Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 133 (2019) 234-247 EISSN 2392-2192

Solving Hexagonal Intuitionistic Fuzzy Fractional Transportation Problem Using Ranking and Russell's Method

A. Anju

Department of Mathematics, PSG College of Arts and Science,
Coimbatore - 641014, Tamil Nadu, India

E-mail address: anjurojin2017@gmail.com

ABSTRACT

This paper presents a solution for fractional transportation problem in an intuitionistic fuzzy environment in which cost are represented by hexagonal intuitionistic fuzzy numbers. Fuzzy fractional transportation is a special kind of optimization problem which is associated with our day to day activities. An optimal solution is found out to show the effectiveness of this method. In this, the problem is solved using ranking and Russell's method for hexagonal intuitionistic fuzzy numbers. An illustrative example is provided to demonstrate the feasibility of this method.

***Keyword*:** Intuitionistic Fuzzy, Fractional Transportation Problem, Ranking Method, Russell's Method

Mathematics Subject Classification (2010): 90C39, 03E72, 90C32

1. INTRODUCTION

Transportation problem is a special kind of linear programming problem where the objective is to minimize the cost of distributing a commodity from one source to another destination. Since it is having a special structure the usual simplex method is not suitable for solving transportation problems. Therefore it requires special method of solution. The problem of finding the minimum-cost distribution of a given commodity from a group of supply centers

(Received 21 July 2019; Accepted 08 August 2019; Date of Publication 10 August 2019)

(sources) $i = 1,2,\ldots,m$ to a group of receiving centers (destinations) $j = 1,2,\ldots,n$. Each source has a certain supply (s_i) and each destination has a certain demand (d_i). In this the cost of shipping from a source to destination is directly proportional to the number of units shipped.

The fractional transportation problem was originally proposed by Swarup [21] in 1966 and it has an important role in logistics and supply chain management for reducing cost and improving service. The fractional transportation problem plays a magnificent role in logistics, transportation and supply management for reducing cost and improving service. In fractional transportation problem the main objective is to optimize the ratios of two cost functions or damage functions or demand functions. As the ratio of two functions is considered, the fractional programming models become more suitable for real world problems. Keeping in view that the complexities associated with real life transportation problem like vagueness and uncertainty involved with the parameters. Therefore it can be very useful if we implement these fuzzy techniques.

The idea of intuitionistic fuzzy sets are introduced by Attanassov in 1986 [1-3]. It deals with vagueness or uncertainty. The main benefit of intuitionistic fuzzy sets is that it include both the degree of membership and non-membership of each element in the set. Recently intuitionistic fuzzy sets plays a vital role in decision making in fuzzy environment. In many cases the decision maker has no precise knowledge about the coefficient belonging to the transportation problem. An intuitionistic fuzzy set is a powerful tool to deal with such vagueness.

In this paper the author introduced fractional transportation problem with hexagonal intuitionistic fuzzy numbers in a more simplified and precise way. This paper is motivated by [4]. Many researchers have keen interest in intuitionistic fuzzy theory, which is applied in the field of decision making. Here the author found out the optimal solution of a fractional transportation problem with intuitionistic fuzzy numbers using the proposed method. In this paper for the first time the author found out the hexagonal intuitionistic fuzzy fractional transportation problem using ranking and Russell's method.

This paper is organized as follows: Section 2 discusses the review of literature of the proposed problem. Section 3 gives preliminary background of the paper. Section 4 analysed problem formulation of fractional transportation problem, intuitionistic fuzzy fractional transportation problem, Ranking method and Russell's method. Illustrative numerical example is given in Section 5. Section 6 gives the conclusion.

2. LITERATURE REVIEW

A lot of researchers have been studied the intuitionistic fuzzy number and ranking methods which is one way or the other relates to this paper.

Aggarwal [5] solved intuitionistic fuzzy solid transportation problem via new ranking method based on signed distance. Gani and Mohamed [6] discussed a method of ranking generalized trapezoidal intuitionistic fuzzy numbers. Gupta and Anupum [7] explained an efficient method for solving intuitionistic fuzzy transportation problem of type-2. Gani and Abbas [8] proposed a new method for solving intuitionistic fuzzy transportation problem. Kour, Mukherjee and K. Basu [11] solved intuitionistic fuzzy transportation problem using linear programming. Kumar and Hussain [12] developed a systematic approach for solving mixed intuitionistic fuzzy transportation problems.

Kaur and Kumar [13] discussed a new method for solving fuzzy transportation problems using ranking function. Liu [14] proposed the total cost bounds of the transportation problem with varying demand and supply. Narayanamoorthy, S. Saranya and S. Maheswari [16] discussed and found out a method for solving fuzzy transportation problem using fuzzy Russell's method. Ponnivalavan and Pathinathan [18] proposed intuitionistic pentagonal fuzzy number.

K. Pramila and G. Uthra [19] found out the optimal Solution of an intuitionistic fuzzy transportation Problem. Verma [23] proposed a paradox in linear fractional transportation problem. Annie Christi and Kasthuri B [4] discussed transportation problem with pentagonal intuitionistic fuzzy numbers solved using ranking technique and Russell's method. Siji and Selva Kumari [22] developed an approach for solving network problem with pentagonal intuitionistic fuzzy numbers using Ranking technique. Helen and Uma [9] gave a new operation and ranking on Pentagon Fuzzy Numbers.

He Y, He Z and Huang H [10] developed decision making with the generalized intuitionistic fuzzy power interaction averaging operators. Ali Mahmoodirad, Tofigh Allahviranloo and Sadegh Niroomand [15] discussed a new effective solution method for fully intuitionistic fuzzy transportation problem. Nagoor Gani [17] proposed a new method on solving intuitionistic fuzzy transportation problem. Razmi J, Jafarian E and Amin SH [20] explained an intuitionistic fuzzy goal programming approach for finding pareto-optimal solutions to multi-objective programming problems. Thamaraselvi and Santhi [27] proposed intuitionistic fuzzy transportation problem using hexagonal intuitionistic fuzzy numbers.

3. PRELIMINARIES

In this section, some necessary background and definitions related to the fuzzy set theory are explained.

Definition 3.1 [27, 28]

Let X be a nonempty set. An intuitionistic fuzzy set $\tilde{H}^I$ of X is defined as $\tilde{H}^I = \left\{ \left\langle x, \mu_{\tilde{H}^I}(x), \nu_{\tilde{H}^I}(x) \right\rangle : x \in X \right\}$ where the function $\mu_{\tilde{H}^I}(x) : X \to [0,1]$ and $\nu_{\tilde{H}^I}(x) : X \to [0,1]$ define the degree of membership and the degree of non-membership functions $x \in X$ and $0 \le \mu_{\tilde{H}^I}(x), \nu_{\tilde{H}^I}(x) \le 1, \forall x \in X$.

Definition 3.2

A fuzzy number is a generalization of a regular real number and which does not refer to a single value but rather to a connected a set of possible values, where each possible value has its range between 0 and 1. This range is called the membership function.

A fuzzy number $\tilde{A}$ is a convex normalized fuzzy set on the real line R such that:

(i) There exist at least one $x \in R$ with $\mu_{\tilde{A}}(x) = 1$.

(ii) $\mu_{\tilde{A}}(x)$ is piecewise continuous.

Definition 3.3

A subset of intuitionistic fuzzy set $\tilde{H}^{I} = \left\{ \left\langle x, \mu_{\tilde{H}^{I}}(x), \nu_{\tilde{H}^{I}}(x) \right\rangle : x \in X \right\}$ of the real line $\Re$ is called an intuitionistic fuzzy number if the following conditions hold

(i) their exists $a \in \Re$, $\mu_{\tilde{H}^{I}}(a) = 1$ and $\nu_{\tilde{H}^{I}}(a) = 0$

(ii) $\mu_{\tilde{H}^{I}}(x) : \Re \to [0,1]$ is continuous and for every $0 \le \mu_{\tilde{H}^{I}}(x), \nu_{\tilde{H}^{I}}(x) \le 1$ holds.

The membership and non-membership function of $\tilde{H}^{I}$ is defined as follows:

$$\mu_{\tilde{H}^{I}}(x) = \begin{cases} p_1(x), & x \in [a-\gamma_1, a) \\ 1, & x = a \\ q_1(x), & x \in (a, a+\delta_1] \\ 0, & otherwise. \end{cases}$$

$$\nu_{\tilde{H}^{I}}(x) = \begin{cases} 1, & x \in (-\infty, a-\gamma_2) \\ p_2(x), & x \in (a-\gamma_2, a) \\ 0, & x = a, x \in [a+\delta_2, \infty)] \\ q_2(x), & x \in (a, a+\delta_2]. \end{cases}$$

where $p_i(x)$ and $q_i(x); i = 1,2$ which are strictly increasing and decreasing functions in $[a-\gamma_i, a)$ and $(a, a+\delta_i]$ respectively. γ_i and δ_i are the left and right spreads of $\mu_{\tilde{H}^{I}}(x)$ and $\nu_{\tilde{H}^{I}}(x)$.

Definition 3.4 Hexagonal fuzzy number [27]

An hexagonal fuzzy number is given by 6-tuples R_H is denoted as $\tilde{R}_H = (a_1, a_2, a_3, a_4, a_5, a_6)$ where a_1, a_2, a_3, a_4, a_5 and a_6 are real numbers and $a_1 \le a_2 \le a_3 \le a_4 \le a_5 \le a_6$ its membership function is given as

$$\alpha_{H^I}(x)=\begin{cases}\frac{1}{2}\left(\frac{x-a_1}{a_2-a_1}\right), & for\ a_1\le x\le a_2\\ \frac{1}{2}+\frac{1}{2}\left(\frac{x-a_2}{a_3-a_2}\right), & for\ a_2\le x\le a_3\\ 1 & for\ a_3\le x\le a_4\\ 1-\frac{1}{2}\left(\frac{x-a_4}{a_5-a_4}\right), & for\ a_4\le x\le a_5\\ \frac{1}{2}\left(\frac{a_6-x}{a_6-a_5}\right), & for\ a_5\le x\le a_6\\ 0, & otherwise\end{cases}$$

4. PROBLEM FORMULATION

4. 1. Transportation Problem (FTP)

The FTP is the problem of minimizing q interval valued objective functions with interval cost. When the objective functions coefficients $\frac{C^q{}_{ij}}{D^q{}_{ij}}, A_i$ is the source parameters, B_j is the destination parameter and C_q, D_q are the conveyance parameters, which are in the form of interval, where $A_i=[s_{Li},s_{Ri}], i=1,2,\ldots,m$ and $B_j=[t_{Li},t_{Ri}], j=1,2,\ldots,n,$ are interval values of source and destination. The formulation for interval fuzzy problem is

$$\begin{cases} Minimize\ Z^q(x)\approx \dfrac{\sum_{i=1}^{m}\sum_{j=1}^{n}[C^q{}_{Lij},C^q{}_{Rij}]x_{ij}+\alpha}{\sum_{i=1}^{m}\sum_{j=1}^{n}[C^q{}_{Lij},C^q{}_{Rij}]x_{ij}+\beta}\quad where\ q=1,2,\ldots,Q\\ subject\ to\\ \quad \sum_{j=1}^{n}x_{ij}-A_i-[s_{Li},s_{Ri}],\ i=1,2,\ldots,m\\ \quad \sum_{j=1}^{n}x_{ij}-B_j-[t_{Li},t_{Ri}],\ j=1,2,\ldots,n\\ \quad x_{ij}\ \ge 0,\ \forall\ i,j \end{cases}$$

the balanced condition is a necessary and sufficient condition for the existence of a feasible solution $[C^q{}_{Lij},C^q{}_{Rij}]$ and $[D^q{}_{Lij},D^q{}_{Rij}],(q=1,2,\ldots,Q),P^q{}_{ij}=[P^q{}_{Lij},P^q{}_{Rij}]=\frac{C^q{}_{ij}}{D^q{}_{ij}}=\frac{C^q{}_{Lij},C^q{}_{Rij}}{D^q{}_{Lij},D^q{}_{Rij}}$ is an interval representing the uncertain cost for the transportation problem. By the above definition the equivalent multi-objective deterministic transportation problem as

$$\begin{cases} Minimize\ Z^q{}_R(x) = \sum_{i=1}^{m}\sum_{j=1}^{n} P^q{}_{Cij}\, x_{ij} + \sum_{i=1}^{m}\sum_{j=1}^{n} P^q{}_{Wij}\, x_{ij} \\ Minimize\ Z^q{}_C(x) = \sum_{i=1}^{m}\sum_{j=1}^{n} P^q{}_{Cij}\, x_{ij} \\ Subject\ to\ \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} \le s_{Ri}, \quad \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} \le s_{Li}, \\ \qquad \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} \le t_{Rj}, \quad \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} \le t_{j}, \\ \qquad x_{ij} \ge 0, \quad \forall\ i, j. \end{cases}$$

4. 2. Intuitionistic Fuzzy Fractional Transportation Problem

The proposed method is a simple method to find the optimal solution of an intuitionistic fuzzy fractional transportation problem having supply and demand which are real numbers and transportation cost $\frac{C_{ij}}{D_{ij}}$ (i=1,2,...,m);(j=1,2,...,n) from ith source to jth destination, taken as intuitionistic fuzzy fractional transportation problem.

4. 3. Hexagonal Intuitionistic Fuzzy Number [27]

An hexagonal intuitionistic fuzzy number is defined as

$$\tilde{R}_H{}^I = (a_1, a_2, a_3, a_4, a_5, a_6)(a_1', a_2', a_3, a_4, a_5', a_6')$$

where $a_1, a_2, a_3, a_4, a_5, a_6, a_1', a_2', a_5'$ *and* a_6' are real numbers and $a_1' \le a_1 \le a_2' \le a_2 \le a_3 \le a_4 \le a_5 \le a_5' \le a_6 \le a_6'$ its membership and non-membership functions are given as,

$$\alpha_{H^I}(x) = \begin{cases} \frac{1}{2}\left(\frac{x-a_1}{a_2-a_1}\right), & for\ a_1 \le x \le a_2 \\ \frac{1}{2}+\frac{1}{2}\left(\frac{x-a_2}{a_3-a_2}\right), & for\ a_2 \le x \le a_3 \\ 1 & for\ a_3 \le x \le a_4 \\ 1-\frac{1}{2}\left(\frac{x-a_4}{a_5-a_4}\right), & for\ a_4 \le x \le a_5 \\ \frac{1}{2}\left(\frac{a_6-x}{a_6-a_5}\right), & for\ a_5 \le x \le a_6 \\ 0, & otherwise \end{cases} \quad \text{and}$$

$$\beta_{H^I}(x)=\begin{cases}1-\frac{1}{2}\left(\frac{x-a_1{'}}{a_2{'}-a_1{'}}\right), & \text{for } a_1{'}\le x\le a_2{'}\\ \frac{1}{2}\left(\frac{a_3-x}{a_3-a_2{'}}\right), & \text{for } a_2{'}\le x\le a_3\\ 0 & \text{for } a_3\le x\le a_4\\ \frac{1}{2}\left(\frac{x-a_4}{a_5{'}-a_4{'}}\right), & \text{for } a_4\le x\le a_5{'}\\ \frac{1}{2}+\frac{1}{2}\left(\frac{x-a_5{'}}{a_6{'}-a_5{'}}\right), & \text{for } a_5{'}\le x\le a_6{'}\\ 1, & \text{otherwise}\end{cases}$$

4. 4. Graphical representation of hexagonal intuitionistic fuzzy number

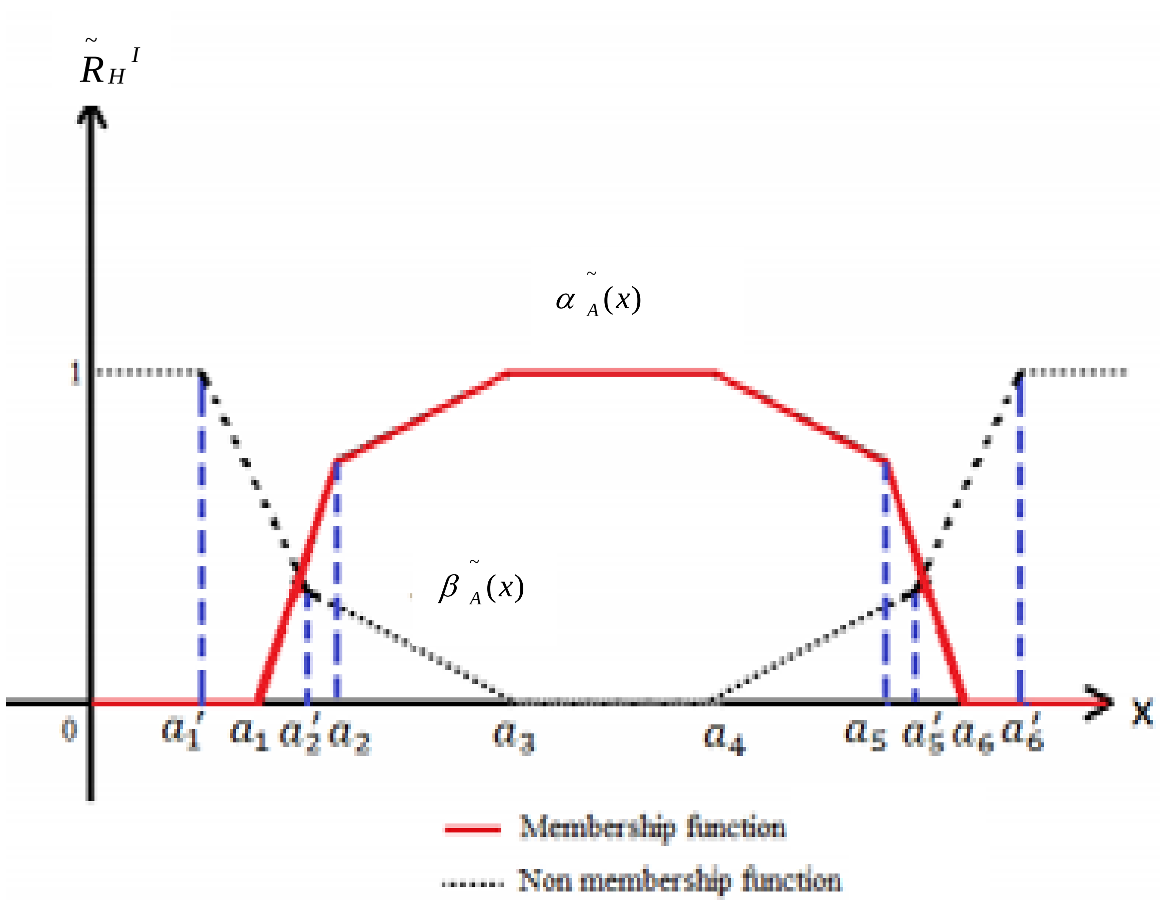

Figure 1. Graphical representation of hexagonal intuitionistic fuzzy number

4. 5. Ranking Method

The ranking of hexagonal intuitionistic fuzzy number

$\tilde{R}_H{}^I = (a_1, a_2, a_3, a_4, a_5, a_6)(a_1', a_2', a_3, a_4, a_5', a_6')$ which maps the set of all fuzzy numbers to set of all real numbers is defined and given as

$$\tilde{R}_H{}^I = [Mag_{\alpha}(\tilde{R}_H{}^I), Mag_{\beta}(\tilde{R}_H{}^I)]$$

where

$$Mag_{\alpha}(\tilde{R}_H{}^I) = \frac{2a_1 + 3a_2 + 4a_3 + 4a_4 + 3a_5 + 2a_6}{18}$$

and

$$Mag_{\beta}(\tilde{R}_H{}^I) = \frac{2a_1' + 3a_2' + 4a_3 + 4a_4 + 3a_5' + 2a_6'}{18}$$

4. 6. Russell's Method [16]

To find the basic feasible solution there are so many methods, one among the method is Russell's method used for solving transportation problem. This method is better than other methods because it generates near optimal initial basic feasible solution. In this paper the author used this method to solve intuitionistic fuzzy fractional transportation problem.

4. 7. Proposed Algorithm

1) In intuitionistic fuzzy fractional transportation problem, the entries in both numerator and denominator table are reduced into an integer using the Russell's ranking method numerator and denominator values are calculated separately.

2) In the reduced intuitionistic fuzzy fractional transportation problem, firstly identify the row and column difference considering the least two numbers of the respective row and column.

3) Now select the maximum among the difference, if more than one value, select any one among them and allocate the respective demand or supply to the minimum value of the corresponding column or row.

4) Take the difference of the respective supply or demand of the allocated cell which leads either one to zero, then eliminate the respective row or column. Check whether I both demand and supply is zero then eliminate both row and column.

5) Repeat the above steps until all the rows and columns are eliminated.

6) Lastly total minimum cost is calculated as the sum of the product of the cost and the allocated value for both numerator and denominator.

7) Now find out the intuitionistic fuzzy fractional transportation problem using values in both numerator and denominator tables.

5. NUMERICAL EXAMPLE

Consider a 3X3 hexagonal intuitionistic fuzzy fractional transportation problem given in the following Table 1 for numerator and Table 2 for denominator.

Table 1. Numerator values for Intuitionistic Fractional transportation problem

	D1	D2	D3	Supply
S1	[(2,4,5,7,10,11) (1,3,5,7,12,13)]	[(3,4,5,6,8,10) (2,4,5,6,10,13)]	[(7,9,11,13,16,20) (5,7,11,13,19,24)]	15
S2	[(6,8,11,14,19,25) (4,7,11,14,21,26)]	[(9,11,13,15,18,20) (8,10,13,15,19,22)]	[(10,12,14,16,20,24) (8,10,14,16,20,25)]	20
S3	[(3,5,6,8,9,10) (2,3,6,8,11,13)]	[(4,7,9,12,15,17) (3,6,9,12,16,18)]	[(10,12,14,16,20,24) (8,10,14,16,20,25)]	35
Demand	25	35	10	

Table 2. Denominator values for Intuitionistic Fractional transportation problem

	D1	D2	D3	Supply
S1	[(3,5,6,8,11,12) (2,4,6,8,13,14)]	[(7,8,10,12,14,17) (6,7,10,12,17,19)]	[(8,10,12,14,17,21) (6,8,12,14,20,24)]	25
S2	[(3,5,7,9,12,15) (2,4,7,9,13,17)]	[(9,11,15,17,21,26) (8,10,13,15,19,22)]	[(7,9,12,15,20,26) (5,7,12,15,22,28)]	30
S3	[(6,8,11,14,19,25) (4,7,11,14,21,27)]	[(4,5,6,7,9,11) (3,5,6,7,11,13)]	[(7,8,10,12,14,17) (6,7,10,12,17,19)]	35
Demand	30	45	15	

In Table 1 and Table 2 it is clear that it is a balanced transportation problem. By using the proposed algorithm the solution of the problem is given as follows. Now apply Russell's ranking method to each row and column we have,

Applying ranking method to each [(2,4,5,7,10,11)(1,3,5,7,12,13)]

$$Mag_{\alpha}(\tilde{R}_H{}^I) = \frac{2\times 2 + 3\times 4 + 4\times 5 + 4\times 7 + 3\times 10 + 2\times 11}{18} = 6.44$$

$$Mag_{\beta}(\tilde{R}_H{}^I) = \frac{2\times 1 + 3\times 3 + 4\times 5 + 4\times 7 + 3\times 12 + 2\times 13}{18} = 6.72$$

Therefore, $\dfrac{Mag_{\alpha}(\tilde{R}_H{}^I) + Mag_{\beta}(\tilde{R}_H{}^I)}{2} = 6.583 = 7$

Similarly we get all values using his method and we can reduce the table with these values and are gien in Table 3 and Table 4.

Reduced Table

Table 3. Reduced table for Numerator

	D1	D2	D3	Supply
S1	7	6	13	15
S2	14	14	16	20
S3	7	11	16	35
Demand	25	35	10	

Table 4. Reduced table for Denominator

	D1	D2	D3	Supply
S1	8	11	14	25
S2	8	17	15	30
S3	14	7	11	35
Demand	30	45	15	

Again by the proposed algorithm, repeating the steps 2, 3 and 4 until all the rows and columns are eliminated the table becomes,

	D1	D2	D3	Supply	Row Difference
S1	~~7~~	~~6~~ 15	~~13~~	~~15~~	1
S2	14	14	16	20	0
S3	7	11	16	35	4
Demand	25	~~35~~ 20	10	Eliminate Row S1	
Column Difference	0	5	3		

Continuing in the same manner we get the optimal solution for numerator and denominator as given in the following Table 5 and Table 6.

Table 5. Optimal solution of numerator

	D1	D2	D3
S1	7	6 $\boxed{15}$	13
S2	14	14 $\boxed{10}$	16 $\boxed{10}$
S3	7 $\boxed{25}$	11 $\boxed{10}$	16

The optimal solution is $15\times 6+10\times 14+10\times 16+25\times 7+10\times 11=675$

Table 6. Optimal solution of Denominator

	D1	D2	D3
S1	8 $\boxed{0}$	11 $\boxed{10}$	14 $\boxed{15}$
S2	8 $\boxed{30}$	17	15
S3	14	7 $\boxed{35}$	11

The optimal solution is $0 \times 8 + 10 \times 11 + 15 \times 14 + 30 \times 8 + 7 \times 35 = 805$

Therefore, the optimal solution of hexagonal intuitionistic fuzzy fractional transportation problem is 0.8385.

6. CONCLUSIONS

Many research and problems were found in many areas including fuzzy numbers, fuzzy equations and more. However the study of solving hexagonal intuitionistic fuzzy fractional transportation problem has not been done by many researchers, this is for the first time the author found out using ranking method and Russell's method. The field of intuitionistic transportation problem is very wide and has drastic importance, especially in our day to day activities and the solution to such are equally importance as well.

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