Cost Optimisation through Modified Vogel's Approximation Method for Unbalanced Transportation Problem

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Abstract

For any manufacturing firm, transportation cost could be a considerable part of the logistics cost. This along with the mounting fuel cost is ultimately passed on to the customers. With rising competition, firms are forced to find out methods of optimising the transportation cost thereby reducing the total cost. There are many methods available in solving a transportation method. However, the traditional Vogel's approximation method has many drawbacks when dealing with situations where the supply and demand are unbalanced. This study examines the effectiveness of using the modified Vogel's method when compared to the traditional approach with the help of a case study. The study found that the use of the proposed method will bring in considerable cost reduction in transportation thereby increasing the profitability of the firm. Moreover the proposed method is easy to implement and will be highly beneficial for the decision makers.

Keywords: Transportation Problem, Vogel's Approximation Method, Initial Solution, Modified VAM

Introduction

Management is on the edge of a major development in understanding how manufacturing company achieve success. The success of a firm depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. In today's competitive world, markets are outside the geographical boundaries of their traditional space and manufacturers attempt to develop their products in all global regions with least cost. In recent years, providing a proper service has been one of the most important factors in customer satisfaction that is one of the things that incurs large costs to companies. In such a scenario, implementation of efficient supply chain management will help the companies to be successful. For the supply chain management to be efficient, the logistics management and transportation management must be efficient. A transportation management system, being an integral part of supply chain management, plays an important role in the company's track of success. Companies must attempt for greatest efficiency in all of their activities and completely utilise any possible chance to gain a competitive advantage over other firms. Among many possible activities, cost reduction in logistics is observed as one of the core areas presenting huge opportunities.

According to Jonsson (2008), there are two kinds of logistic costs: direct and indirect cost. Direct costs include physical handling, transportation, and storage of goods in the flow of materials along with the running costs, whereas indirect costs include capacity and shortage costs. Jonsson (2008) also claimed that direct logistics costs roughly vary between 10% and 30% of the turnover depending on the type of industry. In such situation, it can be said that in order to schedule when and how much to move from each source to its respective destination, implementation of optimisation techniques is a possible way to improve the total cost of logistics. Hence, raise the concept of transportation problem.

Transportation problem is a specific class of linear programming, which is associated with day-to-day activities in our real life. It helps in solving problems on distribution and transportation of resources from place to another. Minimisation of the total transportation costs is the main purpose of such TPs. There are several methods to solve a transportation problem. The most commonly used method for obtaining the initial solution is Vogel's approximation (VAM). However, for unbalanced problems VAM is not found to be efficient as it assigns items to the dummy cells before the other cells in the table (Balakrishnan, 1990). Several researchers have done many studies related to the modification of VAM to get an efficient initial solution. However, this paper uses modified VAM method to find the optimal solution for the unbalanced transportation problem.

Literature Review

Transportation problem is a special case of linear programming in operations research where goods and services are distributed from numerous supply centers to several demand centers. The objective of transportation algorithm is to identify the optimal transportation path along the required quantity of the goods to be shipped in such a way so as to minimise the transportation cost (Sharma, 2013). Transportation problem can be of many forms. It can either be balanced, unbalanced or fuzzy. A transportation problem is said to be balanced when the supply and demand are equal. A transportation problem is unbalanced when the supply and demand are not equal. A fuzzy transportation problem is a transportation problem in which the transportation costs, supply and demand quantities are fuzzy quantities. The objective of the fuzzy transportation problem is to determine the shipping schedule that minimises the total fuzzy transportation cost while satisfying fuzzy supply and demand limits.

The transportation problems, which are not fuzzy in nature, can be solved by using several methods. Mainly there are two steps in solving a transportation problem. First is the determination of initial basic feasible solution. Second is the determination of optimal solution. For the above two steps, several methods are used. The traditional method of solving the transportation problem is by using the simplex method, (Shore, 1970), a well-known but tedious technique for dealing with any linear programming problem.

Edokpia and Ohikhuare (2012), in their study, used linear programming technique in solving the transportation problem though, it was quite time consuming. Another short-cut approach to solving the transportation problem is the Vogel approximation method (VAM), which is a very simple means of performing the steps of the transportation method. Application of VAM to a given problem does not guarantee an optimal solution as in unbalanced transportation problems VAM will usually allocate items to the dummy cells before the other cells in the table (Balakrishnan, 1990). This initial solution may therefore not be very efficient for unbalanced problems. However, a very good solution is invariably obtained, and is obtained with comparatively little effort. To overcome the drawbacks many modifications were done to the traditional VAM.

Goyal (1984) suggested an improved Vogel's approximation method (VAM) for the unbalanced transportation problem were the highest cost was allocated to the dummy point, rather than zero. However, GVAM (Goyal's Modified VAM) was not found to be consistent in providing optimal results. Ramakrishnan (1988) improved Goyal's Modified VAM by subtracting or adding suitable constants to the rows and columns of the cost matrix. Subtract column minima before applying Goyal's technique, and then subtract row/ column minima before the application of VAM (Sultan, 1988). Sultan and Goyal (1988) have studied initial basic feasible solutions and resolution of degeneracy in TPs. Few other researchers have tried to give their alternate methods for solving the transportation problems. Adlakha and Kowalski (1999, 2006) have suggested an alternative solution algorithm for solving certain TPs based on the theory of absolute point. Shimshak, Kaslik, and Barclay (2016) proposed several heuristics for use with VAM. In SVAM, only those penalties that do not involve the dummy row or column are computed. Thus if there is a dummy column, the penalties are not computed for that column and for all the rows. This approach, however, has the drawback that the row-penalties are fundamentally overlooked and therefore the cost matrix is not exploited to the fullest extent possible (Balakrishnan, 1990).

Singh, Dubey, and Shrivastava (2012) stated that VAM is one of the most efficient solution to the transportation problems. They proposed a variant of VAM by using total opportunity cost and allocation cost. Total opportunity cost in transportation has been studied through critical problem in industries, military etc.

Mathirajan and Meenakshi (2004) presented a variant of Vogel's approximation method (VAM) for transportation problems. A few variants of VAM incorporating the total opportunity cost concept were investigated to obtain fast and efficient solutions. Computational experiments were carried out to evaluate these variants of VAM. In a study by Korukoğlu and Ballı (2011), Vogel's approximation method, which is one of well-known transportation methods for getting initial solution, was investigated to obtain more efficient initial solutions. VAM was improved by using total opportunity cost and regarding alternative allocation costs. Proposed method considers highest three penalty costs and calculates additional two alternative allocation costs in VAM procedure. For more penalty costs, alternative allocation costs can be calculated but it increases computational complexity and time too much. Improved Vogel's approximation method (IVAM) considers only two additional costs. Simulation experiments showed that VAM gets efficient initial solutions for small sized transportation problems but it is insufficient for large sized transportation problems.

Balakrishnan (1990) proposed a modified Vogel's approximation method where the column penalties are all computed as earlier, except for the dummy column. For the rows, penalties are computed by calculating the difference between the lowest cost and the second-lowest cost, ignoring the dummy column. By using the proposed modification, it was found that more efficient initial solutions could be obtained for the unbalanced transportation problem.

Theoretical Review of Modified Vogel's Approximation Method

The transportation problem arises frequently in the planning for the distribution of goods and services from several supply locations to several demand locations. Usually the amount of goods available at each supply location (origin) is given and there is a specified amount needed at each demand location (destination). With a variety of shipping routes and differing costs for the routes, the objective is to determine how many units should be shipped from each origin to each destination so that all destination demands are satisfied and total transportation costs are minimised.

Steps of Modified Vogel's Approximation Method

1. Compute all the column penalties, except for the dummy column.
2. Compute the penalties for the rows by calculating the difference between the lowest cost and the second-lowest cost, ignoring the dummy column.
3. Select the row or column with the largest penalty and give as much units as possible in the cell that has the least cost in the selected row or column.
4. If there is a tie in the values of penalties, it can be broken by selecting the cell where the maximum allocation can be made.
5. Adjust the supply and demand and cross out the satisfied row or column.
6. Repeat the steps until the available supply and demand is satisfied. Each time the penalties have to be recomputed.

Methodology

A case study-based method was undertaken at a public limited company which has got warehousing and supply throughout the state. Since the company does not use any optimisation technique, the study focused on finding out the current transportation model used by the company. Recompiling the transportation cost using VAM as well as the modified VAM methods.

Objectives

To analyse effectiveness of the proposed modified VAM when compared to VAM in terms of the cost implications to the firm.

Limitations

- The study was conducted in a short period, and could not be detailed in all aspects.
- The modified approach does not guarantee to perform better than the other procedures for all unbalanced transportation problems. From the study, it is shown that for every 10 transportation problems, the proposed method yields the best initial solution in 7 cases only.
- Transportation cost varies from place to place in the state hence.

Analysis and Discussion

Improper logistics planning and judgments can result in unnecessary expenses, missed delivery deadlines and loss of goodwill to the firm. Hence, optimising operational efficiency and reducing logistics costs should be among the top priorities for any business that has got physical distribution of goods if they expect to remain financially viable.

Summary of Demand During 2015-16

Table 1 shows the summary of demand for Potash at various destinations in the year 2015-16. It can be observed that the maximum demand was at D9 and minimum demand was at D13

Table 1: Summary of Demand During 2015-16

District	Demand (Tonne)
D1	510
D2	1317
D3	1305
D4	2830
D5	4405
D6	3794
D7	5225
D8	5434
D9	5760
D10	2395
D11	4240
D12	2566
D13	436
D14	3388
Total	43605

Source: Secondary Data

Summary of Supply During 2015-16

Since the manufacturing firm does not have any production centres in Kerala, the potash is stored in four warehouses from where the potash is supplied to all the 14 districts of Kerala. Table 2 represents the storage capacity of warehouses at various warehouses. It can be observed that the maximum capacity is at warehouse 3 (W3) and minimum at warehouse1 (W1).

Table 2: Summary of Supply During 2015-16

Warehouse	Material in stock(Tonne)
W1	10000
W2	15200
W3	15600
W4	11900
Total	52700

Source: Secondary Data

Assumptions for Calculating the Transportation Cost

In order to work on the transportation model, the following assumptions were made

I. The distances between the warehouses and the destinations had to be known. The approximate distance between the warehouse & destination was ascertained. This is essential for unit transportation cost

II. Estimation of transportation cost: For estimating the transportation cost, one truck load was assumed to be a minimum of 10 tonnes. Cost for transporting one load is assumed to be Rs.80 per Km (referring to the industry standards). Thus cost for transporting 1 tonne per kilometer was calculated to be Rs. 8.

Estimation of Unit Transportation Cost

Table 3: Estimation of Unit Transportation Cost

Source/ Destination	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	Supply
Warehouse 1	1552	1248	992	488	536	200	672	1168	1280	1600	2248	2264	3064	872	10000
Warehouse 2	952	608	512	368	144	544	1040	1520	1776	1888	2280	2720	3504	824	15200
Warehouse 3	2976	2520	2320	1816	1840	1384	960	1056	608	184	688	768	1480	2200	15600

Source/ Destination	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	Supply
Warehouse 4	2216	1720	1560	1080	1040	616	96	504	408	1000	1432	1664	2432	1200	11900
Demand	510	1317	1305	2830	4405	3794	5225	5434	5760	2395	4240	2566	436	3388	52700

Source: Analysis

Table 3 represents unit cost for transporting potash from different warehouses to various demand destinations. The unit cost will differ since the distance from each warehouse to various demand destinations are varying. Here the cost for transporting one tonne of potash is assumed to be Rs. 8. Now unit transportation cost can be found out by multiplying distance from the origin to destination with cost for transporting one tonne of potash per kilometer.

Unit transportation cost = Distance from the warehouse to the demand destination * cost for transporting one tonne per kilometer.

Calculation of the Existing Transportation Cost matrix

Table 4: Existing Transportation Cost

Source/ Destination	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	Supply
Warehouse 1	878	730	789	585	580	571	558	621	767	890	1109	1095	1227	867	10000
	150	450	255	480	390	3500	106	210	830	60	980	1320	240	213	
Warehouse 2	803	754	565	490	356	640	0	0	0	0	0	0	0	888	15200
	360	867	1050	2350	4015	294								3175	
Warehouse 3	0	0	0	0	0	0	0	608	574	424	686	615	652	0	15600
								38	4930	2335	3260	1246	196		
Warehouse 4	0	0	0	0	0	0	333	552	0	0	0	0	0	0	11900
							5119	5186							
Demand	510	1317	1305	2830	4405	3794	5225	5434	5760	2395	4240	2566	436	3388	

Source: Analysis

The total cost incurred for transporting potash from various sources to demand destinations is calculated by multiplying unit transportation cost from the respective warehouse to the demand destination with supply amount of potash at that destination.

For example from Table 4, the unit transportation cost incurring for transporting potash from Warehouse 1 (W1) to District 1 (D1), one of the demand destinations of the company is Rs. 878. And the company is supplying 150 tonnes of potash from Warehouse 1 to D1. Therefore, total cost incurred to transport potash from W1 to D1 is Rs. 1,31,700 (878 * 150).

Similarly, the total transportation cost incurred from each demand destination is calculated. By summing up the overall cost, the total transportation cost incurred for the company for the whole year can be calculated.

Therefore, in the year 2015-16, total transportation cost incurred was estimated to be Rs. 2,55,33,987.

Optimised Transportation Model Using VAM & Modified VAM

Here in this study, a comparative analysis of two optimisation techniques are used for analysis-namely:

i. Vogel's approximation method
ii. Modified Vogel's approximation method.

Optimising Transportation Cost using VAM

Table 5 represents the initial basic solution for the present demand situation of the company by using Vogel's approximation method.

Thus the total transportation cost incurred by using VAM is Rs. 2,14,59,876.

This optimised model suggests that it's much better when compared to the current transportation method followed by the firm.

Table 5: Optimised Transportation Cost using VAM

Source/ Destination	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**	**Dummy**	**Supply**
Warehouse 1	1552	1248	992	488	536	200	672	1168	1280	1600	2248	2264	3064	872	0	10000
							4519							3388	2093	
Warehouse 2	952	608	512	368	144	544	1040	1520	1776	1888	2280	2720	3504	824	0	15200
	510	1317	1305	2830	4405	3794									1039	
Warehouse 3	2976	2520	2320	1816	1840	1384	960	1056	608	184	688	768	1480	2200	0	15600
										2395	4240	2566	436		5963	
Warehouse 4	2216	1720	1560	1080	1040	616	96	504	408	1000	1432	1664	2432	1200	0	11900
							706	5434	5760							
Demand	510	1317	1305	2830	4405	3794	5225	5434	5760	2395	4240	2566	436	3388	9095	52700

Source: Analysis

Optimising Transportation Cost using Modified VAM

Table 6: Optimising Transportation Cost Using MVAM

Source/ Destination	**D1**	**D2**	**D3**	D4	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**	**Dummy**	**Supply**
Warehouse 1	1552	1248	992	488	536	200	672	1168	1280	1600	2248	2264	3064	872	0	10000
						3794								1687	4519	
Warehouse 2	952	608	512	368	144	544	1040	1520	1776	1888	2280	2720	3504	824	0	15200
	510	1317	1305	2830	4405									1701	3132	
Warehouse 3	2976	2520	2320	1816	1840	1384	960	1056	608	184	688	768	1480	2200	0	15600
									4519	2395	4240	2566	436		1444	
Warehouse 4	2216	1720	1560	1080	1040	616	96	504	408	1000	1432	1664	2432	1200	0	11900
							5225	5434	1241							
Demand	510	1317	1305	2830	4405	3794	5225	5434	5760	2395	4240	2566	436	3388	9095	52700

Table 6 represents the initial basic solution for the current situation of the company by using Modified Vogel's approximation method. Using modified Vogel's approximation method, the total transportation cost was calculated to be Rs 1,99,70,704.

Comparison of the Transportation Models

Table 7: Summary of the Comparison between the Transportation Models

Method	**Total Cost**
Traditional Method	Rs. 2,55,33,987
Vogel's Approximation Method	Rs. 2,14,59,876
Modified Vogel's Approximation Method	Rs. 1,99,70,704

Table 7 shows a comparison of the transportation cost using the traditional method followed by the firm, Vogel's approximation and finally modified Vogel's approximation method. The transportation cost incurred by using the traditional method was Rs. 2,55,33,987 and by using VAM was Rs. 2,14,59,876 and by using MVAM was Rs. 1,99,70,704. This proves that modified Vogels method provides better cost savings than the other two methods. By using modified Vogel's approximation method, the firm can save up to Rs. 55,63,283.

The MVAM is more efficient than VAM. In the long run there will be a positive effect on the profitability of the company.

Conclusion

Since the firm was not adhering to any particular organised transportation method, transportation cost was escalating. However it was proven through this case study that the transportation cost could be reduced as much as Rs. 55,63,283. Through the case study, it was seen that MVAM method had yielded a profit of Rs. 1,489,172 more than VAM. Thus conforming that modified Vogel's approximation was found to be much effective than Vogel's approximation method.

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