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A New Technique for Solving Unbalanced Intuitionistic Fuzzy Transportation Problems

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Abstract: In this paper, a new method is proposed for solving unbalanced Intuitionistic fuzzy transportation problems assuming that a decision maker is uncertain about the precise values of transportation costs, demand and supply of the product. In this proposed method, transportation costs, demand and supply of the product are represented by triangular Intuitionistic fuzzy numbers. To illustrate it, a numerical example is solved and the obtained result is compared with the results of other existing methods. It is very easy to understand this method which can be applied to real life transportation problems.

Keywords: Triangular Intuitionistic fuzzy numbers, Unbalanced Intuitionistic Fuzzy Transportation Problem (UIFTP), Optimal Solution.

1 Introduction

Transportation problem is an important network structured in linear programming (LP) problem that arises in several contexts and has deservedly received a great deal of attention in the literature. Its central concept is to find the minimum transportation cost of a commodity to satisfy demands at destinations using available supplies at origins. Transportation problem can be used for a wide variety of situations such as scheduling, production, investment, plant location, inventory control, employment scheduling. In general, transportation problems are solved with the assumptions that the transportation costs and values of supplies and demands are specified in a precise way i.e. in crisp environment. However, in many cases, decision makers have no crisp information about the coefficients relevant to transportation problem. In these cases, the corresponding coefficients or elements defining the problem can be formulated by means of fuzzy sets, and the fuzzy transportation problem (FTP) appears in natural way.

The basic transportation problem was originally developed by Hitchcock [1]. The transportation problems can be modeled as a standard linear programming problem, which can then be solved by the simplex method. However, because of its very special mathematical structure, it was recognized early that the simplex method applied to the transportation problem can be made quite efficient in terms of how to evaluate the necessary simplex method information (Variable to enter the basis, variable to leave the basis and optimality conditions). Charnes and Cooper [2] developed a stepping stone method which provides an alternative way of defining the simplex method information. Dantzig and Thapa [3] used simplex method as the primal simplex transportation method. An Initial Basic Feasible Solution (IBFS) for the transportation problem can be obtained using the North- West Corner rule NWCR [2], Matrix Minima Method MMM [2], Vogel's Approximation Method. We can find initial basic feasible solution using Vogel's Approximation Method VAM [2]. Several authors attempted Vogel's Approximation method for obtaining initial solutions to the unbalanced transportation problem. Shimshak [4] proposed a modification (SVAM) which ignores any penalty that involves a dummy row/column. Goyal [5] suggested another modification in (GVAM) where the cost of transporting goods to or from a dummy point is set equal to the highest transportation cost in the problem, rather than to zero. The method proposed by Ramakrishnan [6] consists of four steps of reduction and

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one step of VAM. Nagaraj Balakrishnan [7] presented further modification in SVAM. All methods have been established for finding the optimal solution. Some methods directly attain the optimal solution namely zero suffix method [8], ASM–method [9]. But these two methods for finding optimal solution of a transportation problem do not reflect optimal solution proved by Mohammed [10]. Transportation problems are solved with the assumptions that the coefficients or cost parameters are specified precisely.

In real life, there are many diverse situations due to uncertainty in judgments, lack of evidence etc. Sometimes it is impossible to get relevant precise data for the cost parameter. This type of imprecise data is not always well represented by random variable selected from a probability distribution. Fuzzy number Zedeh [11] may represent the data. Hence fuzzy decision making method is used here. Zimmermann [12] showed that solutions obtained by fuzzy linear programming method are always efficient. Subsequently, Zimmermann's fuzzy linear programming has developed into several fuzzy optimization methods for solving the transportation problems. Chanas et al. [13] presented a fuzzy linear programming model for solving transportation problems with crisp cost coefficient, fuzzy supply and demand values. Chanas and Kuchta [14] proposed the concept of the optimal solution for the transportation problem with fuzzy coefficients expressed as fuzzy numbers, and developed an algorithm for obtaining the optimal solution. Saad and Abbas [15] discussed the solution algorithm for solving the transportation problem in fuzzy environment.

Edward Samuel [16,17] showed the unbalanced fuzzy transportation problems without converting into balanced ones achieving an optimal solution, where the transportation cost, demand and supply are represented by triangular fuzzy number. Edward Samuel [18] proposed algorithmic approach to unbalanced fuzzy transportation problem, where the transportation cost, demand and supply are represented by triangular fuzzy number. Liu and Kao [19] described a method for solving fuzzy transportation problem based on extension principle. Gani and Razak [20] presented a two-stage cost minimizing fuzzy transportation problem (FTP) in which supplies and demands are trapezoidal fuzzy numbers. A parametric approach is used to obtain a fuzzy solution and aims to minimize the sum of the transportation costs in two stages. Dinagar and Palanivel [21] investigated FTP, with the aid of trapezoidal fuzzy numbers. Fuzzy modified distribution method is proposed to find the optimal solution in terms of fuzzy numbers. Pandian and Natarajan [22] proposed a new algorithm namely fuzzy zero point method for finding a fuzzy optimal solution for a FTP, where the transportation cost, supply and demand are represented by trapezoidal fuzzy numbers. Atanassov [23] introduced the concept of Intuitionistic Fuzzy Sets (IFS), which is a generalization of the concept of fuzzy set. Nagoor Gani and Abbas [24] proposed a new average method for solving intuitionistic fuzzy transportation problem. There is no uncertainty about transportation costs but demand and supply are represented by triangular intuitionistic fuzzy number.

The present study aims to find an optimal solution for an unbalanced Intuitionistic fuzzy transportation problem (UIFTP). It presents a new method for solving unbalanced Intuitionistic fuzzy transportation problems. This can be an alternative to the modification distribution method. No path tracing is required in this approach. The algorithm of the approach is detailed with suitable numerical examples. Furthermore comparative studies of the new technique with other existing algorithms are established by means of sample problems. One can also implement the proposed algorithm in Maple. Various Maple implementations of different algorithms are discussed in [25,26,27,28,29,30,31,32,33].

2 Preliminaries

In this section, some basic definitions, arithmetic operations and an existing method for comparing Intuitionistic fuzzy numbers are presented.

Definition 1 *[34,35] A fuzzy number $\tilde{A}=(a,b,c)$ is said to be a triangular fuzzy number if its membership function is given by*

$$\mu_{\tilde{A}}(x)=\begin{cases}\frac{x-a}{b-a}, & if\ a\le x\le b\\ \frac{x-c}{b-c}, & if\ b\le x\le c\\ 0, & otherwise\end{cases}$$

Definition 2 *[36,37] A triangular intuitionistic fuzzy number A^{-I} is an intuitionistic fuzzy set in $\Re$ with the following membership function $\mu_{A^{-I}}(x)$ and non-membership function $\gamma_{A^{-I}}(x)$ are defined by*

$$\mu_{A^{-I}}(x)=\begin{cases}\frac{x-a_1}{a_2-a_1}, & a_1<x\le a_2\\ \frac{a_3-x}{a_3-a_2}, & a_2\le x<a_3\\ 0, & otherwise\end{cases}$$

and

$$\gamma_{A^{-I}}(x)=\begin{cases}\frac{a_2-x}{a_2-a_1^I}, & a_1^I<x\le a_2\\ \frac{x-a_2}{a_3^I-a_2}, & a_2\le x<a_3^I\\ 1, & otherwise\end{cases}$$

where $a_1^1\le a_1<a_2<a_3\le a_3^1$ this TIFN is denoted by $A^{-I}=(a_1,a_2,a_3;a_1^I,a_2,a_3^I)$.

Arithmetic operations

In this section, arithmetic operations between two triangular Intuitionistic fuzzy numbers [38], defined on the universal set of real numbers $\Re$, are presented.

Let $A^{-I}=(a_1,a_2,a_3;a_1^I,a_2,a_3^I)$, and $B^{-I}=(b_1,b_2,b_3;b_1^I,b_2,b_3^I)$ be two triangular intuitionistic fuzzy numbers then the following is obtained.

$(i)\ A^{-I}+B^{-I}$
$= (a_1+b_1, a_2+b_2, a_3+b_3; a_1^I+b_1^I, a_2+b_2, a_3^I+b_3^I)$
$(ii)\ A^{-I}-B^{-I}$
$= (a_1-b_3, a_2-b_2, a_3-b_1; a_1^I-b_3^I, a_2-b_2, a_3^I-b_1^I)$
$(iii)\ A^{-I}\times B^{-I}$
$= (l_1, l_2, l_3; l_1^I, l_2, l_3^I,),$

where

$$l_1=\min[a_1b_1,a_1b_3,a_3b_1,a_3b_3],\quad l_2=a_2b_2,$$
$$l_3=\max[a_1b_1,a_1b_3,a_3b_1,a_3b_3],$$
$$l_1^I=\min[a_1^Ib_1^I,a_1^Ib_3^I,a_3^Ib_1^I,a_3^Ib_3^I],\quad l_2=a_2b_2,$$
$$l_3^I=\max[a_1^Ib_1^I,a_1^1b_3^I,a_3^Ib_1^I,a_3^Ib_3^I]$$

Ranking function

Let A^{-I} and B^{-I} two triangular intuitionistic fuzzy numbers, then

$$\Re(\tilde{A})=\left(\frac{(a_1+2a_2+a_3)+(a_1^I+2a_2+a_3^I)}{8}\right)$$
$$\Re(\tilde{B})=\left(\frac{(b_1+2b_2+b_3)+(b_1^I+2b_2+b_3^I)}{8}\right)$$

3 Proposed Method

The adopted method of unbalanced intuitionistic fuzzy transportation problems provides us with an efficient way of finding the optimal solution. It involves the following steps:

I. **Initialization:** Construct the fuzzy transportation table for the given unbalanced intuitionistic fuzzy transportation problem. Then, convert it into a balanced one.

II. **Develop the cost table:**
(a)Perform row wise reduction: Locate the largest element in each row of the given fuzzy cost table. Then, subtract that from each element of that row.
(b)Perform column wise reduction: In the reduced matrix obtained from II(a), locate the largest element in each column. Then, subtract that from each element of that column.
(c)Verify each row and column have at least one intuitionistic fuzzy zero value. If there is no intuitionistic fuzzy zero value in the row (column) in the reduced matrix obtained from step II(b) select the smallest value in row (column) and subtract from the largest cost.

III. **Make allocation in the opportunity cost matrix:**
(a)Identify the largest unit transportation cost in the cost matrix obtained from step II or step IV.
(b)Select a row single intuitionistic fuzzy zero and/ or column single intuitionistic fuzzy zero cell for allocation, corresponding to ith row and jth column, if exist.
(c)Allocate the minimum possible to that cell, and adjust the supply and demand as well as cross out the satisfied the row or column.
(d)If row single intuitionistic fuzzy zero or column single intuitionistic fuzzy zero cell does not exist in both ith row and jth column, select the next largest unit transportation cost and repeat the process from step III(a) to step III(d).

IV. **Revise the opportunity cost table:**
(a)After performing step III verify each row and column possess at least one intutionistic fuzzy zero. If not, go to step IV(b). Otherwise go to step V.
(b)If there is no single intuitionistic fuzzy zero for each row and column, locate the smallest element and subtract it with each row (column).

V. **Determination of cell for allocation:** Repeat step III to IV until the entire demand at various destinations and available supply at various sources are satisfied.

VI. Compute total fuzzy transportation cost for the feasible allocation from the original fuzzy cost table.

Remark 1 *1. If there is a tie in the values of largest transportation cost, calculate their corresponding row and column value and select with maximum one for cell allocation.*
2. If there is no single intutionistic fuzzy zero in the ith row and jth column in the reduced matrix, identify the largest unit transportation cost cell from the given unbalanced transportation cost table then select a (row/column) single intutionistic fuzzy zero for allocation.

4 Numerical Example

Example 1 *Table 1 presents the availability of the product supply at three sources S1, S2, S3 and their demand at three destinations D1, D2, D3. The approximate unit transportation cost, demand and supply of the product from each source to each destination are represented by triangular intuitionistic fuzzy number. define the intuitionistic fuzzy optimal transportation of the products such that the total transportation cost is Minimum.*

Since $\sum_{i=1}^{3} a_i = (14,20,28;13,20,35)$, *is not equal to* $\sum_{j=1}^{3} b_j = (15,23,35;11,23,43)$ *so the chosen problem is a unbalanced IFTP.*

Iteration 1: *Using step 1, we get Table 2. Now from Table 2, we have* $\sum_{i=1}^{4}(15,23,35;11,23,43)$ *is the same as*

Table 1: Availability of the product supply

	D1	D2	D3	Supply (a)
S1	(1,2,5;0,2,6)	(4,5,9;2,5,13)	(3,4,6;2,4,7)	(4,5,7;3,5,10)
S2	(5,6,9;3,6,10)	(2,3,6;1,3,8)	(1,2,3;0,2,4)	(2,6,9;1,6,12)
S3	(6,8,11;4,8,12)	(7,9,13;6,9,14)	(1,2,5;0,2,6)	(8,9,12;7,9,13)
b_j	(7,8,10;6,8,13)	(4,10,18;2,10,20)	(4,5,7;3,5,10)	

Table 2: Iteration 1: Using step 1

	D1	D2	D3	Supply (a)
S1	(1,2,5;0,2,6)	(4,5,9;2,5,13)	(3,4,6;2,4,7)	(4,5,7;3,5,10)
S2	(5,6,9;3,6,10)	(2,3,6;1,3,8)	(1,2,3;0,2,4)	(2,6,9;1,6,12)
S3	(6,8,11;4,8,12)	(7,9,13;6,9,14)	(1,2,5;0,2,6)	(8,9,12;7,9,13)
S4	(0,0,0;0,0,0)	(0,0,0;0,0,0)	(0,0,0;0,0,0)	(1,3,7;0,3,8)
Demand (b)	(7,8,10;6,8,13)	(4,10,18;2,10,20)	(4,5,7;3,5,10)	

Table 3: Iteration 2: Using step 2

	D1	D2	D3	Supply (a)
S1	**(-9,0,9;-17,0,17)**	(-6,3,12;-16,3,20)	(-4,6,14;-11,6,19)	(4,5,7;3,5,10)
S2	(-5,3,12;-11,3,20)	**(-8,0,8;-14,0,14)**	(-6,3,10;-10,3,15)	(2,6,9;1,6,12)
S3	(-8,2,12;-14,2,19)	(-7,3,13;-13,3,17)	**(-14,0,14;-14,0,14)**	(8,9,12;7,9,13)
S4	(-1,3,8;-4,3,13)	**(-8,0,8;-14,0,14)**	(-5,4,1;-9,4,9)	(1,3,7;0,3,8)
Demand (b)	(7,8,10;6,8,13)	(4,10,18;2,10,20)	(4,5,7;3,5,10)	

Table 4: Iteration 3: Using step 3

	D1	D2	D3	Supply (a)
S1	**(-9,0,9;-17,0,17)** (4,5,7;3,5,10)	(-6,3,12;-16,3,20)	**(-4,6,14;-11,6,19)**	(4,5,7;3,5,10)
S2	(-5,3,12;-11,3,20)	**(-8,0,8;-14,0,14)**	(-6,3,10;-10,3,15)	(2,6,9;1,6,12)
S3	(-8,2,12;-14,2,19)	(-7,3,13;-13,3,17)	**(-14,0,14;-14,0,14)**	(8,9,12;7,9,13)
S4	(-1,3,8;-4,3,13)	**(-8,0,8;-14,0,14)**	(-5,4,1;-9,4,9)	(1,3,7;0,3,8)
Demand (b)	(7,8,10;6,8,13)	(4,10,18;2,10,20)	(4,5,7;3,5,10)	

Table 5: Iteration 4: Using step 4 and step 5

	D1	D2	D3	Supply (a)
S1	**(-9,0,9;-17,0,17)** (4,5,7;3,5,10)	*	*	*
S2	*	**(-8,0,8;-14,0,14)** (2,6,9;1,6,12)	*	*
S3	**(-20,0,20;-33,0,33)** (0,3,6;-4,3,10)	**(-20,0,20;-30,0,30)** (-5,1,8;-13,1,14)	**(-14,0,14;-14,0,14)** (4,5,7;3,5,10)	*
S4	*	**(-8,0,8;-8,0,8)** (1,3,7;0,3,8)	*	*
Demand (b)	*	*	*	

$\sum_{i=1}^{4}(15,23,35;11,23,43)$.

Iteration 2: *Using step 2, we get Table 3.*

Iteration 3: *Using step 3, we get Table 4.*

Iteration 4: *Using step 4 and step 5, we get we get Table 5.*

Iteration 5: *Using step 6, we get we get Table 6. Finally, The minimum fuzzy transportation cost is = (4,5,7;3,5,10) (1,2,5;0,2,6) + (2,6,9;1,6,12) (2,3,6;1,3,8) + (0,3,6;-4,3,10) (6,8,11;4,8,12) + (-5,1,8;-13,1,14) (7,9,13;4,8,12) + (4,5,7;3,5,10) (1,2,5;0,2,6) = (-144, 71, 489; -481, 71, 602).*

The ranking function R(A) = 93.75

Example 2 *To illustrate our procedure in Example 1 further, the solutions obtained by NWCR, MMM, VAM*

Table 6: Iteration 5: Using step 6

	D1	D2	D3	Supply (a)
S1	(1,2,5;0,2,6) **(4,5,7;3,5,10)**	(4,5,9;2,5,13)	(3,4,6;2,4,7)	(4,5,7;3,5,10)
S2	(5,6,9;3,6,10)	(2,3,6;1,3,8) **(2,6,9;1,6,12)**	(1,2,3;0,2,4)	(2,6,9;1,6,12)
S3	(6,8,11;4,8,12) **(0,3,6;-4,3,10)**	(7,9,13;6,9,14) **(-5,1,8;-13,1,14)**	(1,2,5;0,2,6) **(4,5,7;3,5,10)**	(8,9,12;7,9,13)
Demand (b)	(7,8,10;6,8,13)	(4,10,18;2,10,20)	(4,5,7;3,5,10)	

Table 7: Randomly generated unbalanced intuitionistic fuzzy transportation problems

	D1	D2	D3	Supply (a)
S1	(1,2,4;0,2,9)	(5,7,14;4,7,17)	(13,14,17;12,14,22)	(4,5,7;3,5,10)
S2	(2,3,5;1,3,8)	(2,3,5;1,3,8)	(1,2,3;0,2,4)	(7,8,10;6,8,11)
S3	(4,5,7;3,5,10)	(3,4,6;2,4,9)	(5,7,14;4,7,17)	(5,7,10;4,7,13)
S4	(1,2,3;0,2,4)	(3,6,12;2,6,15)	(1,2,4;0,2,9)	(14,15,19;13,15,20)
Demand (b)	(5,7,10;4,7,13)	(8,9,11;7,9,14)	(16,17,22;15,17,23)	

Table 8: Solutions obtained by all procedures

S.NO	ROW	COLUMN	NWCR	MMM	VAM	MODI	PM
1.	4	3	148.88	147.00	107.25	103.50	93.75
2.	4	4	176.00	158.13	151.38	149.75	142.63
3.	3	3	160.25	130.00	102.75	102.75	102.75
4.	3	4	4239.38	2933.50	2455.63	2455.63	2455.63
5.	3	3	2975.00	2932.50	2667.50	2529.75	2460.00
6.	3	4	1851.25	1816.25	1765.25	1671.63	1668.00
7.	4	5	13112.00	9817.50	9217.50	9217.50	9217.50
8.	4	3	615.75	527.50	527.50	527.50	527.50
9.	4	3	248.75	182.25	157.50	156.25	142.00
10.	3	4	69.75	69.50	63.00	58.13	53.75
11.	4	5	1389.00	1017.50	1163.50	1014.00	947.50
12.	3	3	632.50	635.50	500.25	500.25	500.25
13.	4	4	121.25	110.25	99.75	97.75	91.25
14.	4	5	940.50	824.25	797.00	790.75	787.25
15.	4	5	644.75	632.25	534.63	515.13	514.75

and MODI Method and our proposed method (PM) with fifteen problems randomly generated unbalanced intuitionistic fuzzy transportation problems are shown in the following Table 7. The complete sets of results of these fifteen problems are not shown here due to space consideration, and can be made from author.

Comparison among different existing transportation methods are given in Table 8.

5 Results and Discussion

The above-mentioned investigations and results demonstrate that the proposed method is better than other existing methods. It is also used for solving unbalanced intuitionistic fuzzy transportation problems and provides an optimal solution.

6 Conclusion

In the present paper, a new method was proposed for finding optimal solution of intutionistic fuzzy transportation problem in which the transportation costs, demand and supply of the product are represented by triangular intuitionistic fuzzy numbers. Thus, this technique can be applied for solving intuitionistic fuzzy transportation problems occurring in real life situations.

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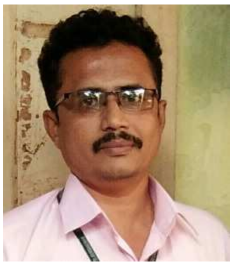

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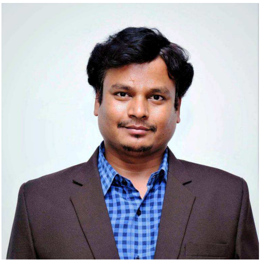

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