



RESEARCH ARTICLE

IN FUZZY TRANSPORTATION PROBLEM USING RANKING FUNCTIONS
WITH HEXAGONAL INTUITIONISTIC FUZZY NUMBERS (IVIFNS)Sathya, S.^{1,*} and Uma, S.²

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ABSTRACT

By assuming α and β cut values, the idea of modified arithmetic operations on interval valued intuitionistic fuzzy numbers is used to solve interval valued intuitionistic fuzzy transportation problems with hexagonal intuitionistic fuzzy numbers. In this study, we use Hexagonal Intuitionistic Fuzzy Numbers (a_1, a_4) to convert the traditional transportation problem into a fuzzy transportation problem. Lastly, a numerical example was put out.

INTRODUCTION

Fuzzy data must be handled and evaluated in order to make decisions in many real-world situations. Atanssov introduced fuzzy sets in notation (1,2). Since its inception, the intuitionistic fuzzy set (IFS) has drawn increasing interest due to the fact that attribute value information is typically ambiguous or fuzzy. Addressing uncertainty and imprecision has become a critical component of problem-solving in the modern optimization and decision-making landscape. This paper explores the complex field of transportation issues and offers a transformative method that turns traditional crisp scenarios into their fuzzy equivalents. The use of hexagonal intuitionistic fuzzy numbers, which add a subtle layer of ambiguity to the conventional issue formulations, is the fundamental component of this change. By providing insights into their use in various problem-solving scenarios, this study aims to increase knowledge of fuzzy optimization techniques. Beyond the theoretical sphere, this study has practical ramifications that address the intricacies and uncertainties present in modern optimization settings.

2. Preliminaries

Definition 1.

Given a fixed set $X = \{X_1, X_2, \dots, X_n\}$ an intuitionistic fuzzy set (IFS) is defined as $\tilde{A}^I = (\langle x_i, \mu_{\tilde{A}^I}(x_i) \rangle / x_i \in X)$ which assigns to each element x_i a membership degree $\mu_{\tilde{A}^I}(x_i)$ and a non membership degree $\nu_{\tilde{A}^I}(x_i)$ under the condition $0 \leq \mu_{\tilde{A}^I}(x_i) + \nu_{\tilde{A}^I}(x_i) \leq 1$

Definition 2

A hexagonal intuitionistic fuzzy numbers (HIFN) $\tilde{A}^I$. Is an intuitionistic fuzzy set in R with the following membership function $\mu_{\tilde{A}^I}(x)$ and non membership function $\nu_{\tilde{A}^I}(x)$

$$\mu_{\tilde{A}^I}(x) = \begin{cases} 0 & x < a \\ \frac{x-a}{2b-2a} & a \leq x \leq b \\ \frac{1}{2} + \left(\frac{x-b}{2c-2b} \right) & b \leq x \leq c \\ 1 & c \leq x \leq d \\ 1 - \left(\frac{x-d}{2e-2d} \right) & d \leq x \leq e \\ \frac{f-x}{2f-2e} & e \leq x \leq f \\ 0 & x > f \end{cases}$$

$$v_{\tilde{A}'}(x) = \begin{cases} 1 & x < a \\ \frac{2b-a-x}{2b-2a} & a \leq x \leq b \\ \frac{1}{2} - \left(\frac{x-b}{2c-2b} \right) & b \leq x \leq c \\ 0 & c \leq x \leq d \\ \left(\frac{x-d}{2e-2d} \right) & d \leq x \leq e \\ \frac{x-2e+f}{2f-2e} & e \leq x \leq f \\ 1 & x > f \end{cases}$$

Definition 3

Operations on Hexagonal Fuzzy Numbers

$$\tilde{A} = (a_1, a_2, a_3, a_4, a_5, a_6),$$

$$\tilde{B} = (b_1, b_2, b_3, b_4, b_5, b_6)$$

- i) Addition: $\tilde{A} (+) \tilde{B} = (a_1, a_2, a_3, a_4, a_5, a_6) + (b_1, b_2, b_3, b_4, b_5, b_6) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4, a_5 + b_5, a_6 + b_6)$
- ii) Subtraction: $\tilde{A} (-) \tilde{B} = (a_1, a_2, a_3, a_4, a_5, a_6) - (b_1, b_2, b_3, b_4, b_5, b_6) = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4, a_5 - b_5, a_6 - b_6)$
- iii) Multiplication: $\tilde{A} (\times) \tilde{B} = (a_1, a_2, a_3, a_4, a_5, a_6) \times (b_1, b_2, b_3, b_4, b_5, b_6) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4, a_5 \times b_5, a_6 \times b_6)$

Python code to find Addition, Subtraction, Multiplication and Division of Two Hexagonal Fuzzy Numbers

```
print('Enter Your first Hexagonal number=') # display the message for user
a1=float(input("")) #first component of first fuzzy number
b1=float(input("")) #second component of first fuzzy number
c1=float(input("")) #third component of first fuzzy number
d1=float(input("")) #fourth component of first fuzzy number
e1=float(input("")) #fifth component of first fuzzy number
f1=float(input("")) #sixth component of first fuzzy number
a=(a1,b1,c1,d1,e1,f1) # list of first Hexagonal fuzzy number
print('Enter Your second Hexagonal number')
a2=float(input("")) #first component of second fuzzy number
b2=float(input("")) #second component of second fuzzy number
c2=float(input("")) #third component of second fuzzy number
d2=float(input("")) #fourth component of second fuzzy number
e2=float(input("")) #fifth component of second fuzzy number
f2=float(input("")) #sixth component of second fuzzy number
b=(a2,b2,c2,d2,e2,f2) # list of second hexagonal fuzzy number
print('Enter Your Choice 1= Addition 2= Subtraction 3 = Multiplication ,4 = order')
ch=int(input("")); # switch statement for operation on fuzzy number choice
```

if(ch==1):

#case 1 for the addition of the fuzzy number

'Addition of two fuzzy Hexagonal numbers is'

$$c=(a1+a2,b1+b2,c1+c2,d1+d2,e1+e2,f1+f2)$$

print(c)

elif(ch==2):

#case 2 % case 2 for the subtraction of the fuzzy number

'subtraction of two fuzzy Hexagonal is(a-b)'

c=(a1-f2,b1-e2,c1-d2,d1-c2,e1-b2,f1-a2) # difference of fuzzy numbers

print(c)

elif(ch==3):

#case 3 % case 3 for multiplication of fuzzy number

'Multiplication of two fuzzy Hexagonal is(a-b)'

$$c=(a1*a2,b1*b2,c1*c2,d1*d2,e1*e2,f1*f2)$$

print(c)

Definition 4

A positive interval valued intuitionistic fuzzy number is denoted as $\{(a_1, a_2); (a'_1, a'_2)\}$ where all a_i s and a'_i 's > 0 for all $i=1,2$

Definition 5

A negative interval valued intuitionistic fuzzy number is denoted as $\{(a_1, a_2); (a'_1, a'_2)\}$ where all a_i s and a'_i 's < 0 for all $i=1,2$

Definition 6

(Modified operations of interval valued intuitionistic fuzzy numbers using function principle). According to K.Ganesan and P.Veeramani the following are the modified operations that can be performed on interval intuitionistic fuzzy numbers;

$$\text{Let } \tilde{A}' = \{(a_1, a_2); (a'_1, a'_2)\} \text{ and } \tilde{B}' = \{(b_1, b_2); (b'_1, b'_2)\}, m_1 = \frac{a_1 + a_2}{2}, m_2 = \frac{b_1 + b_2}{2}, \\ m'_1 = \frac{a'_1 + a'_2}{2}, m'_2 = \frac{b'_1 + b'_2}{2}$$

(i) Addition

$$\tilde{A}' + \tilde{B}' = \{(m_1 + m_2 - k); (m_1 + m_2 + k); (m'_1 + m'_2 - k); (m'_1 + m'_2 + k')\}$$

Where

$$k = \frac{(b_2 + a_2) - (b_1 + a_1)}{2}, k' = \frac{(b'_2 + a'_2) - (b'_1 + a'_1)}{2}$$

(ii) Subtraction

$$[\tilde{A}' - \tilde{B}' = \{(m_1 - m_2 - k); (m_1 - m_2 + k); (m'_1 - m'_2 - k); (m'_1 - m'_2 + k')\}]$$

Where

$$k = \frac{(b_2 + a_2) - (b_1 + a_1)}{2}, k' = \frac{(b'_2 + a'_2) - (b'_1 + a'_1)}{2}$$

(iii) Multiplication

$$\tilde{A}' \times \tilde{B}' = \{(m_1 m_2 - k); (m_1 m_2 + k); (m'_1 m'_2 - k); (m'_1 m'_2 + k')\}$$

Where $k = \min \{m_1 m_2 - \alpha, \beta - m_1 m_2\}$

(iv) Inverse

$$\frac{1}{\widetilde{A}'} = \left(\frac{1}{m_1} - k, \frac{1}{m_1} + k \right); \left(\frac{1}{m_1'} - k', \frac{1}{m_1'} + k' \right)$$

$$\text{where } k = \min \left\{ \frac{1}{a_2} \left(\frac{a_2 - a_1}{a_1 + a_2} \right), \frac{1}{a_1} \left(\frac{a_2 - a_1}{a_1 + a_2} \right) \right\}$$

$$k' = \min \left\{ \frac{1}{a_2'} \left(\frac{a_2' - a_1'}{a_1' + a_2'} \right), \frac{1}{a_1'} \left(\frac{a_2' - a_1'}{a_1' + a_2'} \right) \right\}$$

3. Numerical Example:

Consider the following crisp transportation problem: Suppose there are three factories (F1, F2, and F3) and four warehouses. The transportation costs per unit from each factory to each warehouse are given in the following table

	I	II	III	I V	supply
A	2	2	2	1	3
B	10	8	5	4	7
C	7	6	6	8	5
Demand	4	3	4	4	

The objective is to determine the optimal transportation plan that minimizes the total transportation cost while satisfying the supply and demand.

To solve this crisp transportation problem, we can use any of the traditional methods, such as the Least Cost Method. Minimum transportation cost = 79.

3.1 Fuzzy Transportation Problem by Using hexagonal intuitionistic fuzzy number

	I	II	III	IV	supply
A	((1,1.5,2.2,5.3,3.5):1,0))	((1,1.5,2.2,5.3,3.5):1,0))	((1,1.5,2.2,5.3,3.5):1,0))	((0,0.5,1,1.5,2.2,5):1,0))	((2.2,5.3,3.5,4.4,5):1,0))
B	((9,9.5,10,10.5,11,11.5):1,0))	((7,7.5,8.8,5.9,9.5):1,0))	((4,4.5,5.5,6.6,5.5):1,0))	((3,3.5,4.4,5.5,5.5):1,0))	((6,6.5,7.7,5.8,8.5):1,0))
C	((6,6.5,7.7,5.8,8.5):1,0))	((5,5.5,6.6,5.7,7.5):1,0))	((5,5.5,6.6,5.7,7.5):1,0))	((7,7.5,8.8,5.9,9.5):1,0))	((4,4.5,5.5,6.6,5.5):1,0))
Demand	((3,3.5,4.4,5.5,5.5):1,0))	((2,2.5,3.3,5.4,4.5):1,0))	((3,3.5,4.4,5.5,5.5):1,0))	((3,3.5,4.4,5.5,5.5):1,0))	

The objective is to determine the optimal transportation plan that minimizes the total transportation cost while satisfying the supply and demand.

To solve this crisp transportation problem, we can use any of the traditional methods, such as the Least Cost Method. Minimum transportation cost = 79.

3.1 Fuzzy Transportation Problem by Using hexagonal intuitionistic fuzzy number FLCM for central hexagonal fuzzy number into interval fuzzy number (d=0.5)

Take $\alpha=1, \beta=0$

	I	II	III	IV	supply
A	[2,2]	[2,2]	[2,2]	[1,1] ^[3,3]	[3,3]
B	[10,10]	[8,8]	[5,5]	[4,4]	[7,7]
C	[7,7]	[6,6]	[6,6]	[8,8]	[5,5]
Demand	[4,4]	[3,3]	[4,4]	[4,4]	

	I	II	III	IV	supply
A	[2,2]	[2,2]	[2,2]	[1,1] ^[3,3]	[3,3]
B	[10,10] ^[2,2]	[8,8]	[5,5] ^[4,4]	[4,4] ^[1,1]	[7,7]
C	[7,7] ^[2,2]	[6,6] ^[3,3]	[6,6]	[8,8]	[5,5]
Demand	[4,4]	[3,3]	[4,4]	[4,4]	

Minimum interval number transportation cost = (1,1)(3,3)+(10,10)(2,2)+(5,5)(4,4)+(4,4)(1,1)+(7,7)(2,2)+(6,6)(3,3)=79.

	I	II	III	IV	supply
A	((-5,-2,1,3,6,9):1,0))	((-5,-2,1,3,6,9):1,0))	((-5,-2,1,3,6,9):1,0))	((-6,-3,0,2,5,8):1,0))	((-4,-1,2,4,7,10):1,0))
B	((3,6,9,11,14,17):1,0))	((1,4,7,9,12,15):1,0))	((-2,1,4,6,9,12):1,0))	((-3,0,3,5,8,11):1,0))	((0,3,6,8,11,14):1,0))
C	((0,3,6,8,11,14):1,0))	((-1,2,5,7,10,13):1,0))	((-1,2,5,7,10,13):1,0))	((1,4,7,9,12,15):1,0))	((-2,1,4,6,9,12):1,0))
Demand	((-3,0,3,5,8,11):1,0))	((-4,-1,2,4,7,10):1,0))	((-3,0,3,5,8,11):1,0))	((-3,0,3,5,8,11):1,0))	

FLCM for central hexagonal fuzzy number into interval fuzzy number (d=4)

Take $\alpha=1, \beta=0$

	I	II	III	IV	supply
A	[-5,9]	[-5,9]	[-5,9]	[-6,8]	[-4,10]
B	[3,17]	[1,15]	[-2,12]	[-3,11]	[0,14]
C	[0,14]	[-1,3]	[-1,3]	[1,15]	[-2,12]
Demand	[-3,11]	[-4,10]	[-3,11]	[-3,11]	

	I	II	III	IV	supply
A	[-5,9]	[-5,9]	[-5,9]	[-6,8] ^[-4,10]	[-4,10]
B	[3,17] ^[-5,23]	[1,15]	[-2,12] ^[-3,11]	[-3,11] ^[-13,15]	[0,14]
C	[0,14] ^[-12,2]	[-1,13] ^[-4,10]	[-1,13]	[1,15]	[-2,12]
Demand	[-3,11]	[-4,10]	[-3,11]	[-3,11]	

Minimum interval number transportation cost =

(-6,8)(-4,10)+(-2,12)(-3,11)+(-3,11)(-13,15)+(0,14)(-12,2)+(-1,13)(-4,10)+(3,17)(-5,23)=79.

4. CONCLUSION

Recent research has examined the idea of fuzzy numbers and their practical applications. This paper describes how to apply modified operations to solve transportation problems using hexagonal fuzzy numbers, where $\alpha = 1, \beta = 0$.

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