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THE TRIPLE TEST ALGORITHM TO GET FEASIBLE SOLUTION FOR TRANSPORTATION PROBLEMS

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Abstract

In this paper, we consider transportation problem to obtain the solution almost optimal or a better initial solution. The most important and successful applications in the optimization refer to transportation problem, that is, a special class of the linear programming in the operation research. The main objective of transportation problem is to minimize the cost or the time of transportation. Most of the currently used methods for solving transportation problems are trying to reach the optimal solution, whereby, most of these methods are considered complex and very expansive. Approximate heuristics give good starting solution to the transportation problem like Vogel's Approximation Method (VAM). In this study, we develop a heuristic to obtain a good initial solution to the transportation problem, namely, Triple Test Algorithm (TTA) in which the key idea is to obtain the closest to optimal solution or a better initial solution than other

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available methods. Comparatively, applying the TTA in the proposed method obtains the best initial feasible solution to a transportation problem and performs faster than the existing methods with a minimal computation time and less complexity. We hope that the proposed method would be an attractive alternative to traditional transportation problem solution methods.

1. Introduction

In this study, we propose Triple Test Algorithm to get a better initial feasible solution that is mostly optimal. We give a brief literature review and methods in Sections 1 and 2. In Section 3, we introduce the algorithm and give computational experience on the performance of heuristic developed in this paper, and compare it with the VAM method. In Section 4, we give our conclusions.

Literature review

Let us consider the standard balanced transportation problem, with the optimal pattern of the product units' distribution from m sources to n destinations. Suppose there are m points of sources $S_1, \ldots, S_i, \ldots, S_m$ and n destinations $D_1, \ldots, D_j, \ldots, D_n$. The point S_i $(i = 1, \ldots, m)$ can supply s_i units, and the destination D_j $(j = 1, \ldots, n)$ requires d_j units (see equation (1))

$$\sum_{i=1}^{m} s_i = \sum_{j=1}^{n} d_j. \tag{1}$$

The cost of shipping a unit from S_i to D_j, is computed as c_{ij}. As well as, the problem in determining the optimal distribution pattern consists the pattern for which shipping costs are at a minimum. Moreover, the requirements of the destinations D_j, $j = 1, \ldots, n$, must be satisfied by the supply of available units at the points of origin S_i, $i = 1, \ldots, m$.

If x_{ij} is the number of units that are shipped from S_i to D_j, then the problem in determining the values of the variables x_{ij}, $i = 1, ..., m$ and $j = 1, ..., n$, should minimize the total of the shipping costs. The transportation problem can be represented as a linear programming model. Since the objective function in this problem is to minimize the total transportation cost,

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{2}$$

while

$$\sum_{j=1}^{n} x_{ij} \leq s_i \quad (i = 1, ..., m), \tag{3}$$

$$\sum_{i=1}^{m} x_{ij} \geq d_j \quad (j = 1, ..., n), \tag{4}$$

$$x_{ij} \geq 0 \quad (i = 1, ..., m;\ j = 1, ..., n). \tag{5}$$

There are several different algorithms to solve transportation problem that is represented as LP model. Among these are the known algebraic procedures of the simplex method that might not be the best method to solve the problem. So, more efficient and simpler procedures have been improved to solve transportation problems. The most well-known is probably the transshipment problem [1]. The min-cost flow problem is a further generalization of the transshipment problem, introducing capacities on the arcs. In the fixed-charge transportation problem [2], a fixed cost may be incurred for every arc in the transportation network that is used. Numerous other generalizations of the transportation problem have been presented, for instance to solve spatial economic equilibrium problems [3], and aircraft routing problems [4], or even to deal with wartime conditions where distances from some sources to some destinations are no longer definite (i.e., the gray transportation problem, [5]). And also, Chanas et al. developed a method for solving fuzzy transportation problems by applying the parametric programming technique using the Bellman-Zadeh criterion [6].

Transportation problem is a special class of linear programming problems which deals with the distribution of single commodity from various sources of supply to various destinations of demand in such a manner that the total transportation cost is minimized. Transportation problem can be adopted in the linear programming technique with equality constraints. LP technique can be used in different product areas such as oil plum industry [7]. However, the LP technique can be generally used by genetic algorithm such as Sudha and Thanushkodi [8]. The transportation solution problem can be found with a good success in the improving the service quality of the public transport systems [9]. Also, it is found in Ismail et al. [10]. As well as, the transportation solution problem is used in the electronic commerce area [11], and it can be used in a scientific field such as the simulated data for biochemical and chemical oxygen demands transport [12], and many other fields. Moreover, ad-hoc networks are designed dynamically by group of mobile devices. In ad-hoc network, nodes between source and destination act as routers so that source node can communicate with the destination node [13].

Typically, the standard scenario for solving transportation problems is working by sending units of a product across a network of highways that connect a given set of cities. Each city is considered as a source (*S*) in that units will be shipped out from, while units are demanded there when the city is considered as a destination (*D*). In this scenario, each destination has a given demand, the source has a given supply, and the highway that connects source with destination as a pair has a given transportation cost/(shipment unit). Figure 1 shows the standard scenario for cities on the highway in the form of a network.

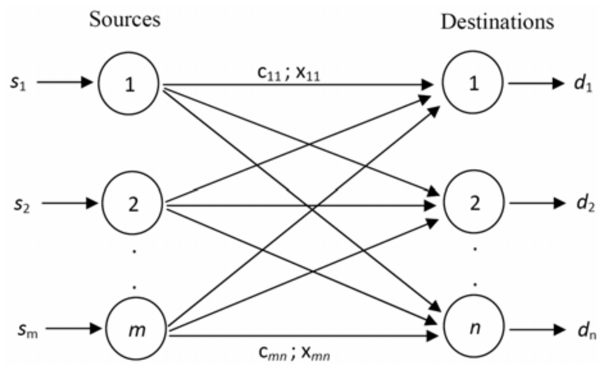

Figure 1. Network flow model of the transportation problem.

As shown by Figure 1, the problem is to determine an optimal transportation scheme that is to minimize the total of the shipments cost between the nodes in the network model, subject to supply and demand constraints.

2. Materials and Method

In a transportation problem, we are focusing on the source points. These points may represent factories to produce items, and to supply a required quantity of the products to a certain number of destinations. This process must be done successfully in such a way as to maximize the profit or minimize the cost transportation. Therefore, the places of production and supply are collected as the original points and the destinations, respectively. Sometimes the sources and destinations points are also termed as original and sink. However, to illustrate a typical transportation model, suppose that m sources supply certain items to n destinations. As well as, let source i $(i = 1, 2, ..., m)$ produce s_i units, and the destination j $(j = 1, 2, ..., n)$ requires d_j units. Furthermore, suppose the cost of transportation from source i to destination j is c_{ij}. The decision variables x_{ij} are being the transported amount from the source i to the destination j. Typically, our objective is to find the transportation pattern that will minimize the total cost (see Table 1).

Table 1. The matrix of a transportation problem

	Destinations				**Available**
Sources	1	2	…	n	
1	c_{11}	c_{12}	…	c_{1n}	a_1
2	c_{21}	c_{22}	…	c_{2n}	a_2
…	…	…	…	…	…
m	c_{m1}	c_{m2}	…	c_{mn}	a_m
Required	b_1	b_2	…	b_n	

There are several well-known algorithms to get feasible solution for transportation problems which are based on different special linear programming methods, among these are:

1. Northwest Corner Method
2. Minimum Cost Method
3. Genetic Algorithm
4. Vogel's Approximation Method
5. Row Minimum Method
6. Column Minimum Method
7. Best Candidate Method [14].

These methods are different in terms of the quality for the produced basic starting solution and the best starting solution that aims smaller objective value. In this study, we develop a heuristic to obtain a good initial solution to the transportation problem, namely, *Triple Test Algorithm* (*TTA*) in which the key idea is to obtain the closest to optimal solution or a better initial feasible solution than other available methods.

Vogel's Approximation Method (VAM)

This method also takes costs into account in allocation. The Vogel's Approximation Method (VAM) usually produces an optimal or near-optimal starting solution.

Five steps are involved in applying this heuristic:

Step 1: Determine the difference between the lowest two cells in all rows and columns, including dummies. The result of subtracting the smallest unit cost element in the row/column (cell) from the immediate next smallest unit cost element in the same row/column is determining a penalty measure for the target row/column.

Step 2: Identify the row or column with the largest penalty. Ties may be broken arbitrarily.

Step 3: Allocate as much as possible to the lowest-cost cell in the row or column with the highest difference. If two or more differences are equal, allocate as much as possible to the lowest-cost cell in these rows or columns.

Step 4: Stop the process if all row and column requirements are met. If not, then go to the next step.

Step 5: Recalculate the differences between the two lowest cells remaining in all rows and columns. Any row and column with zero supply or demand should not be used in calculating further differences. If one row/column with positive supply (demand) remains uncrossed out, then determine the basic variables in the row/column by the lowest cost method, and then stop. Otherwise, go to Step 2.

3. Proposed Method "Triple Test Algorithm"

In this study, we proposed a new solving method for transportation problems, namely, *Triple Test Algorithm* (*TTA*). The proposed method must operate as the following:

Step 1: We must check the matrix balance, if the total supply is equal to the total demand, then the matrix is balanced. If the total supply/

demand is not equal to the total demand/supply, then we add a dummy row or column as needed to make equal. The transportation costs in this dummy row or column should be assigned to zero.

Step 2: Identify as much as three smallest costs as candidate entering variables for each column. If there are more than one candidate entering variables which have the same cost, choose the variable that has smallest index as a candidate.

Step 3: If there is no candidate variable in a row, choose the smallest as a candidate entering variable and also if there are more than one candidate entering variables which have the same cost, choose the variable that has smallest index as a candidate.

Step 4: Count the number of candidates for each row. Select the row which has minimum candidates. Choose the candidate entering variable that has minimum cost in the row as basic variable. If there are more than one candidate rows which have the same number of candidates, then choose the row that has smallest index. Then allocate the demand and the supply as much as possible to the variable and adjust the associated amounts of supply and demand by subtracting the allocated amount. If the supply in row i is satisfied remove row i or if the demand in column j is satisfied remove column j. If the supply in row i and the demand in column j is satisfied as the same time, remove either row i or row j, but not both.

Step 5: Update the table. If all units have been allocated, then stop. The solution is feasible. Otherwise, go to Step 2.

Problem. Finding the optimal cost for the problem of delivering goods from plants to customers.

Table 2. The cost matrix

Plants	D1	D2	D3	D4	D5	Supply
S1	14	10	15	16	18	20
S2	18	9	12	14	16	16
S3	16	8	13	12	14	13
S4	13	10	11	15	12	16
S5	10	14	10	12	14	25
Demand	18	16	12	15	29	

Table 3. The proposed method - process 1

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	14*	**16** 10*	15	16	18	4	2
S2	18	x 9*	12*	14*	16	16	3
S3	16	x 8*	13	12*	14*	13	3
S4	13*	x 11	11*	15	12*	16	3
S5	10*	x 14	10*	12*	14*	25	4
Demand	18	0	12	15	29		

Table 4. The proposed method - process 2

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	4 14*	16 10	x 15	x 16	x 18	0	1
S2	18	x 9	12*	14*	16	16	2
S3	16	x 8	13	12*	14*	13	2
S4	13*	x 11	11*	15	12*	16	3
S5	10*	x 14	10*	12*	14*	25	4
Demand	14	0	12	15	29		

Table 5. The proposed method - process 3

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	18	x 9	**12** 12*	14*	16	4	2
S3	16*	x 8	x 13	12*	14*	13	2
S4	13*	x 11	x 11*	15	12*	16	2
S5	10*	x 14	x 10*	12*	14*	25	3
Demand	14	0	0	15	29		

Table 6. The proposed method - process 4

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14*	x 16	0	1
S3	16*	x 8	x 13	12*	14*	13	3
S4	13*	x 11	x 11	15*	12*	16	3
S5	10*	x 14	x 10	12*	14*	25	3
Demand	14	0	0	11	29		

Table 7. The proposed method - process 5

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14	x 16	0	x
S3	16*	x 8	x 13	**11** 12*	14*	2	3
S4	13*	x 11	x 11	x 15*	12*	16	3
S5	10*	x 14	x 10	x 12*	14*	25	3
Demand	14	0	0	0	29		

Table 8. The proposed method - process 6

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14	x 16	0	x
S3	x 16*	x 8	x 13	**11** 12	**2** 14*	0	2
S4	13*	x 11	x 11	x 15	12*	16	2
S5	10*	x 14	x 10	x 12	14*	25	2
Demand	14	0	0	0	27		

Table 9. The proposed method - process 7

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14	x 16	0	x
S3	x 16	x 8	x 13	**11** 12	**2** 14	0	x
S4	x 13*	x 11	x 11	x 15	**16** 12*	0	2
S5	10*	x 14	x 10	x 12	14*	25	2
Demand	14	0	0	0	11		

Table 10. The proposed method - process 8

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14	x 16	0	x
S3	x 16	x 8	x 13	**11** 12	**2** 14	0	x
S4	x 13	x 11	x 11	x 15	**16** 12	0	x
S5	**14** 10*	x 14	x 10	x 12	14*	11	2
Demand	0	0	0	0	11		

Table 11. The feasible and also optimal solution

Plants	D1	D2	D3	D4	D5	Supply	The number of min costs
S1	**4** 14	**16** 10	x 15	x 16	x 18	0	x
S2	x 18	x 9	**12** 12	**4** 14	x 16	0	x
S3	x 16	x 8	x 13	**11** 12	**2** 14	0	x
S4	x 13	x 11	x 11	x 15	**16** 12	0	x
S5	**14** 10	x 14	x 10	x 12	**11** 14	0	x
Demand	0	0	0	0	0		

We found that the result by using TTA as:

$$4 * 14 + 16 * 10 + 12 * 12 + 4 * 14 + 11 * 12 + 2 * 14$$

$$+ 16 * 12 + 14 * 10 + 11 * 14 = 1062$$

is alternative optimal solution.

Also, we get different alternative optimal solution by using Vogel's Approximation Method (VAM). The solution is represented below.

Table 12. The optimal solution by Vogel's Approximation Method (VAM)

Plants	D1	D2	D3	D4	D5
S1	14	**16** 10	15	**4** 16	18
S2	18	9	**12** 12	**4** 14	16
S3	16	8	13	**7** 12	**6** 14
S4	13	11	11	15	**16** 12
S5	**18** 10	14	10	12	**7** 14

4. Results and Conclusion

In this study, we have proposed a new algorithm, namely, Triple Test

Algorithm (TTA), for the transportation problem because of its wide applicability in different areas. Using the TTA, we obtained an initial feasible solution.

Efficiently, TTA works to obtain the optimal solution or the closest to optimal solution like Vogel's Approximation Method (VAM) than other available methods. Since it has a better initial solution.

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