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# Time-Cost Minimization Algorithm for IBFS of Transportation problem

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**ABSTRACT:** Transportation Problem (TP) deals with cost as well as time minimization for transportation of the goods from the source to the destination and Initial Basic Feasible Solution (IBFS) is presented to find the way out in obtaining an optimal solution. Vogel's Approximation Method (VAM) commonly found in operations research textbooks, which primarily focuses on minimizing costs in the classical transportation problem. Recognizing the need for a more versatile approach that considers both time and cost optimization objectives, this paper introduces a novel Time-Cost Algorithm. The proposed algorithm aims to provide an initial feasible solution for the transportation problem by concurrently minimizing both time and cost variables. By bridging the gap between traditional methods, the research contributes to a more comprehensive and adaptable framework for addressing transportation problems in real-world scenarios.

**KEYWORDS:** Time-Cost Minimization, Transportation Problem, Modified VAM Algorithm, IBFS for Transportation problem.

## I. INTRODUCTION

Many applications of linear programming fall into the category of transportation problems for cost and time minimization. However, all methods can be applied simultaneously. Cost minimization problems discussed by JK Shama in his book Operation Research Theory and Applications<sup>1</sup>. Also, Various new modified methods to minimize the cost minimization problem was given by Dr.Reena G Patel<sup>3</sup> and Daniel Shimshak, James Alan Kaslik, Thomas Barclay<sup>2</sup> in 2016. Chakraborty Ananya and Chakraborty M.<sup>4</sup> Discussed about time and cost minimization problem but it was about fuzzy parameters. Time minimization problems were discussed by Kanti Swarup and J.K. Sharma<sup>5</sup> in 1977. Also, these methods are only to minimize the time in transportation problems. Minimization of time and cost in the single algorithm is effective for any transportation problem but it is challenging because of two different matrices. A proportion method developed from VAM method is discussed in this paper which gives not satisfactory but good results in some problems. To combine time and cost matrix proportion is used and the rest of algorithm developed as per VAM method. A total of six problems were solved by this method and a comparison of those results is analyzed.

## II. FORMULATION OF PROBLEM

Assume there are  $n$  destinations and  $m$  sources and unit cost, time, demand, and quantity available at the origin are all known. A further assumption is that the product can be carried from any point of origin to any point of destination, and the transportation time does not depend on the quantity of product transported. Let  $t_{ij}$  be the time unit for transporting the product from origin  $i$  to destination  $j$ ,  $c_{ij}$  be the transport cost of a unit of product from origin  $i$  to destination  $j$  and  $a_i$  be the units of product  $i$  available at the origin,  $b_j$  be the demand at destination  $j$  and  $x_{ij}$  be the number of units of product transported from origin  $i$  to destination  $j$ . The goal is to minimize the overall cost of transportation and the duration of transportation subject to constraints. The mathematical formulation of this bi-objective problem can be represented as follows:

Find

$$x_{ij} \geq 0 (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

Minimize

$$Z1 = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij}$$



Minimize

$$Z1 = \sum_{i=1}^m \sum_{j=1}^n t_{ij}y_{ij}$$

Where

$$y_{ij} = 1, \text{ if } x_{ij} > 0$$

$$y_{ij} = 0, \text{ if } x_{ij} = 0$$

Subject to the constraints :

$$\sum_{j=1}^n x_{ij} = b_i$$

$$\sum_{i=1}^m x_{ij} = a_j$$

$$x_{ij} \geq 0 (i = 1, 2, \dots, m; j = 1, 2, \dots, n)$$

Where

$$\sum_{i=1}^m a_i = \sum_{j=1}^n b_j$$

### III. METHODOLOGY

1. Determine the proportion of each cost  $c_{ij}$  relative to the total cost  $C$  of the entire cost matrix say it  $[c'_{ij}]$ , as well as the percentage of time  $t_{ij}$  relative to the total time  $T$  of the entire time matrix say it  $[t'_{ij}]$ . This will result in the same weightage of each cost and time being used to determine the Penalties.
2. In the new proportion cost matrix  $[c'_{ij}]$ , calculate the penalties for each row (column) by calculating the difference between the least and next smallest unit transportation cost in the same row (column). This difference is the penalty or additional cost that must be paid if the decision-maker fails to allocate to the cell with the lowest unit transit cost. Say these penalties as cost penalties. Repeat same process in percentage time matrix  $[t'_{ij}]$  also, Say this penalties as time penalties.
3. Choose the row or column with the highest penalty considering time and cost penalties, then allocate as much as possible in the cell with the lowest cost in the chosen row or column that also meets the rim requirements. If there is a tie in the penalty values, it can be broken by picking the cell with the highest allocation. Adjust supply and demand as needed, and then eliminate the fulfilled row or column. If a row and a column are both satisfied, just one of them is eliminated, and the remaining row (column) is assigned a supply (demand) of zero. Future penalties should not be computed using any row or column with zero supply or demand.
4. Continue from steps 1 through 3 until all sources and destinations have sufficient supply and demand.
5. Utilising the assigned matrix, determine the total cost and time. This will gives the Initial basic feasible solution of the given problem.
6. This solution is the first basic feasible solution by the approximation method.

### IV. NUMERICAL EXAMPLE

Cost Matrix  $[c_{ij}]$

		Destinations					Supply
		$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	
Sources	$S_1$	225	131	146	512	325	25
	$S_2$	514	521	121	124	325	13
	$S_3$	341	252	324	111	214	14
	$S_4$	321	112	512	411	214	52
	$S_5$	541	321	412	555	253	32
Demand		16	23	30	35	32	

Time Matrix $[c_{ij}]$

		Destinations					Supply
		$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	
Sources	$S_1$	12	15	12	20	17	25
	$S_2$	14	10	17	25	18	13
	$S_3$	15	15	12	11	15	14
	$S_4$	18	25	19	21	16	52
	$S_5$	12	18	15	12	23	32
Demand		16	23	30	35	32	

proportion Cost Matrix

$$[c'_{ij}] = \begin{bmatrix} 2.8345 & 1.6503 & 3.0990 & 6.4500 & 4.0942 \\ 6.4752 & 6.5634 & 1.5243 & 1.5621 & 4.0942 \\ 4.2958 & 3.1746 & 4.0816 & 1.3983 & 2.6959 \\ 4.0438 & 1.4109 & 6.4500 & 5.1776 & 2.6959 \\ 6.8153 & 4.0438 & 5.1902 & 6.9917 & 3.1872 \end{bmatrix}$$

proportion Time Matrix

$$[t'_{ij}] = \begin{bmatrix} 2.9484 & 3.6855 & 2.9484 & 4.9140 & 4.1769 \\ 3.4398 & 2.4570 & 4.1769 & 6.1425 & 4.4226 \\ 3.6855 & 3.6855 & 2.9484 & 2.7027 & 3.6855 \\ 4.4226 & 6.1425 & 4.6683 & 5.1597 & 3.9312 \\ 2.9484 & 4.4226 & 3.6855 & 2.9484 & 5.6511 \end{bmatrix}$$

Allocations made by Time-Cost Algorithm are

		Destinations					Supply
		$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	
Sources	$S_1$	0	08	17	0	0	25
	$S_2$	0	0	13	0	0	13
	$S_3$	0	0	0	14	0	14
	$S_4$	05	15	0	0	32	52
	$S_5$	11	0	0	21	0	32
Demand		16	23	30	35	32	

Initial Basic Feasible Solutions By Time-Cost Algorithm are

- Minimum Cost

$$Z_1 = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij}$$

$$= 8 * 131 + 17 * 246 + 13 * 121 + 14 * 111 + 214 * 32 + 321 * 5 + 112 * 15 + 11 * 541 + 555 * 21 = 36096$$

- Minimum Time

$$Z_2 = \sum_{i=1}^m \sum_{j=1}^n t_{ij} y_{ij} = 15 + 12 + 17 + 11 + 18 + 25 + 16 + 12 + 12 = 138$$

Now if we apply the VAM algorithm to only the Cost matrix and determine the allocation then the minimum Cost and Time by that allocations are as follows.



		Destinations					
		$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	Supply
Sources	$S_1$	08	0	17	0	0	25
	$S_2$	0	0	13	0	0	13
	$S_3$	0	0	0	14	0	14
	$S_4$	08	23	0	21	0	52
	$S_5$	0	0	0	0	32	32
Demand		16	23	30	35	32	

- Minimum Cost

$$Z_1 = \sum_{i=1}^m \sum_{j=1}^n c_{ij}x_{ij}$$

$$= 8 * 225 + 17 * 246 + 13 * 121 + 14 * 111 + 8 * 321 + 23 * 112 + 21 * 411 + 32 * 253$$

$$= 30980$$

- Minimum Time

$$Z_2 = \sum_{i=1}^m \sum_{j=1}^n t_{ij}y_{ij} = 12 + 12 + 17 + 11 + 18 + 25 + 21 + 23 = 139$$

Also, if we apply the VAM algorithm to only the Time matrix and determine the allocation then the minimum Cost and Time by that allocation are as follows.

		Destinations					
		$D_1$	$D_2$	$D_3$	$D_4$	$D_5$	Supply
Sources	$S_1$	0	0	25	0	0	25
	$S_2$	0	13	0	0	0	13
	$S_3$	0	0	0	14	0	14
	$S_4$	15	0	05	0	32	52
	$S_5$	1	10	0	21	0	32
Demand		16	23	30	35	32	

- Minimum Cost

$$Z_1 = \sum_{i=1}^m \sum_{j=1}^n c_{ij}x_{ij}$$

$$= 25 * 246 + 13 * 521 + 14 * 111 + 15 * 321 + 5 * 512 + 32 * 214 + 1 * 541 + 10 * 321$$

$$+ 21 * 555$$

$$= 44106$$

- Minimum Time

$$Z_2 = \sum_{i=1}^m \sum_{j=1}^n t_{ij}y_{ij} = 12 + 10 + 11 + 18 + 19 + 16 + 12 + 18 + 12 = 128$$

### V. EXPERIMENTAL RESULTS

In order to investigate the effect of applying the proportion on given transportation problem, a computer program was developed to find proportion of given transportation time and cost matrices. Algorithm as described above has been applied on that matrices and supply and demand allocated. Here different kinds of the results are found in each problem. Here as shown in table we applied three different methods in each problem. In case II and III minimised time and cost matrix by using only time and cost matrix by VAM method minimum cost and minimum time and cost found by same allocations. Here as shown in table we applied three different methods in each problem. In case II and III minimised time and cost matrix by using only time and cost matrix by VAM method minimum cost and minimum time and cost found by same allocations.





1. Time-Cost Algorithm for minimization of time and cost both by using both matrices.
2. VAM method on cost matrix of given TP to minimise cost.
3. VAM method on Time matrix of given TP to minimise time.

Following observations are found after application of these three cases.

- In algorithm when we apply the proportion method then for calculation we will use one of matrix from time and cost matrices in each iteration. So, in which the maximum penalty occurs either it is cost penalty or time penalty that matrix will be selected.
- After calculating some problems I found that in some problems only time matrix or the only cost matrices are involved in each iteration. Also in some problems both matrices are involved during calculation.
- Two problem out of six in which found that both time and cost matrices are involved.
- Getting lowest cost by Time-Cost Algorithm in three problems. In problem 1,4 and 5.
- Getting lowest time by Time-Cost Algorithm in three problems. In problem 1,5 and 6.

		T-C Algorithm		Vam Method			
		Cost	Time	By Cost Matrix		By Time Matrix	
Pr.No.	Pr.Size	Cost	Time	Cost	Time	Cost	Time
1	3x4	2450	428	2500	550	3200	425
2	5x5	36096	138	30980	139	44106	128
3	4x6	132140	267	131990	257	159725	262
4	4x6	162485	267	159725	262	162485	267
5	4x4	102460	176	15925	187	103720	177
6	5x5	146387	365	140483	446	144203	403

Table 1: Comparison of Methods

## VI. CONCLUSION

VAM algorithm is employed with the primary objective of minimizing either Time or Cost in the given problem. This optimization is achieved by selectively utilizing one of the matrices for computation. It is noteworthy that focusing on a singular matrix enhances the algorithm’s performance, particularly evident in the resultant table. Upon closer examination, it becomes evident that the Time Cost algorithm, when applied, yields an amalgamation of minimum cost and time. This combination results in a superior outcome, showcasing a reduced cost when compared to the results obtained solely through the VAM algorithm using the Time matrix. The same holds true for achieving minimum Time. It is crucial to note that while the algorithm may not universally excel across all problems, its efficacy becomes apparent when the objective is to simultaneously minimize both time and cost. Suppliers seeking to optimize both criteria should duly consider the results obtained through this methodology, as it may unveil potentially advantageous outcomes.

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