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Use of Transportation Problem in Iron and Steel Plant to Minimize Raw Material Costs

Akshita Sarda,

NMIMS University,
Mumbai, Maharshtra, India.

Aman Parasramka,

NMIMS University,
Mumbai, Maharshtra, India.

Ayushi Shah,

NMIMS University,
Mumbai, Maharshtra, India.

ABSTRACT

It is very important to optimize costs in any industry to increase profit margins, so as to sustain in the long run as one can not drastically increase the demand for its products but can work towards optimizing its cost structure internally. Hence the research paper is aimed at finding the optimal cost for transportation of raw material from various sources to plants.

We chose the iron and steel industry as it comprises of one of the major contributors of GDP of any economy.

The data for transportation costs, demand at plants and supply at sources has been collected from the company.

We will be using Northwest Corner Rule, Least Cost Method and Vogel's Approximation Method to find out the feasible transportation costs. Then, we shall use What's Best Solver to find the optimum transportation cost.

We then find the variations in costs between 3 feasible and the optimal solution to know which method is the most accurate to gauge the optimality of a solution. In our case, Least Cost method gives the solution closest to optimal solution.

We further compare the actual costs with the optimum solution to determine the amount of cost cutting needed. In our case, costs must be reduced by 1.5% of its actual costs.

At the end we analyze the sensitivity report, which gives us the maximum cost which should be incurred on each additional unit of raw material purchased within an allowable range.

Hence the suggestions in our research paper can help enhance the production process in the iron and steel industry.

Lastly, the limitations of the study have been highlighted so that the following factors can be incorporated while putting the proposed plan into use.

Keywords: Raw material cost minimization, Northwest corner rule, Least cost method, Vogel's approximation method, What's Best Solver.

INTRODUCTION:

Any country in the world is largely dependent on the iron and steel industry as it is the "Backbone" of an economy. It is used for construction, transport (railways), energy (pipelines), packaging etc.

It is important to study the iron and steel industry as it is a major contributor to the GDP, creates employment opportunities and one of the bulk exported products. To suffice for such uses of iron, the production and transportation process of iron should be cost effective and operationally feasible. Hence the study aims to search for better methods of transportation to minimize the transportation cost of transporting raw materials from sources to manufacturing plants.

The main aim of our study is to analyze the demand for raw materials of the company's various iron production plants along with its supply from various source locations across India. Also we attempt to find the transportation cost for transporting to plants such that the total cost for transportation is minimum, thereby increasing the profitability of the company.

This would help the company to cut down its production costs, thereby making it more efficient and helping it to attain a competitive edge over its competitors.

Major ways of transporting raw materials is either by road (trucks) or water (ships). The difficulties faced are as follows:

1.) Lack of connectivity
2.) Lack of use of new technologies
3.) Shortage of storage space
4.) Freight movement problems such as border crossing procedures, tolls etc
5.) Neglecting environmental disruption

To overcome these problems of transportation of raw materials, companies need operations research techniques to optimize their total transportation cost.

LITERATURE REVIEW:

The paper finds a way to optimize the transportation cost of raw materials for the Raipur steel and thermal power plant. It states that Rs.11589.46 can be saved in 30 days which can be utilized to increase the productivity by 1.37%.(Dharmendra Yadav,2017)

The paper proposes a contiguous period scheduling approach using transportation model known as Contiguous Cells Transportation Algorithm. It was found suitable for scheduling maintenance operations of a fleet of ships in South Western Nigeria.(Oliver Charles-Owaba, Victor Oladokun, Oladunni Okunade,2015)

The paper proposes a multi-objective transportation problem. The main objective is to minimize total transportation cost and delivery time. It is an interval version of Vogel's Approximation Method without converting it into classical multi-objective interval problem.(G Ramesh, G Sudha, K Ganesan,2010)

The paper is focused on consolidation planning and transportation scheduling. It proposes a Two Layer Multi-objective Variable Neighborhood Search Algorithm to decide the trade off between maximum of load of ships and maximum efficiency of the whole logistics.(Kun Li, Huixin Tian,2015)

The paper says that transportation network designs can be classified into Shortest Path Problem, Transportation Problem, Assignment Problem, Vehicle Routing Problem, Optimal Assignment Problem, Spanning Tree Problem, Network Flow Problem and so on. There have been various changes that have happened to these methods throughout the years and the minor changes have been noted. **(**J., & Marsh, M.,1993)

The transportation problems arising due to miscalculated selection of suppliers and stock houses has been going on since years. A major problem has been the determination of prices for the conveyance of these goods and services. The objective of the paper was to see whether it is more practical to arrange smaller shipments from the providers as often as possible at a higher per-unit shipping cost, or to arrange bigger shipments less often, which fabricates the holding cost at the assembling office. Our methods hope to eliminate the ambiguity regarding who reduces prices when to attract customers, and in doing so, using a mixed-integer nonlinear programming model to determine the proper balance of inventory, warehousing and transportation costs.(Mendoza, A., & Ventura, J. A.,2013**)**

An attempt at bringing efficiency in supply chain management says that the stock as a backup is usually calculated by an assumption of the Poisson distribution. As of now, there is no structure that uses actual freight costs in the model. We will be attempting to do so in our paper. The structure of this method influenced by VAM, had majorly two outcomes. 1. Economies of scale due to optimization of resources. 2. Benefits of deciding the number of times a supplier is contacted in one cycle.

In spite of the fact that the primary focal point of this paper was to demonstrate the expanded advantages of consolidating transportation costs in the improvement display with the goal that economies of scale in transportation might be used, the present model could without much difficulty be broadened to the situation where the request amounts set to every chosen provider are of the same estimate. (Adlakha, V., & Kowalski ,2003)

The traditional approach too has been modified to improve optimality by reducing opportunity row and column costs as this improvement has proven to give more accurate results to large scale problems as supply and

demand constraints. This was a suggestion in their attempts at improving efficiency even after the introduction of VAM due to certain loopholes and extra cost calculations. (Korukoğlu, S., & Ballı, S., 2011)
The paper discusses another method to optimize our resources by minimizing the amount of combinations by utilizing the best candidates' method. Rather than minimizing cost by choosing the least expensive candidates which translates to lower output employees, we use the most efficient candidates to reduce the amount of resources and combination of resources required altogether.(Abdallah A. Hlayel, Mohammad A. Alia,2012)
The paper discusses the methods to minimize the resources required and optimize the distribution of the same. We optimize the possibilities repeatedly till we get the minimum possible utilization of resources. (Noraini Abdullah; Ting Kien Hua,2017)
The paper discusses techniques and methods of Operations Research that may be applied to optimize passenger railway transportation to minimize the resources required and maximize the objectives.(Dennis Huisman; Leo G. Kroon; Ramon M. Lentink; and Michiel J.C.M. Vromans,2005)

METHODOLOGY:

General Mathematical Model

minimize $\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$

subject to

$\sum_{j=1}^{n} x_{ij} \le S_i$ for i = 1,2, ..., m (supply)

$\sum_{i=1}^{m} x_{ij} \ge D_j$ for j = 1,2, ..., n (demand)

$x_{ij} \ge 0$

For a feasible solution to exist, it is necessary that total capacity equals total requirements.
Total supply = total demand.
Or $\Sigma a_i = \Sigma b_j$.

Assumptions in Transportation Problem:

- Only a single type of commodity is being shipped from an origin to a destination.
- Total supply is equal to the total demand.
- $\sum_{i=1}^{m} S_i = \sum_{j=1}^{n} D_j$
- Si (supply) and Dj (demand) are all positive integers.

There are 3 methods to minimize the transportation cost: Northwest corner rule, Least cost method and Vogel's approximation method.
Initially you have to balance the transportation table by adding dummy columns or rows if number of plants isn't equal to number of sources.
Northwest corner rule: The name is given since the fundamental factors are chosen from the extreme left.
Least cost method: The allocations in this method are done starting from the lowest cost, moving to higher costs.
Vogels's approximation method (VAM): It is a scientifically developed method in which penalties are used to define the cells where allocations are to be made.
VAM is the best method out of the three to get the least feasible transportation cost. This answer obtained from VAM is further improved to optimality by using Modified distribution method (MODI).
On obtaining the allocations through VAM, we first check for the rim condition i.e.
RC=m+n-1.
Where m=no. of plants
n= no. of sources

If RC is equal to no. of allocations then the solution is non-degenerate, otherwise it is degenerate.
Incase of MODI method, penalties are calculated for each of the sources and plants.
Penalty=difference between the 2 lowest costs in a row or column.
Allocation is done where there is highest penalty.

Test for optimality:

1.) Calculate Ui and Vj by taking Ui for first source to be 0, using the formula Cost=Ui+Vj
2.) Calculate Delta values for empty cell using the formula Delta=cost-(Ui+Vj)

A negative delta value signifies that there is still a possibility to reduce the transportation cost further. If all delta values are positive it implies that the solution obtained is optimal.
If the solution isn't optimal, we need to start looping from the cell having negative delta value. You need to make a closed loop such that at each allocation encountered you take a turn and close the loop at the cell having negative delta value. Alternate signs are to be assigned to the corners of the loop starting with the cell having negative delta value to be assigned as a positive sign. Make changes in allocation based on the lowest allocation having the negative value in the loop.
Continue the looping process until you obtain all positive delta values.
The solution for optimality is obtained using What's Best Solver.

Special cases:

1.) Incase any delta=0, it implies that there is an alternate optimum solution.
2.) Incase of degeneracy, we introduce epsilon whose value is as good as 0.It is put in an empty cell having minimum cost and shouldn't form a closed loop.
3.) Prohibited transportation problem: You have to take the cost for the prohibited route as "M" i.e. its value is equal to infinity and carry out similar procedure as mentioned above.

The data has been collected from the Finance Manager of the company.

Data obtained is as follows:

1.) Data for plants and raw material procurement units has been collected from the company.
2.) Transportation cost of raw materials is determined based majorly on fuel consumption per ton per km based on the distances from various source locations.
3.) The demand at various plants has been judged by the amount of iron produced from raw materials.
4.) The supply at various sources has been estimated as the amount of raw materials supplied from that source location.

ANALYSIS:

Assumptions:

1.) In our study we assume that there is no drastic change in demand for finished products.
2.) The fuel prices are relatively constant in the long run.

The company has its plants located at the following places:

1.) Durg (Chhattisgarh)
2.) Umred (Maharashtra)
3.) Khapoli (Maharashtra)

The company procures raw materials from 4 different places across the country.
The further data given below is for a month-
The demand for raw materials at various plants is as follows:

1.) Durg plant 1: 15000 tons
2.) Durg plant 2: 17500 tons
3.) Umred plant 3: 21250 tons
4.) Khapoli plant 4: 10000 tons

The supply of raw materials is as follows:

1.) Source 1: 12500 tons

2.) Source 2: 26000 tons
3.) Source 3: 15500 tons
4.) Source 4: 9750 tons

The cost is in terms of Rs/ton.
The transportation costs for transporting from sources to plants is as follows:

Cost Per Unit	Plant 1	Plant 2	Plant 3	Plant 4
Source 1	1800	1700	2000	1600
Source 2	1400	1200	1000	1900
Source 3	1650	1400	1760	1880
Source 4	1550	1460	1260	1660

Hence the transportation model is as follows:

Cost Per Unit	Plant 1	Plant 2	Plant 3	Plant 4	Supply
Source 1	1800	1700	2000	1600	12500
Source 2	1400	1200	1000	1900	26000
Source 3	1650	1400	1760	1880	15500
Source 4	1550	1460	1260	1660	9750
Demand	15000	17500	21250	10000	63750

In our study, we have found out the feasible transportation costs through various methods such as Northwest Corner rule, Least Cost Method, Vogel's Approximation method and further reduced the answer obtained through it to its optimal transportation cost using What's Best Solver in excel.
Northwest Corner rule is the simplest method of solving a transportation model as allocations start from first cell i.e. in our case first allocation will be made from Source 1 to Plant 1 of 12500 tons at Rs1800/ton. Further allocations will be made depending on the remaining demand and supply at various sources and plants.
Least Cost Method takes into account the lowest cost from the possible allocations i.e.in our case you make the first allocation from Source 2 to Plant 3 of 21250 tons at Rs1000/ton. Further allocations will be made based on increasing cost.
Vogel's Approximation Method is based on penalties i.e. you choose the highest penalty in a row or column and then make allocation at the lowest cost. Hence the first allocation is made from Source 1 to Plant 4 of 12500 tons at Rs1600/ton.
What's Best Solver on excel was used to find out the optimal allocation by putting subject to constraints for optimization of transportation cost.

The feasible solution obtained by Northwest Corner rule is as follows:

Allocation	Plant 1	Plant 2	Plant 3	Plant 4	Supply
Source 1	12500				12500
Source 2	2500	17500	6000		26000
Source 3			15250	250	15500
Source 4				9750	9750
Demand	15000	17500	21250	10000	63750
Feasible Transportation Cost	96495000				

The feasible solution obtained by Least Cost Method is as follows:

Allocation	Plant 1	Plant 2	Plant 3	Plant 4	Supply
Source 1	2500			10000	12500
Source 2		4750	21250		26000
Source 3	2750	12750			15500
Source 4	9750				9750
Demand	15000	17500	21250	10000	63750
Feasible Transportation Cost	84950000				

The feasible solution obtained by Vogel's Approximation Method is as follows:

ALLOCATION	Plant 1	Plant 2	Plant 3	Plant 4	Supply
Source 1				12500	12500
Source 2	2500	2000	21250	250	26000
Source 3		15500			15500
Source 4				9750	9750
Demand	15000	17500	21250	10000	63750
Feasible Transportation Cost	85510000				

The optimum solution obtained by What's Best Solver is as follows:

ALLOCATION	Plant 1	Plant 2	Plant 3	Plant 4	Supply
Source 1	2500	0	0	10000	12500
Source 2	2750	2000	21250	0	26000
Source 3	0	15500	0	0	15500
Source 4	9750	0	0	0	9750
Demand	15000	17500	21250	10000	63750
Optimum Transportation Cost	84812500				

Methods	Cost
NWCR	96495000
LCM	84950000
VAM	85510000
SOLVER	84812500

Variations in cost between Feasible and Optimal solution is as follows:
NWCR and SOLVER-
=96495000-84812500
=11682500
LCM and SOLVER-
=84950000-84812500
=137500
VAM and SOLVER-
=85510000-84812500
=697500

It can be seen from the above conclusions that feasible cost for transportation of raw materials to the plants can range between Rs.84950000 to Rs.96495000 for a month based on the method used for calculation.
Also the optimum cost for transportation of raw materials to the plants is Rs.84812500.
Since the difference between the variation in cost obtained through LCM and SOLVER was the least, it can be concluded that Least Cost method is the most accurate way to calculate feasible solution in the given case.
The actual cost incurred by the firm currently is Rs.86100000.
The firm's optimal cost is Rs.84812500.
Therefore percentage targeted cost reduction
=(86100000 – 84812500)/ 86100000
=1.50%
Hence it can be inferred that the company can improve its operational and production efficiency by cutting down its raw material costs by 1.5% of its existing costs.

SENSITIVITY REPORT:

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
B14	DEMAND Plant 1	15000	1800	15000	0	2500
C14	DEMAND Plant 2	17500	1600	17500	0	2000

		Final	Shadow	Constraint	Allowable	Allowable
Cell	**Name**	**Value**	**Price**	**R.H. Side**	**Increase**	**Decrease**
D14	DEMAND Plant 3	21250	1400	21250	0	2500
E14	DEMAND Plant 4	10000	1600	10000	0	10000
F10	Source 1 SUPPLY	12500	0	12500	1E+30	0
F11	Source 2 SUPPLY	26000	-400	26000	2500	0
F12	Source 3 SUPPLY	15500	-200	15500	2000	0
F13	Source 4 SUPPLY	9750	-250	9750	2500	0

Analysis of the sensitivity report:
Since the final value is equal to constraint, it means that there are no slack variables that none of the variables is unutilized.
Shadow price represents the maximum price company should pay to procure 1 more unit of raw material.
For eg- To fulfill any further demand for raw materials at Plant 1 company should procure each unit of raw material at not more than Rs.1800/ton and likewise for other plants.
To fulfill any further supply obligations of raw materials, at Source 1 there should be no cost cutting that each additional unit having a cost reduction of Rs0/ton, at Source 2 for supply of each additional unit maximum cost cutting should be Rs 400/ton.
Allowable increase and allowable decrease is the range in which the value of shadow price works for each additional unit of raw material.
For eg- Plant 1 having an allowable increase of 0 units and an allowable decrease of 2500 units means that each of 2500 units of raw material procured at the end (raw materials after 12500 tons) could be purchased for Rs.1800/ton.
At Source 1, the allowable increase is infinite and allowable decrease is 0 hence shadow price is Rs0/ton, not applicable in this case.
At Source 2, the allowable increase is 2500 units and allowable decrease is 0 units which means that each of 2500 additional raw material units produced after 26000 units (raw materials till 28500 units) can be supplied by reducing cost by Rs400/ton.

DISCUSSION AND CONCLUSION:

It can be concluded from the above study that the most effective way to find out a feasible solution among NWCR, LCM and VAM is Least Cost Method. But this is not the optimal cost structure. Optimal cost structure is obtained from Solver.

The feasible transportation costs obtained through various methods is as follows:
1.)North West Corner rule=Rs 96495000
2.)Least Cost Method=Rs 84950000
3.)Vogel's Approximation Method=Rs 85510000

The most accurate solution is obtained through Least Cost Method=Rs84950000 as it has the least variation as compared to the optimal solution.
The optimal transportation cost obtained through What's Best Solver=Rs 84812500
The company is actually incurring a cost of Rs 86100000.
The company needs to cut down its costs by 1.5% of its current costs to reach optimality.
The maximum price at which each additional unit can be procured at plant 1, plant 2, plant 3 and plant 4 is Rs1800, Rs1600, Rs1400, Rs1600 respectively.
The maximum cost cutting at which each additional unit should be supplied from source 1, source 2, source 3 and source 4 is Rs0, Rs400, Rs200, Rs250 respectively.

LIMITATIONS TO THE STUDY:

1.) Non realistic assumptions
2.) Unavailability to procure raw materials at specified cost reductions as in the sensitivity report.

3.) Unable to fulfill the objective of the paper i.e. utilize reduction in costs to increase sales due to other constraints.
4.) Time constraint to apply the proposed solution.
5.) Difficulty in execution of the proposed plan.
6.) Non quantifiable factors not included in the proposed plan.

For further improvement in results, the scope of these limitations needs to be reduced.

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