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Original Article

A Novel Heuristic for the Transportation Problem: Dhouib-Matrix-TP1

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Abstract - *The transportation problem is widely applied in the real world. This problem aims to minimize the total shipment cost from a number of sources to a number of destinations. This paper presents a new method named Dhouib-Matrix-TP1, which generates an initial basic feasible solution based on the standard deviation metric with a very reduced number of simple iterations. A comparative study is carried out in order to verify the performance of the proposed Dhouib-Matrix-TP1 heuristic.*

Keywords - *Transportation problem, Operational research, Combinatorial optimization, Optimal solution, Initial basic feasible solution, Heuristic, Dhouib-Matrix.*

1. Introduction

Many real-world industrial problems deal with shipping some products from supply to demand with minimal total cost. This problem is known as the Transportation Problem (TP). In fact, several methods exist in the literature to find the Initial Basic Feasible Solution (IBFS), which represents a significant step to achieving the optimal solution. [1] proposed a method to generate an IBFS for the modified unbalanced TP. [2], [3] and [4] examined the importance of certain modifications to VAM for obtaining the minimal total cost solution to unbalanced TP. [5] studied a sensitivity analysis on the TP with varying demands and supplies within their respective ranges. [6] designed a heuristic to search for lower and upper minimal bounds. [7] generated an approach, namely an innovative method (NMD), to provide an IBFS for the TP. Here we present a new heuristic, based on the standard deviation metric, to obtain the IBFS for the TP. This method is denoted by Dhouib-Matrix-TP1 (DM-TP1).

The remainder of this research paper is organized as follows: Section 2 deals with the mathematical formulation of the TP. The proposed new heuristic DM-TP1 is detailed in section 3. In section 4, the stepwise of the DM-TP1 is presented with several numerical illustrations. Finally, the conclusion and the future research scope on this topic will be presented in section 5.

2. The Mathematical Formulation of the Transportation Problem

The objective of the Transport Problem (TP) is to search for the optimal value of x_{ij} that will minimize the total transportation cost (see Eq. 1) while satisfying the supply and demand restrictions (see Eq. 2). The TP is mathematically formulated as follows by:

$$\text{Minimize: } z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{1}$$

Subject to:

$$\begin{aligned} &\sum_{j=1}^{n} x_{ij} = a_i \;;\; i = 1, 2, \ldots, m \\ &\sum_{i=1}^{m} x_{ij} = b_j \;;\; j = 1, 2, \ldots, n \\ &x_{ij} \geq 0 \text{ for all } i \text{ and } j \end{aligned} \tag{2}$$

The notation of the TP is:

m total number of supplies (sources)

n total number of demands (destinations)

a_i Amount of supply at source i

b_j Amount of demand at destination j

c_{ij} Transportation cost from supply i to demand j

x_{ij} Amount to be shipped from source i to destination

3. The Proposed Method: DM-TP1

Very recently, we designed and developed a new range of heuristics, Dhouib-Matrix-TSP1 (DM-TSP1) and Dhouib-Matrix-TSP2 (DM-TSP2), for the traveling salesman problem [8, 9, 10, 11, 12, 13]. Whereas in this paper, we design another original heuristic for the TP, namely Dhouib-Matrix-TP1 (DM-TP1), which is a deterministic method based on several rules. Fig. 1 depicts the 8 steps of the DM-TP1 heuristic.

Dhouib-Matrix (DM-TP1)

- Step 1: balance the sum of supplies and demands for the transport matrix.
- Step 2: compute the standard deviation for each row and multiply it by the corresponding supply value. Then, place the Standard Deviation Supply Row (SDSR) at the last column.
- Step 3: apply the same operation on each column. Compute the standard deviation for each column and multiply it by the corresponding demand value. Then, place the Standard Deviation Demand Column (SDDC) at the last row.
- Step 4: identify the highest element among the SDSR and SDDC, if it is in SDSR then select the minimal element (x_{ij}) of its corresponding row else check the minimal element (x_{ij}) of its corresponding column.
- Step 5: if $a_i <= b_j$ then allocate the a_i amount of units to the x_{ij}, affect $b'_j = b_j - a_i$ and discard row i.
- Step 6: if $a_i > b_j$ then allocate the b_j amount of units to the x_{ij}, affect $a'_i = a_i - b_j$ and discard column j.
- Step 7: repeat steps 4-5 and 6 until all columns are discarded.
- Step 8: calculate the minimum transportation cost.

Fig. 1 The DM-TP1 Heuristic

The proposed DM-TP1 heuristic is a very simple and fast method. In fact, it needs only n iterations to generate the optimal or near-optimal solution. Furthermore, in this paper, the standard deviation metric is used for selection; however, any other metric function can be used.

4. The Computational Results

In order to prove the performance of the proposed method, three numerical examples will be presented in this section (these examples are taken from [14]).

4.1. Example 1

Fig. 2 depicts the transportation matrix for a motorbikes company with three factories and four showrooms.

Factories	Showrooms				Supply (a_i)
	D_1	D_2	D_3	D_4	
W_1	9	8	5	7	12
W_2	4	6	8	7	14
W_3	5	8	9	5	16
Demand (b_j)	8	18	13	3	42

Fig. 2 The transportation matrix

The first step is to compute for each row and column the corresponding SDSR and SDDC. Then, place these values respectively at the last column and row and select the highest element, which is 28.57 (see Fig. 3).

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1	9	8	5	7	12	17.75
W_2	4	6	8	7	14	20.71
W_3	5	8	9	5	16	28.57
Demand (b_j)	8	18	13	3		
SDDC	17.18	16.97	22.10	2.83		

Fig. 3 Compute the corresponding SDSR and SDDC

Then, select the smallest element in the row, which is 5 at position W_3D_1, and affect 8 units (which represents the smallest element between demand 8 and supply 16). Now, discard the saturated element, which is the column of D_1 (see Fig. 4).

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1		8	5	7	12	14.97
W_2		6	8	7	14	11.43
W_3		8	9	5	8	13.59
Demand (b_j)		18	13	3		
SDDC		16.97	22.10	2.83		

Fig. 4 Discard column D1

Next, find the highest element in SDSR and SDDC (which is 22.10 in column D_3). Then, select the smallest element in this column (which is 5 at position W_1D_3) and affect 12 units (which represents the smallest element between demand 13 and supply 12). Finally, discard the saturated element, which is the row of W_1 (see Fig. 5).

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1						
W_2		6	8	7	14	11.43
W_3		8	9	5	8	13.59
Demand (b_j)		18	1	3		
SDDC		18	0.50	3		

Fig. 5 Discard row W1

Now, the highest element in SDSR and SDDC is 18 in column D_2. So, the smallest element in this column is selected, which is six at position W_2D_2 and affects 14 units. Finally, discard the row of W_2 (see Fig. 6).

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1						
W_2						
W_3		8	9	5	8	13.60
Demand (b_j)		4	1	3		
SDDC		0	0	0		

Fig. 6 Discard row W2

4.2. Example 2

This example is taken from [14], where a company manufactures Toys Robots composed of three factories, W_1, W_2, and W_3, and four showrooms, D_1, D_2, D_3, and D_4. The stepwise application of the DM-TP1 heuristic is depicted in Fig. 7.

a)

Factories	Showrooms				Supply (a_i)
	D_1	D_2	D_3	D_4	
W_1	2	2	2	1	3
W_2	10	8	5	4	7
W_3	7	6	6	8	5
Demand (b_j)	4	3	4	4	

b)

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1	2	2	2	1	3	1.30
W_2	10	8	5	4	7	16.70
W_3	7	6	6	8	5	4.15
Demand (b_j)	4	3	4	4		
SDDC	13.20	7.48	6.80	11.47		

c)

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1	2	2	2		3	0
W_2	10	8	5		3	6.16
W_3	7	6	6		5	2.36
Demand (b_j)	4	3	4			
SDDC	13.20	7.48	6.80			

d)

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1						
W_2	10	8	5		3	6.16
W_3	7	6	6		5	2.36
Demand (b_j)	1	3	4			
SDDC	1.5	3	2			

e)

Factories	Showrooms				Supply (a_i)	SDSR
	D_1	D_2	D_3	D_4		
W_1						
W_2						
W_3	7	6	6		5	2.36
Demand (b_j)	1	3	1			
SDDC	0	0	0			

$$z = (4*4)+(2*3)+(5*3)+7+(6*3)+6=68$$

Fig. 7 Just four iterations to solve the 3x4 transport matrix

4.3. Example 3

Fig. 8 presents another stepwise application of the DM-TP1 heuristic for a company composed of three factories, W_1, W_2, and W_3, with weekly production capacities (respectively equal to 9, 8, and 10) and three supplies with weekly demands (equal to 7, 12 and 8).

a)

Factories	Showrooms D_1	D_2	D_3	Supply (a_i)
W_1	4	3	5	9
W_2	6	5	4	8
W_3	8	10	7	10
Demand (b_j)	7	12	8	

b)

Factories	Showrooms D_1	D_2	D_3	Supply (a_i)	SDSR
W_1	4	3	5	9	7.35
W_2	6	5	4	8	6.53
W_3	8	10	7	10	12.48
Demand (b_j)	7	12	8		
SDDC	11.43	35.33	9.98		

c)

Factories	Showrooms D_1	D_2	D_3	Supply (a_i)	SDSR
W_1					
W_2	6	5	4	8	6.53
W_3	8	10	7	10	12.48
Demand (b_j)	7	3	8		
SDDC	7	7.5	12		

d)

Factories	Showrooms D_1	D_2	D_3	Supply (a_i)	SDSR
W_1					
W_2	6	5		8	4
W_3	8	10		2	2
Demand (b_j)	7	3			
SDDC	7	7.5			

e)

Factories	Showrooms D_1	D_2	D_3	Supply (a_i)	SDSR
W_1					
W_2	6			5	0
W_3	8			2	0
Demand (b_j)	7				
SDDC	7				

$$z = (3*9)+(7*8)+(5*3)+(6*5)+(8*2)=144$$

Fig. 8 Just four iterations to solve the 3x4 transport matrix using DM-TP1

4.4. Comparative Results

Table 1. summarizes the results found by the proposed DM-TP1 method and other methods from the literature [13], namely: the Average Penalty (AP), the North West Corner (NWC), the Matrix Minima Method, and the Vogel Approximation Method (VAM). The Relative Error (RE) is calculated for each method by RE(%) = ((*Best* - *Optimal*)/*Optimal*) x 100.

Table 1. Comparison between the DM-TP1 and four existing methods

Methods	Example 1		Example 2		Example 3	
	Best	RE	Best	RE	Best	RE
AP	248	0.03	68	0.00	139	0.00
NWC	320	0.33	93	0.37	150	0.08
MMM	248	0.03	79	0.16	145	0.04
VAM	248	0.03	68	0.00	150	0.08
DM-TP1	240	0.00	68	0.00	144	0.04
Optimal	240	0.00	68	0.00	139	0.00

Fig. 9 shows the DE percentage (taken from Table 1) of DM-TP1 and the other methods. This figure validates that DM-TP1 found the best DE (%) except for example 3, where the AP method found a better value than the DM-TP1 with a deviation of (0.04).

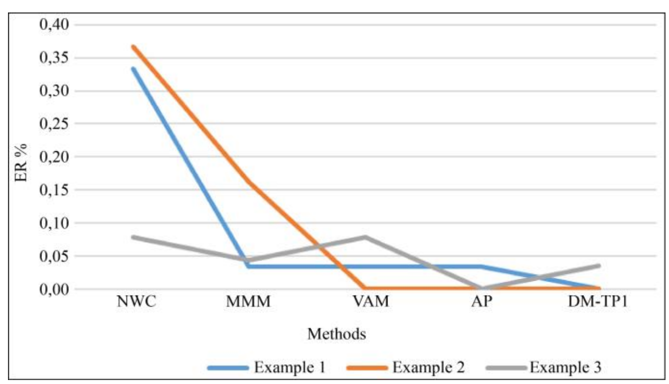

Fig. 9 The DE percentage of the DM-TP1 and other methods

5. Conclusion

A new heuristic, namely Dhouib-Matrix-TP1, is proposed to solve the transportation problem (in just *n* iterations) based on the standard deviation metric. Several examples are used to test the performance of the proposed Dhouib-Matrix-TP1 method. Then, the obtained results are compared with those of other methods from the literature. Further research work will deal with the application of the Dhouib-Matrix-TP1 heuristic in an uncertain environment.

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