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## Improved total difference method (ITDM): a new approach to solving transportation problem based on modifications of total difference method 1 and integration of total ratio cost matrix

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**Abstract:** In this paper, the initial basic feasible solution is referred to as the initial feasible solution (IFS). There are two phases in solving the transportation problem (TP). An IFS is determined in the first phase by using the least distribution cost, followed by the calculation of the optimal solution through the modification of total difference method (TDM 1), integrated with total ratio cost matrix (TRCM) in the second phase. In some cases, it has been found that TP has equal values of the distribution least costs so that the existing methods generate two or more IFS values. The newly developed algorithm obtains the optimal solution of TP. A total of 26 numerical examples were selected from reputed journals to evaluate the performance of the newly developed algorithm. The computational performances were compared to the existing methods in the literature and the results showed that this algorithm not only solves TP with similar values optimal solution but also produces better minimal solutions than existing methods.

**Keywords:** transportation problem; IFS; initial feasible solution; optimal solution; total difference method; TRCM; total ratio cost matrix.

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## 1 Introduction

Oil and gas companies incur huge operating expenditure for Oil distribution from refinery production factory to petrol stations throughout the country. Hitchcock (1941) said that optimum solution of the transportation problems (TP) is modelled by linear programming (LP) to achieve the most cost effective transportation routes and network. According to Juman and Hoque (2015), TP revolve around the distribution of the commodities and sources from suppliers to customers, whereby ideally, total supplies must equal total demand.

Generally, there are two phases in solving TP. The first phase involves finding an initial feasible solution (IFS), and the second phase involves searching for the optimal solution of TP based on the IFS obtained. A well performing algorithm is desired to find an IFS for TP because it can significantly affect the computation and iteration process of obtaining the optimal solution for TP. In certain situations, there is a possibility that the IFS is equal to the optimal solution for TP. Furthermore, there is also the possibility that two or more IFSs may not generate the best optimal solution for the TP. Therefore, this research creates a new algorithm for the IFS finding that can prevent two or more IFS complications.

Three well-known classical algorithms are used to obtain the IFS, i.e., northwest corner method (NCM), least cost method (LCM) and Vogel's approximation method (VAM). Many previous studies have been conducted to improve these classical algorithms by proposing an alternative algorithm. For instance, Shimshak et al. (1981) proposed modification of VAM through the heuristics approach to find an IFS for the unbalanced TP; while Goyal (1984) introduced a new version of VAM, known as the Goyal's VAM. Another method to solve TP i.e., total opportunity cost method (TOCM) was introduced by Kirca and Satir (1990). Furthermore, the combinations of TOCM and VAM was proposed by Mathirajan and Meenakshi (2004) and Korukoglu and Balli (2011). Islam et al. (2012) combined TOCM and distribution indicators (DIs) in order to obtain the optimal solution for TP. Khan et al. (2015) introduced the TOCM-SUM approach for a similar purpose. Allocation table method (ATM) and incessant allocation method (IAM) were presented by Ahmed et al. (2016) and Ahmed et al. (2016). Deshmukh (2012) presented a similar algorithm approach. Juman and Hoque (2015) compared VAM, zero suffix method (ZSM) and Sudhakar et al. (2012)'s method. The comparison showed that the Juman Hoque Method (JHM) is superior in obtaining the minimal total cost of 16 out of 18 standard test TP.

Hosseini (2017) did a modification of the total difference method 1 (TDM 1). The VAM algorithm calculates penalty for both rows and columns, while TDM 1 only considers penalty for rows of TP. Harrath and Kaabi (2018) introduced the global minimum method (GMM) and claimed that the performance is better than classical methods especially for large scale of TP. Azad and Hasan (2019) presented an effective algorithm, as known the Azad Hasan method (AHM), for allocating the lowest amount of demand and supply to the lowest distribution cost of the TP. They also claimed this new method is easier and involves less iteration than most of the classical methods. The modification of TDM 1 by adding the rules for selecting the highest penalty value and checking the lowest distribution cost, followed by the combination of TOCM and TDM 1 modification, was introduced (Amaliah et al., 2019). A novel approximation method i.e., the Karagul Sahin Approximation Method (KSAM) was developed (Karagul and Sahin, 2020).

All proposed methods above by previous researchers illustrate the importance of the least distribution costs of TP as a basis for allocating the amount of supply and demand of the TP because it will affect the value of IFS, the performance computation process, the iteration steps, and the minimum total cost.

However, these proposed methods can only run perfectly if the TP do not have equal least cost during the TP computation. Whenever there is equal least cost in TP computation, the methods will fail to determine the least cost. Several alternative solutions have been proposed by choosing one of the equal least cost values available. Nevertheless, these alternative solutions for TP will result in more than one IFS value. Consequently, the IFS value generated will be different and depending on the least cost value which is chosen to compute the IFS.

Therefore, the objective of this research is to overcome the limitations and complications of having two or more IFS values generated through the modification of TDM 1, followed by integrating with total ratio cost matrix (TRCM), which is named as Improved TDM (I-TDM). The proposed I-TDM is designed to obtain an optimal IFS value for the TP.

The rest of this paper is organised as follows. Section 2 introduces the formulation of TP. Section 3 presents the ITDM, Section 4 illustrates the numerical experiment by using the proposed algorithm mentioned in Section 3, while comparative studies are discussed in Section 5, and the conclusion of this research is given in Section 6.

## 2 Formulation of transportation problem

The formulation of TP is illustrated in Figure 1 with the aim to determine the approximation value of  $x_{ij}$  that minimises the total distribution cost as follows

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

subject to

$$\begin{aligned} \sum_{j=1}^n x_{ij} &\leq s_i, \quad i = 1, 2, \dots, m \\ \sum_{i=1}^m x_{ij} &\leq d_j, \quad j = 1, 2, \dots, n \\ x_{ij} &\geq 0, \quad \forall i, j \end{aligned} \tag{2}$$

where  $m$  represents total supply,  $n$  represents total demand,  $s_i$  is  $i$ th supply,  $d_j$  is  $j$ th demand,  $c_{ij}$  is distribution cost from  $i$ th supply to  $j$ th demand,  $x_{ij}$  is the number of approximation unit to assign from  $i$ th supply to  $j$ th demand,  $\min T$  is minimal total distribution cost, while, total supply identically to total demand is referred as balanced TP and given as

$$\sum_{i=1}^m s_i = \sum_{j=1}^n d_j \tag{3}$$

**Figure 1** The transportation problem table

	$D_1$	$D_2$	...	$D_n$	$s_i$
$S_1$	$x_{11}$ $c_{11}$	$x_{12}$ $c_{12}$	...	$x_{1n}$ $c_{1n}$	$s_1$
$S_2$	$x_{21}$ $c_{21}$	$x_{22}$ $c_{22}$	...	$x_{2n}$ $c_{2n}$	$s_2$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
$S_m$	$x_{m1}$ $c_{m1}$	$x_{m2}$ $c_{m2}$	...	$x_{mn}$ $c_{mn}$	$s_m$
$d_j$	$d_1$	$d_2$	...	$d_n$	

### 3 Improved TDM (I-TDM)

The proposed algorithm was checked to see whether or not equation (3) is satisfied, followed by the calculation of row ratio matrix ( $\alpha_{ij}$ ) and column ratio matrix ( $\beta_{ij}$ ) by using equations (4) and (5), respectively. By determining the sum of  $\alpha_{ij}$  and  $\beta_{ij}$ , the resulting value is called TRCM. The new proposed algorithm in detail is shown in Algorithm 1,

$$\alpha_{ij} = \frac{c_{ij}}{\theta_i}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (4)$$

$$\beta_{ij} = \frac{c_{ij}}{\theta_j}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (5)$$

where  $\theta_i = \min(c_{ij}) = (c_{i1}, c_{i2}, \dots, c_{in})$  and  $\theta_j = \min(c_{ij}) = (c_{1j}, c_{2j}, \dots, c_{mj})$

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#### Algorithm 1: A New Heuristic TP Algorithm

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**Data:** Initialization: Number of rows is m, Number of column is n, supply ( $s_i$ ), demand ( $d_j$ ), distribution cost ( $c_{ij}$ ), the number of approximation unit ( $x_{ij}$ )

**Result:** min T by Eq. (1)

Calculate  $\alpha_{ij}$  by Eq. (4) and  $\beta_{ij}$  by Eq. (5);

Calculate the TRCM which is the entries are the sum of the row and column ratio matrix;

TRCM is denoted by  $\omega_{ij}$ ;

**repeat**

  {Produce a minimal total distribution cost} ;

**for**  $i=1$  to  $n$  **do**

    Find the penalty ( $F_j$ ) for each  $j^{th}$  column by  $F_j = \sum_{i=1}^m (\omega_{ij} - \min(\omega_{ij}))$ ;

    Select highest of  $F_j$  (HF) by  $HF = \max(F_j)$ ;

    In case of a break-even (i.e. equal HF);

      (a) select HF with the smallest  $\omega_{ij}$  ;

      (b) if (a) is equal, then select  $F_j$  with the greatest total of TRCM by  $T\omega_j = \sum_{i=1}^m \omega_{ij}$  ;

      (c) if (b) is equal, then select penalty with the max allocation of  $x_{ij}$ .

    Select the least  $\omega_{ij}$  of HF. If tie, then select least  $\omega_{ij}$  with max  $x_{ij}$ ;

    Allocate the  $x_{ij}$  to it;

    There may arise the following three cases;

**if**  $\min(s_i, d_j) = s_i$  **then**

      |  $x_{ij} = s_i, d_j = d_j - s_i, s_i = 0$ , cross out of  $s_i$

**end**

**if**  $\min(s_i, d_j) = d_j$  **then**

      |  $x_{ij} = d_j, s_i = s_i - d_j, d_j = 0$ , cross out of  $d_j$

**end**

**if**  $s_i = d_j$  **then**

      |  $s_i = 0, d_j = 0$ , cross out of  $s_i$  and  $d_j$

**end**

**end**

  Recalculate the penalty without considering the cross out rows and columns

**until**  $\{ \sum_{i=1}^m s_i = \sum_{j=1}^n d_j \}$ ;

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#### 4 Algorithm in practice

This research used 26 test problems taken from selected journals to explain the proposed algorithm. For instance, the numerical example of Jude et al. (2017) was: Given a company has four supply plants which produces 6, 9, 7, and 12 cars. The company supplies to four customers, whose demands are 10, 4, 6 and 14 cars, respectively. The distribution cost of the car is shown in Table 1. The objective is to obtain the minimum total distribution cost. The problem is presented in Table 1, solved by using Algorithm 1 as follows,

**Table 1** An original data of transportation problem

	$D_1$	$D_2$	$D_3$	$D_4$	$s_i$
$S_1$	2.0	6.0	5.0	3.0	6.0
$S_2$	9.0	6.0	2.0	1.0	9.0
$S_3$	5.0	2.0	3.0	6.0	7.0
$S_4$	7.0	7.0	2.0	4.0	12.0
$d_j$	10.0	4.0	6.0	14.0	

The solution of the transportation problem example in Table 1 is solved by using Algorithm 1 as follows:

*Step 1:* Calculating  $\alpha_{ij}$  and  $\beta_{ij}$ . For  $i, j = 1, 2, 3, 4$  are obtained as bellows:

$$\alpha_{ij} = \begin{pmatrix} 1.0 & 3.0 & 2.5 & 1.5 \\ 9.0 & 6.0 & 2.0 & 1.0 \\ 2.5 & 1.0 & 1.5 & 3.0 \\ 3.5 & 3.5 & 1.0 & 2.0 \end{pmatrix} \text{ and } \beta_{ij} = \begin{pmatrix} 1.0 & 3.0 & 2.5 & 3.0 \\ 4.5 & 3.0 & 1.0 & 1.0 \\ 2.5 & 1.0 & 1.5 & 6.0 \\ 3.5 & 3.5 & 1.0 & 4.0 \end{pmatrix}$$

*Step 2:* Calculating  $\omega_{ij}$ . For  $i, j = 1, 2, 3, 4$  is produced as bellow

$$\omega_{ij} = \begin{pmatrix} 1.0 + 2.0 = 3.0 & 3.0 + 3.0 = 6.0 & 2.5 + 2.5 = 5.0 & 1.5 + 3.0 = 4.5 \\ 9.0 + 4.5 = 13.5 & 6.0 + 3.0 = 9.0 & 2.0 + 1.0 = 3.0 & 1.0 + 1.0 = 2.0 \\ 2.5 + 2.5 = 5 & 1.0 + 1.0 = 2.0 & 1.5 + 1.5 = 3.0 & 3.0 + 6.0 = 9.0 \\ 3.5 + 3.5 = 7 & 3.5 + 3.5 = 7 & 1.0 + 1.0 = 2.0 & 2.0 + 4.0 = 6.0 \end{pmatrix}$$

*Step 3:* Calculating  $F_j$ . For  $j=1$  so  $F_1$  is obtained is  $F_1$  of column-1 = 19.5; column-2 = 15.0; column-3 = 6.00; column-4 = 13.0.

*Step 4:* Selecting the highest of  $F_1$  is  $F_1$  of column-2

*Step 5:* Selecting the least  $\omega_{ij}$  in  $F_1$  of column-2 is  $\omega_{11}$ .

*Step 6:* Allocating the  $x_{11}$  to  $\omega_{11}$  with  $x_{11} = \min(s_1, d_1) = \min(6, 10) = 6$  such that  $s_1 = s_1 - x_{11} = 6 - 6 = 0$  and  $d_1 = d_1 - x_{11} = 10 - 6 = 4$ . Since  $s_1 \neq 0$  and  $d_1 = 4$  then cross out of  $s_1$ .

*Step 7:* Re-calculating the penalty without considering  $d_2$  such that for  $j=2$  is obtained  $F_2$  of column-1 = 10.5; column-2 = 12.0; column-3= 2.00; column-4 = 11.0.

*Step 8:* Repeat Step 3 until Step 6 such that  $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$ . The final result is shown in Table 2

*Step 9:* Finally, calculating minimal total distribution cost by using equation (1). The result of min T is 83. The feasible solution table of example 1 shown in Table 2.

## 5 Result of comparison

This section provides a comparison between the existing algorithms i.e., TDM 1 (Hosseini, 2017), AHM (Azad and Hasan, 2019), KSAM (Karagul and Sahin, 2020), and TOCM-MT (Amaliah et al., 2019)) with the proposed algorithm. The comparison results are shown in Table 3. The test problems used in this section are taken from 26 different reputable journals (Kaur et al., 2019; Babu et al., 2013; Karagul and Sahin, 2020; Juman et al., 2013; Juman and Hoque, 2015; Sujatha, 2015; Das et al., 2014; Deshmukh, 2012; Rahman et al., 2017; Islam et al., 2012; Rahman, 2017,?; Jude et al., 2017; Amaliah et al., 2019; Geetha and Anandhi, 2018; Kulkarni and Datar, 2010), where several TP are balanced and the rest are unbalanced problems. The details of the problems is shown in Table 3.

**Table 2** The improved TDM with a penalty based on Jude et al. (2017) numerical example

	$D_1$	$D_2$	$D_3$	$D_4$	$s_i$
$S_1$	2.0 (6.0)	6.0 (0.0)	5.0 (0.0)	3.0 (0.0)	6.0
$S_2$	9.0 (0.0)	6.0 (0.0)	2.0 (0.0)	1.0 (9.0)	9.0
$S_3$	5.0 (3.0)	2.0 (4.0)	3.0 (0.0)	6.0 (0.0)	7.0
$S_4$	7.0 (1.0)	7.0 (0.0)	2.0 (6.0)	4.0 (5.0)	12.0
$d_j$	10.0	4.0	6.0	14.0	
$F * 1$	19.5	15.0	6.00	13.5	
$F * 2$	10.5	12.0	2.00	11.5	
$F * 3$	2.00	0.00	1.00	3.00	
$F * 4$	0.00	0.00	0.00	0.00	

Table 3 shows that in terms of IFS the proposed algorithm can solve 10 out of 26 of the test problems which is better compared to TDM 1 algorithm and similar with the other 9 TPs. Moreover, Table 3 also indicates that the TDM 1 algorithm generates better results compared to the proposed algorithm for TP5 and the rest of TP (TP2, TP8, TP12, TP13, TP22 and TP23). The TDM 1 algorithm produced two IFSs, while the proposed algorithm produced only one IFS and for the test problems of TP2, TP8 and TP22, all IFSs produced by TDM 1 algorithm are worse off compared to the proposed algorithm. Next, for test problems of TP12 and TP13, the first IFS produced by the TDM 1 algorithm is equal to the proposed algorithm. In contrast, the second IFS produced by the TDM 1 algorithm is worse than the proposed algorithm. As for test problem TP23, both IFSs produced by the TDM 1 algorithm are better than the proposed algorithm.

The proposed algorithm presented 13 better results out of 26 test problems compared to the AHM algorithm and broke-even with remaining 8 test problems. Table 3 shows that the AHM algorithm produced better results compared to the proposed algorithm for TP5 and for the remaining of TP (TP1, TP3, TP14 and TP22), the AHM algorithm generated two and two of IFS, while the proposed algorithm generated only one IFS. For the test problem of TP1, TP3, TP14 and TP22, all IFSs produced by the AHM algorithm are worsted than the proposed algorithm.

Table 3 also shows that the proposed algorithm provided 15 better results out of 26 test problems compared to weighted transportation cost matrix by supply (WCS) of the KSAM algorithm. Seven of the test problems have equal results and for the remaining TP i.e., TP4, TP16, TP19 and TP21, the WCS of the KSAM algorithms produced two IFSs which. For TP4, TP16 and TP21, both IFSs produced by WCS of KSAM algorithms are not

good compared to the proposed algorithm. For TP21, the first IFS produced by the KSAM algorithm is equal to the proposed algorithm, while the KSAM algorithm is not good as the proposed algorithm in producing IFS. Table 3 also shows that the proposed algorithm produced 16 better results out of 26 test problems, compared to the weighted transportation cost matrix by demand (WCD) of the KSAM algorithm and achieved similar results with the 7 test problems. The remaining 3 problems (TP5, TP22 and TP23), the WCD of the KSAM algorithm produced better results than the proposed algorithm. However, for one test problem (TP8), the WCD of the KSAM algorithm produced two IFSs while the other IFSs produced by worse optimal solution compared to the proposed algorithm.

**Table 3** The comparison of experiment results with existing algorithm

TP	$m \times n$	Initial feasible solution (IFS)					
		TDMI	AHM	KSAM		TOCM-MT	I-TDM
				WCS	WCD		
TP1	3 × 5	40	42 & 45	43	43	40	40
TP2	4 × 6	118 & 129	118	123	117	114	114
TP3	5 × 6	98	110 & 103	101	103	100	98
TP4	4 × 4	435	410	435 & 470	415	415	415
TP5	5 × 5	1102	1496	1104	1102	1127	1104
TP6	5 × 4	2292000	2328050	2418050	2229000	2228500	2168500
TP7	3 × 3	4450	5025	5025	4525	5225	4525
TP8	3 × 4	930 & 960	920	1050	1040 & 1060	930	920
TP9	3 × 4	859	799	894	924	799	799
TP10	3 × 4	476	412	516	476	412	412
TP11	4 × 5	3709	3511	3735	3598	3502	3502
TP12	3 × 4	104 & 105	104	127	109	104	104
TP13	3 × 4	1060 & 1100	1060	1060	1060	1060	1060
TP14	3 × 5	280	325 & 445	340	280	280	280
TP15	3 × 3	555	595	555	655	555	555
TP16	3 × 5	870	870	924 & 963	930	870	870
TP17	3 × 3	230	95	95	95	96	95
TP18	3 × 4	248	241	240	248	240	240
TP19	4 × 3	81	81	81 & 127	81	81	81
TP20	4 × 4	83	112	130	83	83	83
TP21	4 × 4	2400	3760	2520 & 2540	2500	2400	2360
TP22	3 × 4	1080 & 1090	1095 & 965	995	965	960	980
TP23	3 × 4	4720 & 4740	5140	5050	4810	4830	4820
TP24	4 × 3	1465	1675	1465	1545	1465	1465
TP25	3 × 4	608	678	608	628	658 & 678	606
TP26	4 × 3	980	1020	850	880	980	840

Table 3 also illustrates that the proposed algorithm can solve the test problems better than the TOCM-MT algorithm (10 out of 26 test problems). Both the algorithms have equal results in 14 of test problems. For the one remaining of test problem (TP22), the TOCM-MT algorithm produced better results than the proposed algorithm. For TP25, the TOCM-MT algorithm produced two IFSs. All IFSs produced by the TOCM-MT algorithm are not as good compared to the proposed algorithm.

Babu et al. (2020) proposed the improved VAM (IVAM) to overcome the limitations and computational errors of VAM to determine the IFS of TP. When the IVAM was compared



to the proposed algorithm, the IFS is superior to that of IVAM. However, in the case of large scale TP, the IVAM has been proven to solve the problems, while the proposed algorithm has not been tested on TP of this scale. Our research is currently focused on overcoming the same cost matrix for TP. Large scale TP can be considered by researchers in future to develop this research.

## 6 Conclusions

The determination of IFS is an important part in TP in order to obtain optimal solution, i.e., the minimum total distribution cost. This proposed algorithm is based on the integration of TRCM and of the modified TDM1 algorithms. It also takes into account the ratio cost matrix by row and column as well as the distribution least cost and includes the penalty calculations for each column. This proposed algorithm has the ability to determine the IFS effectively and efficiently. Another unique benefit of this new algorithm is the capability to solve TP that has equal values of least distribution cost, balance and unbalanced TP problems.

Twenty-six test problems selected from reputable journals indicate that the proposed algorithm's numerical results are comparably better than the existing methods. The proposed algorithm achieved better performance than the TDM1, AHM, TOCM-MT, and KSAM algorithms for most test problems. It is recommended that the proposed algorithm should be integrated with the Stepping Stone and MODI methods in future research which will explore the evaluation of the optimal solution TP, large scale of TP and determination of optimal solutions in the event of information uncertainty about the parameters of TP.

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**Final Refereeing Decision IJCSM\_318392**

1 message

**Inderscience Publishers** <noreply@indersciencemail.com>

19 March 2021 at 18:58

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To: muhammad.92sam@gmail.com, yosya@uthm.edu.my, nazarudin@uthm.edu.my, farikhin.math.undip@gmail.com, Editor &lt;zhiwei.cui@gm.com&gt;

Dear Muhammad Sam'an, Yosza Dasril, Nazarudin Bin Bujang, Farikhin Farikhin,

Ref: Submission "A New Approach in Solving Transportation Problem Based on Modifications of TDM 1 and Integration of Total Ratio Cost Matrix"

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28 February 2021 at 05:45

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Dear Author(s),

We have received the review reports for your paper "A New Approach in Solving Transportation Problem Based on Modifications of TDM 1 and Integration of Total Ratio Cost Matrix".

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Suggestions which would improve the quality of the paper but are not essential for publication:

Need to some improvements for paper.

There are some typos erros.

Writers should write belows explanations:

- 1) alpha\_44 change to ---> alpha\_ij
- 2) beta\_44 change to ---> beta\_ij
- 3) Need to explicitly explaining wij how can calculated. It is not understandable for readers.
- 4) Typos errors

alpha\_12--->3, double check

alpha\_13--->2.5, double check

beta\_13--->2.5, double check

beta\_21--->4.5, double check

beta\_43--->1, double check

Changes which must be made before publication:

Need to some improvements for paper.

There are some typos erros.

Writers should write belows explanations:

- 1) alpha\_44 change to ---> alpha\_ij
- 2) beta\_44 change to ---> beta\_ij
- 3) Need to explicitly explaining wij how can calculated. It is not understandable for readers.
- 4) Typos errors

alpha\_12--->3, double check

alpha\_13--->2.5, double check

beta\_13--->2.5, double check

beta\_21--->4.5, double check

beta\_43--->1, double check

Reviewer B Comments:

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Suggestions which would improve the quality of the paper but are not essential for publication:

Authors are encouraged to consider the following points:

1. The proposed algorithm should have a specific name.
2. In Table-1, "Object" is confusing, rather use "Destination".

Changes which must be made before publication:

In this manuscript, authors developed a new algorithm modifying the existing algorithms, TDM 1 and the Integration of Total Ratio Cost Matrix. Authors demonstrate their proposed algorithm with a numerical example and also construct the pseudocode. The manuscript seems to be acceptable with considering the following recommendations:

1. Literature review is not updated as expected. Recent works in Transportation problems are missing. Authors are recommended to include the recent works (like the following one) and mention how the author's algorithm is better

than the recently developed algorithms.

Authors are strongly recommended to add the following paper in their literature review and some others in recent: Babu, M.A., Hoque, M.A. & Uddin, M.S. A heuristic for obtaining better initial feasible solution to the transportation problem. OPSEARCH 57, 221–245 (2020). <https://doi.org/10.1007/s12597-019-00429-5>

2. Authors compare their algorithm with the 26 TPs chosen from the literature. But all these problems are very small in size. This comparison with these small sizes of problems does not reflect the betterness of the proposed algorithm over the existing chosen algorithms. It is observed that the maximum size of the chosen problems is 5x6. Authors are encouraged to do the comparison with randomly generated TPs of the different sizes, especially large size problems. Authors may do the comparative study like the following paper:

Babu, M.A., Hoque, M.A. & Uddin, M.S. A heuristic for obtaining better initial feasible solution to the transportation problem. OPSEARCH 57, 221–245 (2020). <https://doi.org/10.1007/s12597-019-00429-5>

3. Some grammatical mistakes should be corrected in the manuscript.

4. In Table 6, TP-4, Babu et al (2019) is confused. Either it is Babu et al (2013) or Babu et al (2019) is not cited in the reference.

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**Nazarudin Bin Bujang** . <nazarudin@uthm.edu.my>

25 March 2021 at 12:40

To: Inderscience Publishers <noreply@indersciencemail.com>

Cc: "Mr. Muhammad Sam'an" <muhammad.92sam@gmail.com>, Dr Yosza Dasril <yosya@uthm.edu.my>, PhD Farikhin Farikhin <farikhin.math.undip@gmail.com>, "Dr. Zhiwei Cui" <zhiwei.cui@gm.com>

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#### Submission Details

Title: **Improved Total Difference Method (ITDM): A New Approach to Solving Transportation Problem Based on Modifications of Total Difference Method 1 and Integration of Total Ratio Cost Matrix**

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## **Improved total difference method (ITDM): a new approach to solving transportation problem based on modifications of total difference method 1 and integration of total ratio cost matrix**

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**Abstract:** In this paper, the initial basic feasible solution is referred to as the initial feasible solution (IFS). There are two phases in solving the transportation problem (TP). An IFS is determined in the first phase by using the least distribution cost, followed by the calculation of the optimal solution through the modification of total difference method (TDM 1), integrated with total ratio cost matrix (TRCM) in the second phase. In some cases, it has been found that TP has equal values of the distribution least costs so that the existing methods generate two or more IFS values. The newly developed algorithm obtains the optimal solution of TP. A total of 26 numerical examples were selected from reputed journals to evaluate the performance of the newly developed algorithm. The computational performances were compared to the existing methods in the literature and the results showed that this algorithm not only solves TP with similar values optimal solution but also produces better minimal solutions than existing methods.

**Keywords:** transportation problem; IFS; initial feasible solution; optimal solution; total difference method; TRCM; total ratio cost matrix.

**Reference** to this paper should be made as follows: Sam'an, M., Dasril, Y., Bujang, N.B. and Farikhin (2022) 'Improved total difference method (ITDM): a new approach to solving transportation problem based on modifications of total difference method 1 and integration of total ratio cost matrix', *Int. J. Computing Science and Mathematics*, Vol. 16, No. 1, pp.13–23.

**Biographical notes:** Muhammad Sam'an received his Master in Mathematics degree from the University of Diponegoro in 2016. He is currently a PhD student in the Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM). His research interest is the area of fuzzy optimisation.

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Farikhin is a Lecturer at the Department of Mathematics, Universitas Diponegoro. He is interested in numerical optimisation, computing and applied analysis for decision science areas.

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## 1 Introduction

Oil and gas companies incur huge operating expenditure for Oil distribution from refinery production factory to petrol stations throughout the country. Hitchcock (1941) said that optimum solution of the transportation problems (TP) is modelled by linear programming (LP) to achieve the most cost effective transportation routes and network. According to Juman and Hoque (2015), TP revolve around the distribution of the commodities and sources from suppliers to customers, whereby ideally, total supplies must equal total demand.

Generally, there are two phases in solving TP. The first phase involves finding an initial feasible solution (IFS), and the second phase involves searching for the optimal solution of TP based on the IFS obtained. A well performing algorithm is desired to find an IFS for TP because it can significantly affect the computation and iteration process of obtaining the optimal solution for TP. In certain situations, there is a possibility that the IFS is equal to the optimal solution for TP. Furthermore, there is also the possibility that two or more IFSs may not generate the best optimal solution for the TP. Therefore, this research creates a new algorithm for the IFS finding that can prevent two or more IFS complications.

Three well-known classical algorithms are used to obtain the IFS, i.e., northwest corner method (NCM), least cost method (LCM) and Vogel's approximation method (VAM). Many previous studies have been conducted to improve these classical algorithms by proposing an alternative algorithm. For instance, Shimshak et al. (1981) proposed modification of VAM through the heuristics approach to find an IFS for the unbalanced TP; while Goyal (1984) introduced a new version of VAM, known as the Goyal's VAM. Another method to solve TP i.e., total opportunity cost method (TOCM) was introduced by Kirca and Satir (1990). Furthermore, the combinations of TOCM and VAM was proposed by Mathirajan and Meenakshi (2004) and Korukoglu and Balli (2011). Islam et al. (2012) combined TOCM and distribution indicators (DIs) in order to obtain the optimal solution for TP. Khan et al. (2015) introduced the TOCM-SUM approach for a similar purpose. Allocation table method (ATM) and incessant allocation method (IAM) were presented by Ahmed et al. (2016) and Ahmed et al. (2016). Deshmukh (2012) presented a similar algorithm approach. Juman and Hoque (2015) compared VAM, zero suffix method (ZSM) and Sudhakar et al. (2012)'s method. The comparison showed that the Juman Hoque Method (JHM) is superior in obtaining the minimal total cost of 16 out of 18 standard test TP.

Hosseini (2017) did a modification of the total difference method 1 (TDM 1). The VAM algorithm calculates penalty for both rows and columns, while TDM 1 only considers penalty for rows of TP. Harrath and Kaabi (2018) introduced the global minimum method (GMM) and claimed that the performance is better than classical methods especially for large scale of TP. Azad and Hasan (2019) presented an effective algorithm, as known the Azad Hasan method (AHM) for allocating the lowest amount of demand and supply to the lowest distribution cost of the TP. They also claimed this new method is easier and involves less iteration than most of the classical methods. The modification of TDM 1 by adding the rules for selecting the highest penalty value and checking the lowest distribution cost, followed by the combination of TOCM and TDM 1 modification, was introduced (Amaliah et al., 2019). A novel approximation method i.e., the Karagul Sahin Approximation Method (KSAM) was developed (Karagul and Sahin, 2020).

All proposed methods above by previous researchers illustrate the importance of the least distribution costs of TP as a basis for allocating the amount of supply and demand of the TP because it will affect the value of IFS, the performance computation process, the iteration steps, and the minimum total cost.

However, these proposed methods can only run perfectly if the TP do not have equal least cost during the TP computation. Whenever there is equal least cost in TP computation, the methods will fail to determine the least cost. Several alternative solutions have been proposed by choosing one of the equal least cost values available. Nevertheless, these alternative solutions for TP will result in more than one IFS value. Consequently, the IFS value generated will be different and depending on the least cost value which is chosen to compute the IFS.

Therefore, the objective of this research is to overcome the limitations and complications of having two or more IFS values generated through the modification of TDM 1, followed by integrating with total ratio cost matrix (TRCM), which is named as Improved TDM (I-TDM). The proposed I-TDM is designed to obtain an optimal IFS value for the TP.

The rest of this paper is organised as follows. Section 2 introduces the formulation of TP. Section 3 presents the ITDM, Section 4 illustrates the numerical experiment by using the proposed algorithm mentioned in Section 3, while comparative studies are discussed in Section 5, and the conclusion of this research is given in Section 6.

## 2 Formulation of transportation problem

The formulation of TP is illustrated in Figure 1 with the aim to determine the approximation value of  $x_{ij}$  that minimises the total distribution cost as follows

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

subject to

$$\begin{aligned} \sum_{j=1}^n x_{ij} &\leq s_i, i = 1, 2, \dots, m \\ \sum_{i=1}^m x_{ij} &\leq d_j, j = 1, 2, \dots, n \\ x_{ij} &\geq 0, \quad \forall i, j \end{aligned} \tag{2}$$

where  $m$  represents total supply,  $n$  represents total demand,  $s_i$  is  $i$ th supply,  $d_j$  is  $j$ th demand,  $c_{ij}$  is distribution cost from  $i$ th supply to  $j$ th demand,  $x_{ij}$  is the number of approximation unit to assign from  $i$ th supply to  $j$ th demand,  $\min T$  is minimal total distribution cost, while, total supply identically to total demand is referred as balanced TP and given as

$$\sum_{i=1}^m s_i = \sum_{j=1}^n d_j \tag{3}$$

Figure 1 The transportation problem table

	$D_1$	$D_2$	...	$D_n$	$s_i$
$S_1$	$x_{11}$ $c_{11}$	$x_{12}$ $c_{12}$	...	$x_{1n}$ $c_{1n}$	$s_1$
$S_2$	$x_{21}$ $c_{21}$	$x_{22}$ $c_{22}$	...	$x_{2n}$ $c_{2n}$	$s_2$
$\vdots$	$\vdots$	$\vdots$	$\sphericalangle$	$\vdots$	$\vdots$
$S_m$	$x_{m1}$ $c_{m1}$	$x_{m2}$ $c_{m2}$	...	$x_{mn}$ $c_{mn}$	$s_m$
$d_j$	$d_1$	$d_2$	...	$d_n$	

### 3 Improved TDM (I-TDM)

The proposed algorithm was checked to see whether or not equation (3) is satisfied, followed by the calculation of row ratio matrix ( $\alpha_{ij}$ ) and column ratio matrix ( $\beta_{ij}$ ) by using equations (4) and (5), respectively. By determining the sum of  $\alpha_{ij}$  and  $\beta_{ij}$ , the resulting value is called TRCM. The new proposed algorithm in detail is shown in Algorithm 1,

$$\alpha_{ij} = \frac{c_{ij}}{\theta_i}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (4)$$

$$\beta_{ij} = \frac{c_{ij}}{\theta_j}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (5)$$

where  $\theta_i = \min(c_{ij}) = (c_{i1}, c_{i2}, \dots, c_{in})$  and  $\theta_j = \min(c_{ij}) = (c_{1j}, c_{2j}, \dots, c_{mj})$

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#### Algorithm 1: A New Heuristic TP Algorithm

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**Data:** Initialization: Number of rows is  $m$ , Number of column is  $n$ , supply ( $s_i$ ), demand ( $d_j$ ), distribution cost ( $c_{ij}$ ), the number of approximation unit ( $x_{ij}$ )

**Result:** min T by Eq. (1)

Calculate  $\alpha_{ij}$  by Eq. (4) and  $\beta_{ij}$  by Eq. (5);

Calculate the TRCM which is the entries are the sum of the row and column ratio matrix;

TRCM is denoted by  $\omega_{ij}$ ;

**repeat**

  {Produce a minimal total distribution cost} ;

**for**  $i=1$  **to**  $n$  **do**

    Find the penalty ( $F_j$ ) for each  $j^{th}$  column by  $F_j = \sum_{i=1}^m (\omega_{ij} - \min(\omega_{ij}))$ ;

    Select highest of  $F_j$  (HF) by  $HF = \max(F_j)$ ;

    In case of a break-even (i.e. equal HF);

      (a) select HF with the smallest  $\omega_{ij}$  ;

      (b) if (a) is equal, then select  $F_j$  with the greatest total of TRCM by  $T\omega_j = \sum_{i=1}^m \omega_{ij}$  ;

      (c) if (b) is equal, then select penalty with the max allocation of  $x_{ij}$ .

    Select the least  $\omega_{ij}$  of HF. If tie, then select least  $\omega_{ij}$  with max  $x_{ij}$ ;

    Allocate the  $x_{ij}$  to it;

    There may arise the following three cases;

**if**  $\min(s_i, d_j) = s_i$  **then**

      |  $x_{ij} = s_i, d_j = d_j - s_i, s_i = 0$ , cross out of  $s_i$

**end**

**if**  $\min(s_i, d_j) = d_j$  **then**

      |  $x_{ij} = d_j, s_i = s_i - d_j, d_j = 0$ , cross out of  $d_j$

**end**

**if**  $s_i = d_j$  **then**

      |  $s_i = 0, d_j = 0$ , cross out of  $s_i$  and  $d_j$

**end**

**end**

  Recalculate the penalty without considering the cross out rows and columns

**until**  $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$ ;

---

#### 4 Algorithm in practice

This research used 20 test problems taken from selected journals to explain the proposed algorithm. For instance, the numerical example of Jude et al. (2017) was: Given a company has four supply plants which produces 6, 9, 7, and 12 cars. The company supplies to four customers, whose demands are 10, 4, 6 and 14 cars, respectively. The distribution cost of the car is shown in Table 1. The objective is to obtain the minimum total distribution cost. The problem is presented in Table 1, solved by using Algorithm 1 as follows,

**Table 1** An original data of transportation problem

	$D_1$	$D_2$	$D_3$	$D_4$	$s_i$
$S_1$	2.0	6.0	5.0	3.0	6.0
$S_2$	9.0	6.0	2.0	1.0	9.0
$S_3$	5.0	2.0	3.0	6.0	7.0
$S_4$	7.0	7.0	2.0	4.0	12.0
$d_j$	10.0	4.0	6.0	14.0	

The solution of the transportation problem example in Table 1 is solved by using Algorithm 1 as follows:

Step 1: Calculating  $\alpha_{ij}$  and  $\beta_{ij}$ . For  $i, j = 1, 2, 3, 4$  are obtained as bellows:

$$\alpha_{ij} = \begin{pmatrix} 1.0 & 3.0 & 2.5 & 1.5 \\ 9.0 & 6.0 & 2.0 & 1.0 \\ 2.5 & 1.0 & 1.5 & 3.0 \\ 3.5 & 3.5 & 1.0 & 2.0 \end{pmatrix} \text{ and } \beta_{ij} = \begin{pmatrix} 1.0 & 3.0 & 2.5 & 3.0 \\ 4.5 & 3.0 & 1.0 & 1.0 \\ 2.5 & 1.0 & 1.5 & 6.0 \\ 3.5 & 3.5 & 1.0 & 4.0 \end{pmatrix}$$

Step 2: Calculating  $\omega_{ij}$ . For  $i, j = 1, 2, 3, 4$  is produced as bellow

$$\omega_{ij} = \begin{pmatrix} 1.0 + 2.0 = 3.0 & 3.0 + 3.0 = 6.0 & 2.5 + 2.5 = 5.0 & 1.5 + 3.0 = 4.5 \\ 9.0 + 4.5 = 13.5 & 6.0 + 3.0 = 9.0 & 2.0 + 1.0 = 3.0 & 1.0 + 1.0 = 2.0 \\ 2.5 + 2.5 = 5 & 1.0 + 1.0 = 2.0 & 1.5 + 1.5 = 3.0 & 3.0 + 6.0 = 9.0 \\ 3.5 + 3.5 = 7 & 3.5 + 3.5 = 7 & 1.0 + 1.0 = 2.0 & 2.0 + 4.0 = 6.0 \end{pmatrix}$$

Step 3: Calculating  $F_j$ . For  $j=1$  so  $F_1$  is obtained is  $F_1$  of column-1 = 19.5; column-2 = 15.0; column-3 = 6.00; column-4 = 13.0.

Step 4: Selecting the highest of  $F_1$  is  $F_1$  of column-2

Step 5: Selecting the least  $\omega_{ij}$  in  $F_1$  of column-2 is  $\omega_{11}$ .

Step 6: Allocating the  $x_{11}$  to  $\omega_{11}$  with  $x_{11} = \min(s_1, d_1) = \min(6, 10) = 6$  such that  $s_1 = s_1 - x_{11} = 6 - 6 = 0$  and  $d_1 = d_1 - x_{11} = 10 - 6 = 4$ . Since  $s_1 \neq 0$  and  $d_1 = 4$  then cross out of  $s_1$ .

Step 7: Re-calculating the penalty without considering  $d_2$  such that for  $j= 2$  is obtained  $F_2$  of column-1 = 10.5; column-2 = 12.0; column-3= 2.00; column-4 = 11.0.

Step 8: Repeat Step 3 until Step 6 such that  $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$ . The final result is shown in Table 2

Step 9: Finally, calculating minimal total distribution cost by using equation (1). The result of min T is 83. The feasible solution table of example 1 shown in Table 2.



## 5 Result of comparison

This section provides a comparison between the existing algorithms i.e., TDM 1 (Hosseini, 2017), AHM (Azad and Hasan, 2019), KSAM (Karagul and Sahin, 2020), and TOCM-MT (Amaliah et al., 2019)) with the proposed algorithm. The comparison results are shown in Table 3. The test problems used in this section are taken from 26 different reputable journals (Kaur et al., 2019; Babu et al., 2013; Karagul and Sahin, 2020; Juman et al., 2013; Juman and Hoque, 2015; Sujatha, 2015; Das et al., 2014; Deshmukh, 2012; Rahman et al., 2017; Islam et al., 2012; Rahman, 2017,?; Jude et al., 2017; Amaliah et al., 2019; Geetha and Anandhi, 2018; Kulkarni and Datar, 2010), where several TP are balanced and the rest are unbalanced problems. The details of the problems is shown in Table 3.

**Table 2** The improved TDM with a penalty based on Jude et al. (2017) numerical example

	$D_1$	$D_2$	$D_3$	$D_4$	$s_1$
$S_1$	2.0 (6.0)	6.0 (0.0)	5.0 (0.0)	3.0 (0.0)	6.0
$S_2$	9.0 (0.0)	6.0 (0.0)	2.0 (0.0)	1.0 (9.0)	9.0
$S_3$	5.0 (3.0)	2.0 (4.0)	3.0 (0.0)	6.0 (0.0)	7.0
$S_4$	7.0 (1.0)	7.0 (0.0)	2.0 (6.0)	4.0 (5.0)	12.0
$d_j$	10.0	4.0	6.0	14.0	
$F^* 1$	19.5	15.0	6.00	13.5	
$F^* 2$	10.5	12.0	2.00	11.5	
$F^* 3$	2.00	0.00	1.00	3.00	
$F^* 4$	0.00	0.00	0.00	0.00	

Table 3 shows that in terms of IFS the proposed algorithm can solve 10 out of 26 of the test problems which is better compared to TDM 1 algorithm and similar with the other 9 TPs. Moreover, Table 3 also indicates that the TDM 1 algorithm generates better results compared to the proposed algorithm for TP5 and the rest of TP (TP2, TP8, TP12, TP13, TP22 and TP23). The TDM 1 algorithm produced two IFSs, while the proposed algorithm produced only one IFS and for the test problems of TP2, TP8 and TP22, all IFSs produced by TDM 1 algorithm are worse off compared to the proposed algorithm. Next, for test problems of TP12 and TP13, the first IFS produced by the TDM 1 algorithm is equal to the proposed algorithm. In contrast, the second IFS produced by the TDM 1 algorithm is worse than the proposed algorithm. As for test problem TP23, both IFSs produced by the TDM 1 algorithm are better than the proposed algorithm.

The proposed algorithm presented 13 better results out of 26 test problems compared to the AHM algorithm and broke-even with remaining 8 test problems. Table 3 shows that the AHM algorithm produced better results compared to the proposed algorithm for TP5 and for the remaining of TP (TP1, TP3, TP14 and TP22), the AHM algorithm generated two and two of IFS, while the proposed algorithm generated only one IFS. For the test problem of TP1, TP3, TP14 and TP22, all IFSs produced by the AHM algorithm are worsted than the proposed algorithm.

Table 3 also shows that the proposed algorithm provided 15 better results out of 26 test problems compared to weighted transportation cost matrix by supply (WCS) of the KSAM algorithm. Seven of the test problems have equal results and for the remaining TP i.e., TP4, TP16, TP19 and TP21, the WCS of the KSAM algorithms produced two IFSs which. For TP4, TP16 and TP21, both IFSs produced by WCS of KSAM algorithms are not

good compared to the proposed algorithm. For TP21, the first IFS produced by the KSAM algorithm is equal to the proposed algorithm, while the KSAM algorithm is not good as the proposed algorithm in producing IFS. Table 3 also shows that the proposed algorithm produced 16 better results out of 26 test problems, compared to the weighted transportation cost matrix by demand (WCD) of the KSAM algorithm and achieved similar results with the 7 test problems. The remaining 3 problems (TP5, TP22 and TP23), the WCD of the KSAM algorithm produced better results than the proposed algorithm. However, for one test problem (TP8), the WCD of the KSAM algorithm produced two IFSs while the other IFSs produced by worse optimal solution compared to the proposed algorithm.

**Table 3** The comparison of experiment results with existing algorithm

TP	$m \times n$	Initial feasible solution (IFS)					
		TDMI	AHM	KSAM		TOCM-MT	I-TDM
				WCS	WCD		
TP1	3 × 5	40	42 & 45	43	43	40	40
TP2	4 × 6	118 & 129	118	123	117	114	114
TP3	5 × 6	98	110 & 103	101	103	100	98
TP4	4 × 4	435	410	435 & 470	415	415	415
TP5	5 × 5	1102	1496	1104	1102	1127	1104
TP6	5 × 4	2292000	2328050	2418050	2229000	2228500	2168500
TP7	3 × 3	4450	5025	5025	4525	5225	4525
TP8	3 × 4	930 & 960	920	1050	1040 & 1060	930	920
TP9	3 × 4	859	799	894	924	799	799
TP10	3 × 4	476	412	516	476	412	412
TP11	4 × 5	3709	3511	3735	3598	3502	3502
TP12	3 × 4	104 & 105	104	127	109	104	104
TP13	3 × 4	1060 & 1100	1060	1060	1060	1060	1060
TP14	3 × 5	280	325 & 445	340	280	280	280
TP15	3 × 3	555	595	555	655	555	555
TP16	3 × 5	870	870	924 & 963	930	870	870
TP17	3 × 3	230	95	95	95	96	95
TP18	3 × 4	248	241	240	248	240	240
TP19	4 × 3	81	81	81 & 127	81	81	81
TP20	4 × 4	83	112	130	83	83	83
TP21	4 × 4	2400	3760	2520 & 2540	2500	2400	2360
TP22	3 × 4	1080 & 1090	1095 & 965	995	965	960	980
TP23	3 × 4	4720 & 4740	5140	5050	4810	4830	4820
TP24	4 × 3	1465	1675	1465	1545	1465	1465
TP25	3 × 4	608	678	608	628	658 & 678	606
TP26	4 × 3	980	1020	850	880	980	840

Table 3 also illustrates that the proposed algorithm can solve the test problems better than the TOCM-MT algorithm (10 out of 26 test problems). Both the algorithms have equal results in 14 of test problems. For the one remaining of test problem (TP22), the TOCM-MT algorithm produced better results than the proposed algorithm. For TP25, the TOCM-MT algorithm produced two IFSs. All IFSs produced by the TOCM-MT algorithm are not as good compared to the proposed algorithm.

Babu et al. (2020) proposed the improved VAM (IVAM) to overcome the limitations and computational errors of VAM to determine the IFS of TP. When the IVAM was compared

to the proposed algorithm, the IFS is superior to that of IVAM. However, in the case of large scale TP, the IVAM has been proven to solve the problems, while the proposed algorithm has not been tested on TP of this scale. Our research is currently focused on overcoming the same cost matrix for TP. Large scale TP can be considered by researchers in future to develop this research.

## 6 Conclusions

The determination of IFS is an important part in TP in order to obtain optimal solution, i.e., the minimum total distribution cost. This proposed algorithm is based on the integration of TRCM and of the modified TDM1 algorithms. It also takes into account the ratio cost matrix by row and column as well as the distribution least cost and includes the penalty calculations for each column. This proposed algorithm has the ability to determine the IFS effectively and efficiently. Another unique benefit of this new algorithm is the capability to solve TP that has equal values of least distribution cost, balance and unbalanced TP problems.

Twenty-six test problems selected from reputable journals indicate that the proposed algorithm's numerical results are comparably better than the existing methods. The proposed algorithm achieved better performance than the TDM1, AHM, TOCM-MT, and KSAM algorithms for most test problems. It is recommended that the proposed algorithm should be integrated with the Stepping Stone and MODI methods in future research which will explore the evaluation of the optimal solution TP, large scale of TP and determination of optimal solutions in the event of information uncertainty about the parameters of TP.

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