3.5	0
Baroda	3.625	0.95	4.375	0
Rabale	1	18	4.25	0

Table 5: Step 2 - Column Minimization

Location	Panvel	Ahemdabad	Pune	Dummy
Umargam	1.75	5.175	0	0
Baroda	2.625	0	0.875	0
Rabale	0	17.05	0.75	0

Step 3: Select the first zero occurring row wise from the reduced cost matrix. Suppose (i, j)th zero is selected, count the total number of zeros (excluding the selected one) in the ith row and jth column. Now select the next zero and count the total number of zeros in the corresponding row and column in the same manner. Continue it for all zeros in the cost matrix.

Table 4: Number of Zeros on each route

Route	NumberofZeros
Umargam–Pune	1
Umargam–Dummy	3
Baroda–Ahemdabad	1
Baroda–Dummy	3
Rabale–Panvel	1
Rabale–Dummy	3

Step 4: Now choose a zero for which the number of zeros counted in step 3 is minimum and supply maximum possible amount to that cell. If tie occurs for some zeros in step 3 then choose a (k,l)th zero breaking tie such that the total sum of all the elements in the kth row and lth column is maximum. Allocate maximum possible amount to that cell.

Table 5: Allocation And Calculation Of Total Cost

Route	NumberofZeros	Total cost of the k th row and the l th column
Umargam–Pune	1	17
Umargam-Dummy	3	
Baroda-Ahemdabad	1	12.7
Baroda–Dummy	3	
Rabale–Panvel	1	29.625
Rabale-Dummy	3	

Hence, the first allocation will be made for the Rabale – Panvel Route.

Step 5: After performing step 4, delete the row or column for further calculation where the supply from a given source is depleted or the demand for a given destination is satisfied.

Step 6: Check whether the resultant matrix possesses at least one zero in each row and in each column. If not, repeat step 2, otherwise go to step 7.

Step 7: Repeat step 3 to step 6 until and unless all the demands are satisfied and all the supplies are exhausted.

Table 6: Optimum Allocations

Location	Panvel	Ahemdabad	Pune	Dummy	Supply
Umargam	900	0	3100	0	4000
Baroda	600	2400	0	1000	4000
Rabale	2000	0	0	0	2000
Demand	2500	2400	3100	1000	10000

Table 7: Calculation of Total Cost

Route	Allocation	Cost/kg	Totalcost
Umargam–Panvel	900	2.75	2475
Baroda–Panvel	600	3.625	2175
Rabale–Panvel	2000	1	2000
Baroda–Ahemdabad	2400	0.95	2280
Umargam–Pune	3100	3.5	10850
Baroda-Dummy	1000	0	0
			19780

CONCLUSIONS

The optimum costs of transportation hence calculated were the same from both the methods. The ASM method is a reliable one due to its simplicity. The calculated costs can be of help to the company and the industry as a whole since the level of homogeneity of processes in the industry as a whole is very high. Similar protocol exists in the market which makes this paper relevant to not just one but many companies, factories, etc.

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