An Alternate Approach For Finding The Initial Basic Feasible Solution Of Transportation Problem

Lakhveer Kaur, Madhuchanda Rakshit, Sandeep Singh

Abstract: In the supply network, it is very important to transport commodities from different origins to different station in minimum total transportation cost. These types of problems are called transportation problem. To achieve optimal solution of this problem, each individual starts solving the problem with an initial basic feasible solution. On starting with the better initial basic feasible solution, optimal solution (minimal cost) can be obtained in less number of iterations. In this paper, we have proposed a new method for finding initial basic feasible solution of transportation problem, which is based on making allocations in the minimum cost cell corresponding to the maximum cost. The proposed method obtains better initial solution as compare to existing methods. Even in many cases, our proposed method yields direct optimal solution or requires less number of iterations to reach optimal solution and can be easily applicable on the large scale transportation problems. Also, we have given some interesting comparison with existing methods.

Index Terms— Transportation Problem, Basic Cell, Key Cell, IBFS, optimal solution

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1 INTRODUCTION

In the linear programming problems, Transportation Problems plays an important role. Because, in the present business environment competition is raising every day and it is very important for every organization to deliver products to customers in the cost effective way by fulfilling their demands. The classical TP was originally developed by Hitchcock [13]. To solve these TP Dantzig [6] applied simple version of simplex algorithm to solve TP. Then Charnes et al. [5] and Dantzig [7] developed Stepping Stone and Modified Distribution (MODI) Method from simplex algorithm resp. In 1987, Shih [33] modified Stepping Stone Method. Shafaat et al. [30] proposed a new technique to handle degeneracy occurred in Stepping Stone Method. In 1989, Arsham et al.[2] developed simplex type algorithm as an alternative to stepping Stone Method and Dual Matrix approach given by Ji et al. [31]. All of above techniques are used to find optimal solution of TP, in which it is necessary to start with the IBFS. In the literature, huge number of techniques are available to find IBFS, such as, North West Corner Method, Least Cost Method, Vogels Approximation Method (VAM) given by Reinfeld et al. [28]. In 1981,Shimshak et al. [34] given modification in VAM, in which they ignored any penalty that involves a dummy row or column. Goyal [11] given an another suggestion to modify VAM was that, the cost of transporting goods to or from a dummy point was set equal to the highest transportation cost in the problem, rather than to zero. Ramakrishnam [24] and Balakrishan [3] given further modification in VAM. In 1990, Kirca and satir [18] obtained a heuristic named total opportunity cost method (TOM).

In which they obtained a new total opportunity cost matrix (TOCM) from original transportation cost matrix and applied Least Cost Method on new obtained matrix for giving allocations and also claimed that this method gives better solution than VAM for unbalanced transportation problems. Goyal [12] given note on the method obtained by Kirca and Satir to improve the solution. In 1990, Gass [9] reviewed various existing method to solve transportation problems and discussed on solving the the transportation problems. Sharma et al. [32] developed a new approach for obtaining initial solution for dual based techniques used for solving uncapacitated TP. Mathirajan and Minakshi [22] applied two variants of VAM on the total opportunity cost matrix obtained by Kirca and Satir instead of Least Cost Method and they shown that this technique provides, on an average, a very nearly optimal solution and it was expected to yield a very efficient starting solution when VAM applied in conjunction with total opportunity cost matrix instead of with the original transportation cost. Pargar et al. [23] have developed maximum demand heuristic (MDM). Korukoglu et al. [19] applied IVAM on the total opportunity cost matrix. Which gives more efficient initial solution for large scale transportation problems and it reduces total number of iterations. Then Storozhyshina et al. [35] made comprehensive empirical analysis of 16 existing heuristics over 4320 examples and analysed that maximum demand heuristic obtained better initial basic feasible solution than other existing algorithms. In 2012, Sudhakar et al. [37] developed efficient heuristic named zero suffix method (ZSM) and claimed that it gives optimal solution for transportation problems. But Juman et al. [15] demonstrated that ZSM does not always leads optimal and they developed more efficient heuristic named JHM method, which provides minimal transportation cost most of times. For more literature on IBFS, one can see ref. [16, 17, 20, 21, 26, 29]. In this paper, we develop a new way to find IBFS namely, Key cell method (KCM), which is based on avoiding maximum cost cells for making allocations. This method can be applied to any kind of single objective TP, like cost minimization, time minimization and profit maximization etc. But in this paper, our main attention is to minimize the total transportation cost. So we have applied this approach on cost minimization transportation problems.This paper is organized as follows: Section 2 contains basic definitions and theorems. Model

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- *Lakhveer kaur is currently pursuing PH.D in Guru Kashi University, India, E-mail: Sangha.1987.lk@gmail.com*
- *Dr. Madhuchanda Rakshit is assistant professor in Guru Kashi University India.. E-mail: drmrakshit@gmail.com*
- *Dr. Sandeep Singh is assistant professor in Akal University India.. E-mail: sandeepinsan86@gmail.com*

Representation is given in Section 3. In Section 4, An Algorithm to obtain IBFS of TP is Proposed. Numerical examples are given in Section 5 to illustrates the algorithm. In Section 6, comparison between existing best methods and proposed method is given. The last section Contains conclusion.

2 PRILEMNARIES
In this section, some basic definitions and theorems related to our proposed method are reviewed from [31].

2.1. Basic definitions
Definition 1. An n-tuple $(x_1, x_2, \dots x_n)$ of real numbers which satisfies the constraints of a general L.P.P. is called a solution to the general L.P.P.
Definition 2. Any solution to a general L.P.P. which also satisfies the non-negativity condition of general L.P.P. is called feasible solution of general L.P.P.
Definition 3. For m simultaneous linear equation in n variable (m < n) in general L.P.P., a solution obtained by setting n−m variable zero and by solving the resulting system in m variables, is called basic solution. The m variables, which may be all different from zero, are called basic variables.
Definition 4. A feasible solution to general L.P.P., which is also basic solution is called basic feasible solution to general L.P.P.

2.2. Basic Theorems
Theorem 1. A necessary and sufficient condition for the existence of feasible solution to general TP is that
$$\sum_{i=1}^{m} a_i = \sum_{i=1}^{m} b_i = \lambda (say)$$
Theorem 2. The number of basic (decision) variables of the general TP at any stage of feasible solution must be m+n-1, where m the number of sources and n the number of destinations.

3. MODAL REPRESENTATION
In general terms, the transportation problems are related to transporting goods from m sources to n destinations with least expenses while satisfying all supply and demand limitations. The sources may be production facilities, warehouses etc and the destinations may be sales, warehouses, outlets etc. This problem is widely known as cost minimizing transportation problem. In these problems, the decision maker is sure about the transportation cost, availability and demand of the product to be transported from factories to retail stores. A cost minimization transportation problem is formulated as:\
$$Min\ Z = \sum_{i=1}^{m} \sum_{i=1}^{n} c_{ii}^{r} x_{ii}\ ; r = 1, 2, \dots,$$

$$Subject\ to \sum_{i=1}^{n} x_{ii} = a_i,\ a_i > 0$$
$$\sum_{i=1}^{m} x_{ii} = b_i,\ b_i > 0$$
$$x_{ii} \geq 0, for\ i = 1, 2, \dots, m; j = 1, 2, \dots, n.$$

where
m   number of sources (Si)
n   number of destinations (Dj)
a_i supply amount of the product at S_i,
b_j demand of the product at Dj
x_{ij} amount of homogeneous product to be transported from Si to Dj
c_{ij} unit transportation cost of the product from Si to Dj
ai and bj are given non-negative numbers.

***Table 1.** Tabular Representation*

Destination → source ↓	D_1	D_2	...	D_n	supply(a_i)
S_1	c_{11}	c_{12}	...	c_{1n}	a_1
S_2	c_{21}	c_{22}	...	c_{2n}	a_2
⋮	⋮	⋮	...	⋮	⋮
S_m	c_{m1}	c_{m2}	...	c_{mn}	a_m
Demand (b_j)	b_1	b_2	...	b_n	

Remark 1. The above problem is said to be balanced if the total supply of the goods is same as its demand, otherwise the problem is said to be unbalanced.

4. PROPOSED ALGORITHM FOR KCM
The proposed KCM is an alternate approach for finding an IBFS for the transportation problems . This approach is based on making allocations to the minimum cost cell corresponding to row/column of maximum cost cell of TP. Our main aim to introduce this method is to minimize total transportation cost in very easy way with simple calculations. Next, Some important notations to proceed our proposed method are given.

Cost Cell (c_{ij}) :   unit transportation cost of the product from S_i
                                    to D_j.
Basic Cell (c_{rs}) :   Maximum c_{ij}.
Basic Row Cell (c_{rp})   Minimum cost cell in corresponding row of c_{rs}.
Basic Column Cell (c_{ts})   Minimum cost cell in corresponding column of
                                    c_{rs}
Key Cell (T)   Minimun of c_{rp} and c_{ts} .
Allocation (x_{ij})   amount of homogeneous product to be
                                    transpotated from S_i to D_j

By using above notations general steps of proposed algorithm are as follows:

Step 1: Problem Representation
Represent the given transportation problem as Table 1.

Step 2: Balance the unbalanced problem
If total availability and total demand of product is equal, then go to Step 3. Otherwise balance the given problem by introducing the dummy source or destination according to the lesser availability or lesser demand, respectively.
Case 2a:
If $\sum_{i=1}^{m} a_i < \sum_{i=1}^{m} b_i$, add a dummy source S_{m+1} with availability equal to $\sum_{i=1}^{m} b_i - \sum_{i=1}^{m} a_i$

Case 2b:
If $\sum_{i=1}^{m} a_i > \sum_{i=1}^{m} b_i$, add a dummy destination D_{n+1} with demand equal to $\sum_{i=1}^{m} a_i - \sum_{i=1}^{m} b_i$.

Step 3: Cell Selection and Allocation
From the Transportation Problem Table

a: Choose Basic Cell.
If there is a tie in selecting Basic Cell, then select that cell, which has minimum cost cell in corresponding row/column.

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b: Choose Basic Row Cell.
If tie occurs in selecting Basic Row Cell, then select that one, which has maximum cost cell in corresponding column.

c: Choose Basic Column Cell.
If tie occurs in selecting Basic Column Cell, then select that one, which has maximum cost cell in corresponding Row.

d: Choose Key Cell.
If basic Row and Column cell are equal, then select that one, which has maximum cost cell in corresponding column/row resp.

e: Make maximum possible Allocation to Key Cell.

f: Cross out the row/column for which supply/demand is fully satisfied.

Note: If tie not broken by using tie breakers in all above cases, then choose arbitrarily.

Step 4: Stopping Criteria
Repeat the step 3 for uncrossed row/column till all allocations are completed.

Remark 2. Make allocation in the dummy row/column at the end , when allocations are completed for all other rows and columns.

Representation of the proposed method for the balanced Transportation Problem is given by flow chart
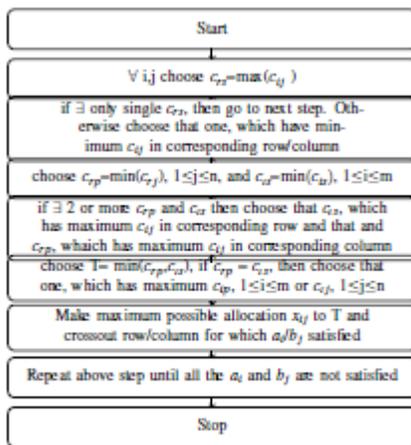

Figure 1: Flow Chart Representation

5. NUMERICAL EXAMPLES

For checking the performance of proposed KCM method, theoretical work is not sufficient. So it is necessary to apply it in practical field. For this, we have applied our proposed KCM method on 12 examples taken from literature and 8 randomly generated problems , which are as given in Table 2 and Table 3 with IBFS obtained by applying proposed KCM method.

6. COMPARATIVE STUDY AND ANALYSIS

VAM is commonly used method to find initial basic feasible solution in most of transportation problems. Also, Storozhyshina et al. [36] analysed that MDM gives more efficient solution than other existing algorithms. So we have compared the solution of our developed KCM method with solution of VAM and MDM by solving examples given in Table 2 and Table 3. For comparative study, we used modified distribution method to find optimal solution and IBFSs are obtained by applying VAM, MDM and KCM for considered examples is given in Table 4 and Table 5.

Table 2: *12 Numerical Examples taken from literature and IBFS using Proposed KCM Method*

Ex.	Input Data	Source	Obtained Allocations	Obtained Cost
1	$[c_{ij}]_{3\times4}$=[18 27 13 19; 25 21 24 14; 23 15 21 17]; $[a_i]_{3\times1}$=[40, 40, 20]; $[b_j]_{1\times4}$=[30, 15, 30, 20]	Goyal (1991)	$x_{11}=10$, $x_{13}=30$, $x_{14}=15$, $x_{24}=20$, $x_{31}=5$, $x_{32}=15$	1565
2	$[c_{ij}]_{4\times6}$=[5 9 16 2 12 32; 2 3 11 5 5 26; 10 6 8 12 3 19; 26 21 19 29 19 4]; $[a_i]_{4\times1}$=[82, 88, 99, 43]; $[b_j]_{1\times6}$=[48, 11, 32, 92, 50, 79]	Dwyer (1955)	$x_{16}=82$, $x_{21}=48$, $x_{22}=11$, $x_{24}=10$, $x_{25}=19$, $x_{33}=32$, $x_{35}=31$, $x_{36}=36$, $x_{46}=43$	1643
3	$[c_{ij}]_{3\times5}$=[5 7 10 5 3; 8 6 9 12 14; 10 9 8 10 15]; $[a_i]_{3\times1}$=[5, 10, 10]; $[b_j]_{1\times5}$=[3, 3, 10, 5, 4]	Ray et al. (2007)	$x_{14}=1$, $x_{15}=4$, $x_{21}=3$, $x_{22}=3$, $x_{23}=4$, $x_{33}=6$, $x_{34}=4$	183
4	$[c_{ij}]_{3\times2}$=[3 6; 4 5; 7 3]; $[a_i]_{3\times1}$=[400, 300, 400]; $[b_j]_{1\times2}$=[450, 350]	Arsham et al. (1989)	$x_{11}=400$, $x_{21}=50$, $x_{32}=350$	2450
5	$[c_{ij}]_{3\times5}$=[3 5 3 1 1; 2 3 3 2 7; 1 1 2 1 2]; $[a_i]_{3\times1}$=[4, 5, 6]; $[b_j]_{1\times5}$=[2, 2, 3, 4, 4]	Balinski et al. (1964)	$x_{15}=1$, $x_{25}=1$, $x_{34}=2$, $x_{35}=2$, $x_{31}=3$, $x_{32}=3$, $x_{33}=1$	23
6	$[c_{ij}]_{4\times4}$=[2 5 9 5; 8 3 5 8; 7 3 1 4; 5 9 7 2]; $[a_i]_{4\times1}$=[3, 2, 3, 3]; $[b_j]_{1\times4}$=[3, 5, 2, 1]	Gleyzal (1955)	$x_{15}=4$, $x_{21}=1$, $x_{23}=4$, $x_{31}=1$, $x_{32}=2$, $x_{33}=3$	35
7	$[c_{ij}]_{5\times5}$=[46 74 9 28 99; 12 75 6 36 48; 35 199 4 5 71; 61 81 44 88 9; 85 60 14 25 79]; $[a_i]_{5\times1}$=[461, 277, 356, 488, 393]; $[b_j]_{1\times5}$=[278, 60, 461, 116, 1060]	Korkoglu (2011)	$x_{11}=240$, $x_{13}=105$, $x_{14}=116$, $x_{23}=38$, $x_{25}=239$, $x_{33}=356$, $x_{45}=488$, $x_{52}=60$, $x_{55}=333$	62884
8	$[c_{ij}]_{3\times7}$=[3 4 6; 7 3 8; 6 4 5; 7 5 2]; $[a_i]_{4\times1}$=[100, 80, 90, 120]; $[b_j]_{1\times3}$=[110, 110, 60]	Kulkarni (2012)	$x_{11}=100$, $x_{22}=80$, $x_{31}=10$, $x_{42}=30$, $x_{43}=60$	870
9	$[c_{ij}]_{3\times3}$=[6 8 10; 7 11 11; 4 5 12]; $[a_i]_{3\times1}$=[150, 175, 275]; $[b_j]_{1\times3}$=[200, 100, 300]	Juman (2015)	$x_{11}=25$, $x_{13}=125$, $x_{23}=175$, $x_{31}=175$, $x_{32}=100$	4525
10	$[c_{ij}]_{3\times3}$=[2.2 2.1 2.4; 1.8 1.9 2.1; 3.0 3.2 3.6]; $[a_i]_{3\times1}$=[250, 300, 200]; $[b_j]_{1\times3}$=[190, 240, 320]	Wu et al. (1981)	$x_{12}=230$, $x_{13}=20$, $x_{23}=300$, $x_{31}=190$, $x_{32}=10$	1763
11	$[c_{ij}]_{3\times6}$=[19 30 50 10; 70 30 40 60; 40 8 70 20]; $[a_i]_{3\times1}$=[7, 9, 18]; $[b_j]_{1\times6}$=[5, 8, 7, 14]	Rashid (2016)	$x_{11}=5$, $x_{16}=2$, $x_{22}=2$, $x_{23}=7$, $x_{32}=6$, $x_{34}=12$	743
12	$[c_{ij}]_{4\times6}$=[5 3 7 3 8 5; 5 6 12 5 7 11; 2 8 3 4 8 2; 9 6 10 5 10 9]; $[a_i]_{4\times1}$=[4, 3, 3, 7]; $[b_j]_{1\times6}$=[3, 3, 6, 2, 1, 2]	Adlakha et al. (1999)	$x_{15}=2$, $x_{16}=2$, $x_{31}=3$, $x_{33}=3$, $x_{42}=3$, $x_{43}=3$, $x_{44}=1$, $x_{46}=2$, $x_{45}=1$	96

Table 3: *8 Randomly generated examples and IBFS using Proposed KCM Method*

Ex.	Input Data	Obtained Allocations	Obtained Cost
1	$[c_{ij}]_{3\times4}$=[13 18 30 40; 20 55 25 8; 30 6 50 10]; $[a_i]_{3\times1}$=[8, 10, 11]; $[b_j]_{1\times4}$=[47 6 12]	$x_{11}=4$, $x_{13}=4$, $x_{25}=2$, $x_{24}=8$, $x_{32}=7$, $x_{34}=4$	368
2	$[c_{ij}]_{3\times4}$=[6 8 10 4; 5 8 11 5; 6 9 13 5]; $[a_i]_{3\times1}$=[50, 75, 25]; $[b_j]_{1\times4}$=[20, 20, 50, 60]	$x_{13}=50$, $x_{23}=20$, $x_{22}=20$, $x_{24}=35$, $x_{34}=25$	1060
3	$[c_{ij}]_{4\times5}$=[4 4 9 8 13; 7 9 8 10 4; 9 3 7 10 9; 11 4 8 3 6]; $[a_i]_{4\times1}$=[100, 80, 70, 80]; $[b_j]_{1\times5}$=[60, 40, 100, 50, 80]	$x_{11}=60$, $x_{12}=40$, $x_{25}=80$, $x_{33}=70$, $x_{43}=30$, $x_{44}=50$	1600
4	$[c_{ij}]_{3\times4}$=[3 6 8 4; 6 1 2 5; 7 8 3 9]; $[a_i]_{3\times1}$=[20, 17, 28]; $[b_j]_{1\times4}$=[19, 15, 13, 18]	$x_{11}=2$, $x_{14}=18$, $x_{21}=2$, $x_{22}=15$, $x_{31}=15$, $x_{33}=13$	249
5	$[c_{ij}]_{5\times4}$=[10 20 5 7; 13 9 12 8; 4 15 7 9; 14 7 1 1; 3 12 5 19]; $[a_i]_{5\times1}$=[200, 300, 200, 400, 400]; $[b_j]_{1\times4}$=[500, 600, 200, 200]	$x_{13}=200$, $x_{22}=30$, $x_{31}=200$, $x_{42}=200$, $x_{44}=200$, $x_{51}=300$, $x_{52}=100$	8200
6	$[c_{ij}]_{4\times6}$=[1 2 1 4 5 2; 3 3 2 1 4 3; 4 2 5 9 6 2; 3 1 7 3 4 6]; $[a_i]_{4\times1}$=[80, 50, 75, 20]; $[b_j]_{1\times6}$=[20, 10, 30, 25, 50, 40]	$x_{13}=30$, $x_{16}=25$, $x_{25}=25$, $x_{21}=20$, $x_{22}=10$, $x_{25}=5$, $x_{26}=40$, $x_{35}=20$	445
7	$[c_{ij}]_{4\times4}$=[5 3 6 10; 6 8 10 7; 3 1 6 7; 8 2 10 12]; $[a_i]_{4\times1}$=[30, 10, 20, 5]; $[b_j]_{1\times4}$=[20, 10, 25, 10]	$x_{11}=5$, $x_{13}=25$, $x_{34}=10$, $x_{31}=15$, $x_{32}=5$, $x_{42}=5$	365
8	$[c_{ij}]_{5\times5}$=[8 8 2 10 2; 11 4 12 9 4; 5 6 2 11 10; 10 6 6 5 2; 8 11 8 6 4]; $[a_i]_{5\times1}$=[40, 70, 35, 90, 85]; $[b_j]_{1\times5}$=[80, 55, 60, 80, 45]	$x_{13}=40$, $x_{22}=55$, $x_{25}=15$, $x_{31}=15$, $x_{33}=20$, $x_{44}=60$, $x_{45}=30$, $x_{51}=65$, $x_{54}=20$	1475

Table 4: Results(IBFS and Optimal Solution of 12 examples taken from literature)

Examples → Methods ↓	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10	Ex-11	Ex-12
VAM	1575	1662	187	2600	23	37	72156	880	5125	1801	749	96
MDM	1725	1662	203	2450	25	37	70228	840	4590	1763	814	106
KCM	1565	1643	183	2450	23	35	62884	840	4525	1763	743	96
Optimal Solution	1565	1643	183	2450	23	35	59332	840	4525	1763	743	96

Table 5: Results(IBFS and Optimal Solution of randomly generated 8 examples)

Examples → Methods ↓	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8
VAM	374	1100	1640	260	9800	455	315	1640
MDM	388	1085	1750	305	8900	475	315	1555
KCM	368	1060	1600	249	8200	445	305	1475
Optimal Solution	368	1060	1600	245	8200	445	305	1475

It can be observed from Table 4 and Table 5 that KCM obtained better initial solution than MDM for 17 examples out of 20 examples solved and for remaining 3 examples both KCM and MDM obtained same initial solution. Again KCM obtained better initial solution than VAM for 18 examples out of 20 examples solved and for remaining 2 examples both KCM and VAM gives same initial solution. Also IBFS obtained by KCM for 18 examples out of 20 examples provide optimal solution, whereas VAM provides optimal solution for only 2 and MDM provides for 3 examples. Here, we give the comparative study of our technique with VAM and MDM method with respect to optimal solution by applying ARPD technique, which is used by Mathirajan (2004). The technique is as follows:

$$ARPD = \frac{1}{N}\sum_{k=1}^{N}(RPD(M,k)) \qquad RPD(M,k) = \frac{(IBFS)_k - (OS)_k}{(OS)_k} \times 100$$

Where ARPD(M)-Average relative percentage deviation of the given method "M", where "M" indicates NWCM, or VAM, or LCM, or HCDM, or EDM, or TOM, or TOCM-VAM, or Proposed Method; RPD(M, K)-Relative percentage deviation of the kth problem between IBFS using method "M" and Optimal Solution;N-the number of problems presented;$(IBFS)_k$-IBFS of kth problem using method M;$(OS)_k$- optimalsolution of kth problem. By using above measures RPD and ARPD of different methods are as given in Table 6 and Table 7.

Table 6: Results related to 12 examples taken from literature (RPD and ARPD in %)

Examples → Methods ↓	RPD												ARPD
	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10	Ex-11	Ex-12	
VAM	.64	1.16	2.19	6.12	0	5.71	21.56	4.76	13.26	2.16	.81	0	4.82
MDM	10.22	1.16	10.93	0	8.70	5.71	18.32	0	1.44	0	9.56	10.42	6.37
KCM	0	0	0	0	0	0	5.94	0	0	0	0	0	.50

Table 7: Results related to 8 randomly generated examples (RPD and ARPD in %)

Examples → Methods ↓	RPD								ARPD
	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	
VAM	1.63	3.77	2.5	6.12	19.51	2.25	3.28	11.19	6.28
MDM	5.43	2.36	9.38	24.49	8.54	6.74	3.28	5.42	8.21
KCM	0	0	0	1.63	0	0	0	0	.20

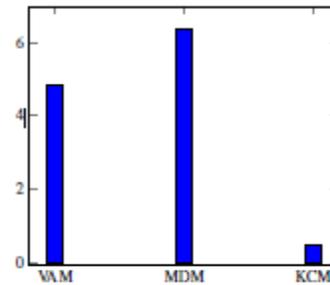Graphical representation ARPD is given firure 2 and figure 3.

Figure 2: ARPD graph representation of VAM, MDM and KCM, when applied on 12 example taken from literature
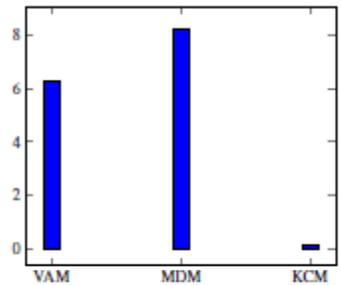
Figure 3: ARPD graph representation of VAM, MDM and KCM, when applied on 8 randomly generated examples

From the above graph, it can be concluded that ARPD of our proposed KCM method is least comparative to VAM and MDM, which shows the effectiveness of the proposed method. Also comparative study of number of iterations to reach optimal solution by MODI method on starting with IBFS obtained by VAM, MDM and KCM is carried out for all considered 20 examples. Results are given for each category of examples in Table 8 and Table 9.

Table 8: Results (number of iteration taken to reach optimal solution on starting with IBFS obtained by VAM, MDM and KCM for 12 examples taken from literature)

Examples → Methods ↓	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8	Ex-9	Ex-10	Ex-11	Ex-12
VAM	1	1	1	1	0	1	5	2	1	2	1	0
MDM	2	1	3	0	1	1	4	0	1	0	2	4
KCM	0	0	0	0	0	0	4	0	0	0	0	0

Table 9: Results (number of iteration taken to reach optimal solution on starting with IBFS obtained by VAM, MDM and KCM for 8 randomly generated examples)

Examples → Methods ↓	Ex-1	Ex-2	Ex-3	Ex-4	Ex-5	Ex-6	Ex-7	Ex-8
VAM	1	1	2	1	1	1	1	2
MDM	1	3	1	1	4	4	1	3
KCM	0	0	0	1	0	0	0	0

From Table 8 and Table 9, it can be observed that KCM takes zero iterations to reach optimal solution for considered examples except for 2 examples and in these examples KCM does not take more iterations to reach optimal solution than VAM and MDM.

7. CONCLUSIONS

A method based on selecting the way with minimum transportation cost is proposed. To make comparision of proposed method with existing efficient techniques, number of examples have been considered from literature and randomly generated. Average rate of deviation of IBFS of proposed

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method, VAM and MDM with respect to optimal solution has been carried out with the help of ARPD technique. From the comparative analysis of developed KCM method with existing method, it is to be noted that KCM obtains better and effective IBFS and developed technique is very easy to apply and consume less time to compute. Also an individual can apply this technique easily to find total transportation cost of large scale TP because there is simple calculation while making allocations. The main aim of the algorithm is to avoid the transportation through the way, on which transportation cost is maximum. Because by doing this transportation cost can be minimized easily, which is the first choice of organizers. Also the present paper can be extend in future by using linear programming software for reporting obtained results as CPU times and computer memory.

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