



A combination of TDM and KSAM to determine initial feasible solution of transportation problems

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Article Info

Article history:

Received Jan 22, 2021

Revised Feb 26, 2021

Accepted March 15, 2021

Keywords:

Transportation problem
Initial feasible solution
Approximation method
Total difference method

ABSTRACT

In case of the Transportation Problem (TP), it was found that TP had equal the smallest c_{ij} so that the existing methods will be generated two or more IFS values. The newly developed algorithm is generated through a combination of Total Difference Method (TDM) and Karagul-Sahin Approximation Method (KSAM) algorithm, is capable to determine the initial feasible solution of TP. Based on the numerical illustration of the TP example to evaluate the performance of the new proposed algorithm. The computational performances have been compared to the existing methods (TDM1 and KSAM) and the results shown this algorithm achieved better performance than the existing methods for TP example. The recommendation of the research is the new proposed algorithm integration with Stepping Stone and MODI methods in future research to evaluate the optimal solution of TP and determination of optimal solution in the event of information uncertainty about the parameters of the TP.

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1. INTRODUCTION

The method of finding Initial Feasible Solution (IFS) by assigning the smallest c_{ij} as base cell in Transportation Problem (TP) table has been widely used by several algorithms such as classical algorithm namely Least Cost Method (LCM) takes into account the smallest c_{ij} in the TP table and Vogel's Approximation Method (VAM) takes into account the highest penalty c_{ij} which is denotes the difference between the smallest c_{ij} and the next smallest c_{ij} in each row and each column of the TP table.

Subsequently, various types of finding IFS methods by determining the smallest c_{ij} of TP table were introduced by many researchers [1]–[3]. The pointer c_{ij} calculated by selecting the difference from the highest c_{ij} and second-highest c_{ij} for each row and each column, unlike VAM [4]. Total Opportunity Cost Table (TOCT) calculate the Distribution Indicators (DI) by the difference of the greatest unit c_{ij} and second greatest unit c_{ij} , then the highest two DI are selected as the base cell, and loads are imposed on the original TP corresponding to the base cells of the TOCT [5]. The lowest Allocation Method (LAM) was developed from LCM that also take into account the minimum of supply or demand for allocation in the smallest c_{ij} of TP table

[6]. Advanced Vogel's Approximation Method (AVAM) to overcome case of TP which has the equal smallest c_{ij} in the TP table [7]. TOCM-SUM Approach is calculated by the pointer c_{ij} for each row and column of the TOCM by selecting the sum of all entries in the respective row or column and made a maximum possible allocation to the smallest c_{ij} cell corresponding to the highest pointer c_{ij} [8]. Tuncay Cana's Approximation Method determined to the cell having the nearest c_{ij} to this average c_{ij} considering the demand and production constraints [9]. Incessant Allocation Method (IAM) [10] and Allocation Table Method (ATM) [11] are iterative methods based on the allocation table. Modification of TDM (Total Different Method) 1 considers penalty only for a row of TP table [12]. Global Minimum Method (GMM) [13]. Azad Hasan Method (AHM) is an effective algorithm for allocating the lowest number of demands and supplies to the lowest distribution cost of TP [14], [15]. The modification of TDM by adding the rules for selecting the highest penalty value and checking the lowest distribution cost followed by a combination of TOCM and TDM modification [16]. Total Opportunity Cost Matrix – Supreme Cell [17]. The novel approximation method is called Karagul-Sahin Approximation Method (KSAM) [18]. Zack algorithm [19] and Key Cell method (KCM) based avoiding maximum cost cells for making allocation [20]. An innovative strategy to obtain IBFS of TP based on penalty value [21]. The bottleneck transportation problem is based on pseudo cost to repair the IBFS that was obtained by classical transportation algorithm [22]. The revised ASM method [23]. The combination of TOCM and ASM (TOCM-ASM) [24], [25].

All proposed methods above by previous researchers illustrated the importance of taking the smallest c_{ij} of TP as a base cell for allocating the numbers of supplies and demands of TP because it will affect the value of IFS. But, these proposed methods will only run perfectly if the TP does not have equal smallest c_{ij} during the TP computations. Whenever there is equal smallest c_{ij} in TP computations, the outcomes of the methods will fail to determine the smallest c_{ij} . Several methods have proposed alternatives solution by choosing one of the equal smallest c_{ij} value available. Nevertheless, these alternative solutions for TP will result in more than one IFS value. Consequently, the IFS value generated will be different and it is depending on the smallest c_{ij} value is chosen which is used 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 and followed by integrating with KSAM algorithm. This new algorithm is proposed which is design to obtain optimal IFS value of TP.

2. MODELLING OF TRANSPORTATION PROBLEM

The modeling of transportation problems (TP) can be formulated the following equation to determine the approximation value of x_{ij} that minimizes the total distribution cost as follows,

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

subject to

$$\sum_{j=1}^n x_{ij} \leq s_i \quad (2)$$

$$\sum_{i=1}^m x_{ij} \leq d_j \quad (3)$$

and

$$x_{ij} \geq 0 \forall i, j (i = 1, 2, \dots, m; j = 1, 2, \dots, n). \quad (4)$$

where m represents a total of supply, n represents a total of 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.

If total supply identically with the total demand is called a balance TP and given as,

$$\sum_{i=1}^m s_i = \sum_{j=1}^n d_j \quad (5)$$

3. THE NEW PROPOSED ALGORITHM

The setting of the smallest c_{ij} which has equal values in the base cells in TP table affects the location of x_{ij} allocated on the resulting IFS value depends on the setting of the smallest c_{ij} . The new proposed algorithm is based on the modification of the TDM algorithm and is integrated with the KSAM algorithm, it is advantageous that the original of TDM and KSAM algorithms are shown as is Algorithm 1 in shown Figure 1 and Figure 2, respectively.

Algorithm 1: TDM Algorithm

Data: Initialization: Number of rows is m, Number of column is n, 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, $i = 1, 2, \dots, m; j = 1, 2, \dots, n$.

Result: min T by Eq. (1)

```

repeat
  {Produce a minimal total distribution cost} ;
  for i=1 to m do
    Find the penalty ( $F_i$ ) for each  $i^{th}$  row by  $F_i = \sum_{j=1}^n (c_{i,j} - \min(c_{i,j}))$ ;
    Select highest of  $F_i$  (HF) by HF = max( $F_i$ );
    Select the least  $c_{i,j}$  of HF;
    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 /  $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$ ;

```

Figure 1. TDM1 algorithm

Algorithm 2: KSAM Algorithm

Data: Initialization: Number of rows is m, Number of column is n, 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, $i = 1, 2, \dots, m; j = 1, 2, \dots, n$.

Result: min T by Eq. (1)

Calculate α_{ij} by Eq. (4) and α_{ji} by Eq. (5);

Calculate the weighted transportation cost matrix by multiplying $c_{i,j}$ with α_{ij} for demand (wcd) and $c_{i,j}$ with α_{ji} for supply (wcs);

```

repeat
  {Produce a minimal total distribution cost} ;
  Determine the least weighted costs in tables of wcd and wcs ;
  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
until /  $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$ ;

```

Compare the solution values of transportation tables. Set the smaller solution as the initial feasible solution

Figure 2. KSAM algorithm

The new proposed algorithm starts by checking either Eq. (5) is satisfied or not and followed by calculation of proportional demand matrix (α_{ij}) and proportional supply matrix (α_{ji}) by using Eq. (6) and (7), respectively [11].

$$\alpha_{ij} = \frac{d_j}{s_i}, i = 1, 2, \dots, m; j = 1, 2, \dots, n. \quad (6)$$

$$\alpha_{ji} = \frac{s_i}{d_j}, j = 1, 2, \dots, n; i = 1, 2, \dots, m. \quad (7)$$

$$\alpha_{ij}\alpha_{ji} = 1 \tag{8}$$

Determine the sum of α_{ij} and α_{ji} , the resulting value is called weighted distribution cost matrix (ω_{ij}). The new proposed algorithm in detail is Algorithm 3 in shown Figure 3.

Algorithm 3: The New Proposed Algorithm

Data: Initialization: Number of rows is m, Number of column is n, 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, $i = 1, 2, \dots, m; j = 1, 2, \dots, n$.

Result: min T by Eq. (1)
 Calculate α_{ij} by Eq. (4) and α_{ji} by Eq. (5);
 Calculate ω_{ij} by $\omega_{ij} = (\alpha_{ij} + \alpha_{ji})c_{ij}$;

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 $HF = \max(F_j)$;
 Select the least ω_{ij} of HF;
 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
 Recalculate the penalty without considering the cross out rows and columns
until $\sum_{i=1}^m s_i = \sum_{j=1}^n d_j$;

Figure 3. The new proposed algorithm

4. NUMERICAL ILLUSTRATIONS

The numerical illustration used an example of a transportation problem to explain the new proposed algorithm is shown Table 1 ([16]).

Table 1. An original data of transportation problem in example .

Sources	Destination						s_i
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	
S ₁	9	12	9	6	9	10	2
S ₂	7	3	7	7	5	5	5
S ₃	6	5	9	11	3	11	6
S ₄	6	8	11	2	2	10	9
d_j	2	2	2	4	4	6	

The solution of the transportation problem example 1 in Table 1 is solved by using Algorithm 3 as follows:

Step 1 : Calculating α_{ij} and α_{ji} . For $i=1,2,3,4; j=1,2,3,4,5,6$ are obtained as bellows

$$\alpha_{46} = \begin{pmatrix} 1 & 1 & 2 & 2 & 2 & 3 \\ 0.4 & 0.4 & 0.8 & 0.8 & 0.8 & 1.2 \\ 0.33 & 0.33 & 0.67 & 0.67 & 0.67 & 1 \\ 0.22 & 0.22 & 0.44 & 0.44 & 0.44 & 0.67 \end{pmatrix} \text{ and } \alpha_{64} = \begin{pmatrix} 1 & 1 & 0.5 & 0.5 & 0.5 & 0.33 \\ 2.5 & 2.5 & 1.25 & 1.25 & 1.25 & 0.83 \\ 3 & 3 & 1.5 & 1.5 & 1.5 & 1 \\ 4.5 & 4.5 & 2.25 & 2.25 & 2.25 & 1.5 \end{pmatrix}^T$$

Step 2: Calculating ω_{ij} . For $i=1,2,3,4; j=1,2,3,4,5,6$ is produced as bellow

$$\omega_{46} = \begin{pmatrix} 18 & 24 & 22.5 & 15 & 22.5 & 33.3 \\ 23.2 & 8.7 & 14.35 & 14.35 & 10.25 & 10.17 \\ 20 & 16.67 & 19.5 & 23.8 & 6.5 & 22 \\ 28.33 & 37.78 & 29.69 & 5.39 & 5.39 & 21.67 \end{pmatrix}$$

Step 3: Calculating F_j . For $j=1$ so F_1 is obtained as bellows

$$\begin{aligned} F_1 \text{ of column-1} &= 14.63 \\ F_1 \text{ of column-2} &= 52.34 \\ F_1 \text{ of column-3} &= 28.59 \\ F_1 \text{ of column-4} &= 37.01 \\ F_1 \text{ of column-5} &= 23.03 \\ F_1 \text{ of column-6} &= 46.5 \end{aligned}$$

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

Step 5: Selecting the least ω_{ij} in F_1 of column-2 is ω_{22} .

Step 6: Allocating the x_{22} to ω_{22} with $x_{32} = \min(s_2, d_2) = \min(2,5) = 2$ such that $s_2 = s_2 - d_2 = 5 - 2 = 3$ and $d_2 = d_2 - d_2 = 2 - 2 = 0$. Since $s_2 \neq 0$ and $d_2 = 0$ then cross out of d_2 .

Step 7: Re-calculating the penalty without considering d_2 such that for $j= 2$ is obtained as bellows.

$$\begin{aligned} F_2 \text{ of column-1} &= 14.63 \\ F_2 \text{ of column-3} &= 28.59 \\ F_2 \text{ of column-4} &= 37.01 \\ F_2 \text{ of column-5} &= 23.03 \\ F_2 \text{ of column-6} &= 46.5 \end{aligned}$$

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.

Table 2. The new proposed algorithm with a penalty.

Sources	Destination					
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆
S ₁	18	24	22.5	15	22.5	33.3
S ₂	23.2	8.7	14.35	14.35	10.25	10.17
S ₃	20	16.67	19.5	23.8	6.5	22
S ₄	28.33	37.78	29.69	5.39	5.39	21.67
F ₁	14.63	52.34	28.59	37.01	23.08	46.5
F ₂	14.63	0	28.59	37.01	23.08	46.5
F ₃	12.33	0	13.13	28.05	18.22	12
F ₄	12.33	0	13.13	0	18.22	12
F ₅	12.33	0	13.13	0	0	12
F ₆	2	0	3	0	0	11.33
F ₇	2	0	3	0	0	0
F ₈	2	0	0	0	0	0
F ₉	0	0	0	0	0	0

Step 9: Finally, calculating minimal total distribution cost by using Eq. (1). The result of minT is 115. The feasible solution table of example 1 can be seen Table 3.

Table 3. The feasible solution table of example.

Sources	Destination						s _i
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	
S ₁	0	0	0	0	0	2	2
S ₂	0	2	0	0	0	3	5
S ₃	2	0	4	0	0	0	6
S ₄	0	0	0	4	4	1	9
d _j	2	2	2	4	4	6	

5. DISCUSSION

The application of the new proposed has been described with a numerical illustration of transportation problem example which has not only one or more the smallest c_{ij} of the TP table. The solving of TP example used the Algorithm 3 did not raise the potential to produce more than one IFS. It can be shown from the highest penalty used to determine which is base cell has not the equal value.

Meanwhile, the solving of TP example used Algorithm 3 (TDM 1[12]) raised the potential to produce more than on IFS. It is because the highest penalty has equal value. The highest penalty of TP example was produced by Algorithm 1 is shown in Table 4. If we compare the highest penalty obtained by Algorithm 1 with Algorithm 3, then Algorithm 3 is better at producing the highest penalty than Algorithm 1. Besides that, Algorithm 1 does not provide additional conditions if there is the highest penalty with the equal value such that it can potentially be Algorithm 1 cannot be made to solve TP example.

Table 4. The penalties of transportation problem in example generated TDM 1.

Sources	Destination						F_i
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	
S ₁	9	12	9	6	9	10	19
S ₂	7	3	7	7	5	5	16
S ₃	6	5	9	11	3	11	27
S ₄	6	8	11	2	2	10	27

Furthermore, the solving of TP example used Algorithm 2 (KSAM [18]) showed also the potential to generate not only one or more on IFS. It is caused by weighted transportation cost matrix by demand (WCD) or weighted transportation cost matrix by supply (WCS) which is assigned to select the smallest c_{ij} as a base cell has equal value. The value of WCD and WCS on TP example as follows,

$$\begin{aligned}
 \text{WCD} &= \begin{pmatrix} 9 & 12 & 18 & 12 & 18 & 30 \\ 2.8 & 1.2 & 5.6 & 5.6 & 4 & 6 \\ 2 & 1.67 & 6 & 7.3 & 2 & 11 \\ 1.3 & 1.78 & 4.89 & 0.89 & 0.89 & 6.67 \end{pmatrix} \text{ and} \\
 \text{WCS} &= \begin{pmatrix} 9 & 12 & 4.5 & 3 & 4.5 & 3.3 \\ 17.5 & 7.5 & 8.75 & 8.75 & 6.25 & 4.17 \\ 18 & 15 & 13.5 & 16.5 & 4.5 & 11 \\ 27 & 36 & 24.75 & 4.5 & 4.5 & 15 \end{pmatrix}^T
 \end{aligned}$$

If we also compare WCS and WCD obtained by Algorithm 2 with the penalty of Algorithm 3, then Algorithm 3 is better than Algorithm 2. Similarly, with the TDM 1, Algorithm 2 does not provide additional conditions if there is the WCD or WCS with the equal value such that it can potentially be Algorithm 2 cannot be made to solve TP example. TDM 1 and KSAM add criteria by freely selected the equal highest penalty (Algorithm 1) and equal value of WCD or WCS (Algorithm 2) so that IFS will be obtained. Therefore, the result comparison Of IFS between the new proposed method (Algorithm 3) with the existing methods (Algorithm 1 [12] and Algorithm 2 [18]) is shown Table 5. In this table can be seen the new proposed algorithm solved the TP example better than TDM 1 and KSAM. The algorithm of TDM and KSAM produced two IFS. The first IFS produced by TDM 1 algorithm is better than the new proposed algorithm and otherwise, the second IFS produced by TDM algorithm fewer results compared to the new proposed algorithm. Meanwhile, both IFS (WCS) generated by KSAM algorithm is better than the new proposed algorithm.

Table 5. The result comparison of IFS.

The existing method	Initial Feasible Solution (IFS)
	117 (1)
TDM1	110 (2)
	123 (WCD)
KSAM	121 (WCS-1)
	131 (WCS-2)
The new proposed algorithm	115

6. CONCLUSION

The importance of setting the smallest c_{ij} as the base cell for finding IFS of TP to determine the optimal solution which is the minimum total cost. The new proposed algorithm is developed based on the KSAM characteristics improvisation plus integration of modified TDM algorithm. It also considers the supply and demand coverage ratio (weights) as well as the smallest c_{ij} and included the penalties calculations for each column. This new proposed algorithm is capable to find the IFS effectively and efficiently. The numerical illustration of TP example indicated that the new proposed algorithm numerical results is comparable to the existing methods. The new proposed algorithm achieved better performance than TDM 1 and KSAM algorithms for TP example. In addition, it is also recommended that the new proposed algorithm integration with Stepping Stone and MODI methods in future research to evaluate the optimal solution of TP and determination of optimal solution in the event of information uncertainty about the parameters of TP.

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