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**Research Article**

# Generalized Intuitionistic Trapezoidal Fuzzy Numbers in Transportation Problems: An Optimizational Method

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**ABSTRACT**

In this study, we propose an optimization method for transportation problems utilizing Generalized Intuitionistic Trapezoidal Fuzzy Numbers (GITFNs). This method effectively handles uncertainty and imprecision in transportation systems, enabling more realistic and reliable decision-making. A GITFN-based transportation model is developed, incorporating fuzzy costs, capacities, and demands. An optimization algorithm is designed to minimize transportation costs while satisfying supply and demand constraints. The method is applied to a numerical example, demonstrating its efficiency in solving complex transportation problems. The results show significant improvements in transportation effectiveness and cost reduction.

**Keywords:** Generalized Intuitionistic Trapezoidal Fuzzy Numbers, Transportation Problems, Optimization, Linear Programming, fuzzy ranking

## 1. INTRODUCTION

In operations research, transportation problems involve studying the transportation distribution of resources to minimize costs. Real-world scenarios require transporting products from various sources to different destinations efficiently. The transportation problem is a specialized linear programming problem that optimizes goods distribution from sources to destinations, considering factors like capacities, demands, and transportation costs. The general transportation problem was first developed by Hitchcock **[1]**, who addressed parameters like transportation cost, resource availability, and demand uncertainty. Modern science and technology involve complex processes with incomplete information, making precise transportation cost determination challenging. Uncertainty is often represented using fuzzy numbers. Fuzzy set theory, established by Zadeh **[2]** in 1965, provides methods for ranking fuzzy numbers to process uncertainty. Many researchers **[3-5]** have applied fuzzy set theory to fuzzy transportation problems. Zimmermann **[3]** developed Zimmermann's fuzzy linear programming, which evolved into various fuzzy optimization methods. Kaur and Kumar **[4]** proposed a new method based on ranking function for solving fuzzy transportation problems using generalized trapezoidal fuzzy numbers. Intuitionistic fuzzy sets, introduced by Atanassov [7], offer a more precise approach by incorporating degrees of membership and non-membership.

Researchers **[8-10]** and [15-19] have explored intuitionistic fuzzy sets, with Aggarwal and Gupta **[9]**, Antony et al. **[10]** and Singh and Yadav **[12]** proposing methods for type-2 intuitionistic fuzzy transportation problems. Ranking intuitionistic fuzzy numbers is crucial, with methods including membership ranking, non-membership ranking, composite, and distance-based ranking. Recent studies [6,11] have introduced novel ranking methods. Babu et al. **[6]** proposed ranking generalized fuzzy numbers using centroids of centroids, while Chhibber et al.**[11]** solved type-1 and type-2 fuzzy transportation problems using incentre of centroids.

Gupta and Kumar **[5]** developed an efficient method for solving intuitionistic fuzzy transportation problems of type-2. Researchers [20-24] have implemented arithmetic operations and ranking functions for intuitionistic fuzzy numbers and applied to transportation problems. The arithmetic operations and the ranking function of IFNs have been implemented by many researchers. the PSK method was applied to solve intuitionistic fuzzy solid assignment problems [13]. A transportation system was developed for urban districts, accompanied by a case study[14].

This paper is organized as follows : Section 2 provides preliminaries on fuzzy concepts, including generalized intuitionistic trapezoidal fuzzy numbers and transportation problems. Section 3 explains the existing methodology for ranking generalized trapezoidal fuzzy numbers. A new methodology for solving transportation problems with generalized trapezoidal intuitionistic fuzzy numbers is presented in section 4. Section 5 illustrates a numerical example applying this methodology to transportation problems with generalized intuitionistic trapezoidal fuzzy numbers. Finally, Section 6 discusses comparative analysis and Section 7 deliberates the results and future research directions.

## 2. PRELIMINARIES

This section contains several simple descriptions as defined in reference [11].

**Definition 2.1**: **Fuzzy Set**

Let U be a universal set. A fuzzy set A of U is defined by a membership function $f_A: U \to [0,1]$, where $f_A(x)$ represents the degree of membership of x in A. The fuzzy set A is represented as: $A = \{(x, f_A(x))/x \in U\}$.

**Definition 2.2 : Intuitionistic Fuzzy Set**

An Intuitionistic Fuzzy Set A in U is defined by $A = \{(x, f_A(x), g_A(x))/x \in U\}$ where $f_A$, and $g_A$ are functions from U to [0, 1] representing the degree of membership and non-membership of x in U, respectively, such that : $0 \le f_A(x) + g_A(x) \le 1$, for all $x \in U$.

**Definition 2.3 : Intuitionistic Fuzzy Number**

An intuitionistic fuzzy set $A = \{(x, f_A(x), g_A(x))/x \in U\}$ is called an intuitionistic fuzzy number on real line **R** if it satisfies

(i) Intuitionistic fuzzy normality ($\exists\, z \in \boldsymbol{R}, f_A(z) = 1$ and $g_A(z) = 0$), (ii) Intuitionistic fuzzy convexity ( $f_A(\lambda x + (1-\lambda)y) \ge Min\,(f_A(x), f_A(y))$ and $g_A(\lambda x + (1-\lambda)y) \le Max\,(g_A(x), g_A(y))$, where $x, y \in U, \lambda \in [0,1]$, (iii) $f_A(x)$ and $g_A(x)$ are piecewise continuous real-valued functions, and (iv) Support of A is bounded.

**Definition 2.4 : Intuitionistic Trapezoidal fuzzy number (Figure 1)**

An intuitionistic fuzzy number A is said to be Intuitionistic Trapezoidal Fuzzy Number (ITFN) and denoted by $A = (a_1, a_2, a_3, a_4); (a'_1, a_2, a_3, a'_4)$ with membership function $f_A$ and non-membership function $g_A$ defined by

$$f_A = \begin{cases} 0, & x < a_1 \\ \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_3-a_4}, & a_3 \le x \le a_4 \\ 0, & a_4 < x \end{cases} \quad \text{and} \quad g_A = \begin{cases} 0, & x < a'_1 \\ \frac{x-a_2}{a'_1-b_2}, & a'_1 \le x \le a_2 \\ 1, & a_2 \le x \le a_3 \\ \frac{x-a_3}{a'_4-a_3}, & a_3 \le x \le a'_4 \\ 0. & a'_4 < x \end{cases}$$

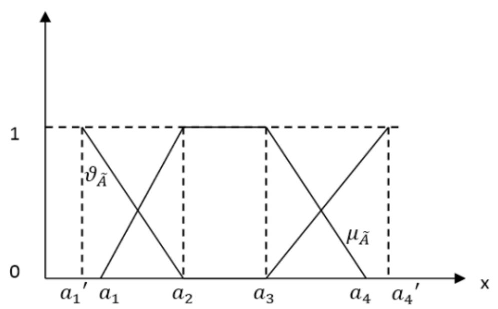


**Figure 1: Intuitionistic Trapezoidal Fuzzy Number (ITFN)**

**Definition 2.5: Generalized ITFN (Figure 2)**

Generalized Intuitionistic Trapezoidal Fuzzy Number is represented by

$A = (a_1, a_2, a_3, a_4; \omega_a)(a_1', a_2, a_3, a_4'; \sigma_a)$ with membership function $f_A$ and non-membership function $g_A$ defined by

$$f_A = \begin{cases} 0, & x < a_1 \\ \frac{x-a_1}{a_2-a_1}\omega_a, & a_1 \le x \le a_2 \\ \omega_a, & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_3-a_4}\omega_a, & a_3 \le x \le a_4 \\ 0, & a_4 < x \end{cases} \quad \text{and} \quad g_A = \begin{cases} 0, & x < a'_1 \\ \frac{x-a_2}{a'_1-b_2}\sigma_a, & a'_1 \le x \le a_2 \\ \sigma_a, & a_2 \le x \le a_3 \\ \frac{x-a_3}{a'_4-a_3}\sigma_a, & a_3 \le x \le a'_4 \\ 0. & a'_4 < x \end{cases}$$

where $\omega_a$ and $\sigma_a$ correspond to a high level of contribution and a low level of non-contribution and $0 \le \omega_a \le 1, 0 \le \sigma_a \le 1, 0 \le \omega_a + \sigma_a \le 1$.

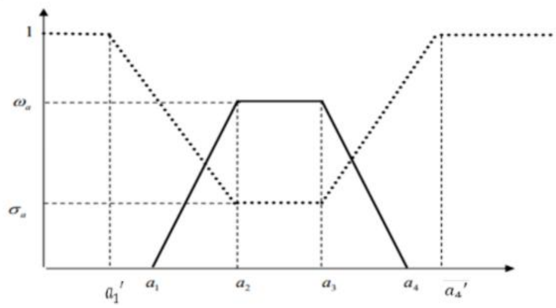


**Figure 2 : Generalized ITFN**

**Arithmetic operations:**

Let $A = \langle(a_1, a_2, a_3, a_4; \omega_a)(a'_1, a_2, a_3, a'_4; \sigma_a)\rangle and\ B = \langle(b_1, b_2, b_3, b_4; \omega_b)(b_1', b_2, b_3, b_4'; \sigma_b)\rangle$ be Generalized trapezoidal intuitionistic fuzzy numbers. Then the arithmetic operations are

(i) Addition:

$$A \oplus B = \begin{Bmatrix} (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; min(\omega_a, \omega_b)) \\ (a'_1 + b'_1, a_2 + b_2, a_3 + b_3, a'_4 + b'_4; max(\sigma_a, \sigma_b)) \end{Bmatrix}$$

(ii) Subtraction:

$$A\Theta B = \begin{Bmatrix} (a_1 - b_4, a_2 - b_2, a_3 - b_3, a_4 - b_1; min(\omega_a, \omega_b)) \\ (a'_1 - b'_4, a_2 - b_2, a_3 - b_3, a'_4 - b'_1; max(\sigma_a, \sigma_b)) \end{Bmatrix}$$

(iii) Scalar Multiplication:

$$k \otimes A = \begin{Bmatrix} (ka_1, ka_2, ka_3, ka_4; \omega_a)(ka'_1, ka_2, ka_3, ka'_4; \sigma_a)\ if\ k \ge 0 \\ (ka_4, ka_3, ka_2, ka_1; \omega_a)(ka'_4, ka_3, ka_2, ka'_1; \sigma_a)\ if\ k < 0 \end{Bmatrix}$$

## 3. EXISTING GENERALIZED ITFN RANKING METHOD [ 25 ]

Consider a Generalized Intuitionistic Trapezoidal Fuzzy Number(GITFN) represented as: $A = (a_1, a_2, a_3, a_4; \omega_a)(a_1', a_2, a_3, a_4'; \sigma_a)$ with membership function $f_A$ and non-membership function $g_A$ as shown in Figure 2. The centroid of the trapezoid is considered its balancing point. Divide the trapezoid into three triangular regions corresponding to the membership function and non- membership functions. Calculate the centroids of each triangle, then compute the overall centroid.

For the membership function, the centroid is :

$$G(x_0, y_0) = \left(\frac{2a_1+7a_2+7a_3+2a_4}{18}, \frac{7\omega_a}{18}\right).$$

The area of the triangle is $x_0.y_0$. denoted as :

$$S_{f_A} = \frac{2a_1+7a_2+7a_3+2a_4}{18} \cdot \frac{7\omega_a}{18}$$

For non-membership function the centroid be $G(x_0, y_0) = \left(\frac{2a_1'+7a_2+7a_3+2a_4'}{18}, \frac{11+7\sigma_a}{18}\right)$

Area of the triangle is $x_0.y_0$. and it is denoted by $S_{g_A} = \frac{2a_1'+7a_2+7a_3+2a_4'}{18} \cdot \frac{11+7\sigma_a}{18}$

Rank of A is defined as $R(A) = \frac{\omega_a S_{f_A} + \sigma_a S_{g_A}}{\omega_a + \sigma_a}$.

**Comparing Generalized intuitionistic trapezoidal fuzzy numbers using the Ranking function :**

Let A and B be two GITFNs. Then :

(i) If R(A) > R(B) then A > B
(ii) If R(A) < R(B) then A < B
(iii) If R(A) = R(B) then A = B

## 4. PROPOSED METHODOLOGY

The proposed method aims to determine the optimal solution $\{x_{ij}\}$ (i=1,2,...,m; j=1,2,...,n) and the generalized intuitionistic trapezoidal fuzzy optimal value z of the transportation problem with $m$ sources ($S_i$ , i =1,2,...,m) and $n$ destinations ($D_j$, j =1,2,...,n) . The supply and demand parameters are represented as real numbers, while the transportation cost, $c_{ij}$ (i=1,2,...,m; j=1,2,...,n), from the $i^{th}$ source to the $j^{th}$ destination is modelled as a generalized intuitionistic trapezoidal fuzzy number, as shown in Table 1.

**Step 1: Obtaining Row Reduced Form Using Existing Ranking Method for Generalized ITFNs (Section 3)**

Using the ranking of each cell in Table 1, select the minimum Generalized ITFN from each row of the Generalized Intuitionistic Trapezoidal Fuzzy Cost Matrix (Table 1) and subtract it from each corresponding Intuitionistic Trapezoidal Fuzzy Numbers in that row.

**Table 1: Transportation problem**

| Destination Sources | $D_1$ | $D_2$ | ... | $D_n$ | 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 $b_j$ | $b_1$ | $b_2$ | ... | $b_n$ | $\sum_i a_i = \sum_j b_j$ |

where, $a_i$ : Quantity of sources of materials availability at Source ($S_i$ , i =1,2,...,m)
$b_j$ : Quantity of sources of material required at destination ($D_j$, j =1,2,...,n)
$c_{ij}$ : Unit cost of transformation from sources $S_i$ to destination $D_j$.

**Step 2: Obtaining Column Reduced Form Using Existing Ranking Method for Generalized ITFNs (Section 3)**

Based on Section3, identify the minimum Intuitionistic Fuzzy Number in each column of the Generalized Intuitionistic Fuzzy Cost Matrix derived in Step 1. Then, subtract this minimum value from all Intuitionistic Fuzzy Numbers within the same column.

**Step 3 : Zero-Centering Generalized Intuitionistic Fuzzy Numbers**

Check whether that each row and each column has at least one generalized intuitionistic fuzzy number whose rank is zero. If it is not so, then repeat Step 1 and Step 2. Otherwise, calculate the intuitionistic fuzzy zero centered value using the formula

$$Z_{ij} = \frac{\text{Total Generalized Intuitonistic Trapezoidal fuzzy cost for cells with zero rank}}{\text{Count of Generalized Intuitonistic Trapezoidal Fuzzy costs with non} - \text{zero ranks}}$$

**Step 4: Cell Assignment**

Select the cell (i,j) with the maximum rank of fuzzy zero-centered value $Z_{ij}$. Assign the maximum possible quantity to this cell. Then, delete either the $i^{th}$ row or $j^{th}$ column, whichever has its quantity fully assigned.

**Step 5 : Iterative Assignment**

Repleat steps 3 and 4 until all assignments are completed.

**Step 6: Determining Optimum Solution and Generalized Intuitionistic Trapezoidal Fuzzy Optimal Value**

The optimum solution $\{x_{ij}\}$ and the generalized intuitionistic trapezoidal fuzzy optimal value, represented as $\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} \otimes x_{ij}$ are obtained from step 5.

## 5. NUMERICAL EXAMPLE

A Generalized ITFN transportation problem, originally presented by Agarwal et al.[27] (Table 2(a)) is addressed using the proposed method. This problem consists of three sources $S_1, S_2, and\ S_3$ and three destinations $D_1, D_2, and\ D_3$ . Ranks of each cell in Table 2(b) is obtained using ranking method [25]

**Table 2 (a) : Generalized Intuitionistic Trapezoidal Fuzzy Transportation Problem**

| Destinations → Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | (2,4,8,15;0.6) (1,4,8,18;0.3) | (3,5,7,12; 0.5) (1,5,7,15;0.3) | (2,5,9,16;0.7) (1,5,9,18;0,3) | 25 |
| $S_2$ | (2,5,8,10;0.6) (1,5,8,12;0.2) | (4,8,10,13;0.4) (3,8,10,15,0.3) | (4,8,10.13;0.4) (3,8,10,15;0.3) | 30 |
| $S_3$ | (2,7,11,15;0.5) (1,7,11,18;0.3) | (5,9,12,16;0.7) (3,9,12,19;0.2) | (4,6,8,10;0.6) (3,6,8,12;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

**Table 2(b) : Ranks of each cell of table2 (a) using ranking method [25]**

| Destinations → <br> Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | 2.6639 | 2.52845 | 3.0682 | 25 |
| $S_2$ | 2.2374 | 3.5976 | 3.5976 | 30 |
| $S_3$ | 3.5667 | 3.8476 | 2.814 | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

**Step 1:** Section 3 describes the existing ranking method for GITFNs used to obtain the row reduced form presented in Table 3.

**Table 3 : Row Reduced Form by Step 1**

| Destinations → <br> Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | (-13,-4,4,13;0.6) <br> (-17,-4,4,17;0.3) | (-12,-3,3,10;0.5) <br> (-17,-3,3,14;0.3) | (-13,-3,5,14;0.6) <br> (-17,-3,15,17;0.3) | 25 |
| $S_2$ | (-8,-3,3,8;0.6) <br> (-11,-3,3,11;0.2) | (-6,0,5,11;0.4) <br> (-9,0,5,14;0.3) | (-6,0,5,11;0.4) <br> (-9,0,5,14;0.3) | 30 |
| $S_3$ | (-8,-1,5,11;0.5) <br> (-11,-1,5,15;0.3) | (-5,1,6,12;0.6) <br> (-9,1,6,16;0.3) | (-6,-2,2,6;0.6) <br> (-9,-2,2,9;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

**Step 2:** Table 4 presents the column reduced form obtained using the existing ranking method for Generalized ITFNs, as described in Section 3.

**Table 4 : Column Reduced Form by Step2**

| Destinations → <br> Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | (-13,-4,4,13;0.6) <br> (-17,-4,4,17;0.3) | (-22,-6,9,22;0.5) <br> (-31,-6,9,26;0.3) | (-13,-3,5,14;0.6) <br> (-17,-3,15,17;0.3) | 25 |
| $S_2$ | (-8,-3,3,8;0.6) <br> (-11,-3,3,11;0.2) | (-16,-3,8,23;0.4) <br> (-23,-3,8,31;0.3) | (-6,0,5,11;0.4) <br> (-9,0,5,14;0.3) | 30 |
| $S_3$ | (-8,-1,5,11;0.5) <br> (-11,-1,5,15;0.3) | (-15,-2,9,24;0.5) <br> (-23,-2,9,33;0.3) | (-6,-2,2,6;0.6) <br> (-9,-2,2,9;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

**Step 3 :** The Zero-Centering Generalized Intuitionistic Trapezoidal Fuzzy Numbers are computed and summarized in Table 5.

**Table 5 : Zero-Centering by Step 3 .**

| Destinations → / Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | (-13,-4,4,13;0.6) (-17,-4,4,17;0.3) | (-44,-15,15,44;0.5) (-57,-15,15,57;0.3) | (-13,-3,5,14;0.6) (-17,-3,15,17;0.3) | 25 |
| $S_2$ | (-8,-3,3,8;0.6) (-11,-3,3,11;0.2) | (-38,-12,14,45;0.4) (-49,-12,14,62;0.3) | (-6,0,5,11;0.4) (-9,0,5,14;0.3) | 30 |
| $S_3$ | (-8,-1,5,11;0.5) (-11,-1,5,15;0.3) | (-27,-8,12,34;0.5) (-35,-8,12,47;0.3) | (-6,-2,2,6;0.6) (-9,-2,2,9;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

**Step 4:** Cell Assignment was calculated using proposed method and the results are presented in Table 6.

**Table 6 : Cell Assignment Using Step 4**

| Destinations → / Sources ↓ | $D_1$ | $D_2$ | Supply $s_i$ |
|---|---|---|---|
| $S_1$ | (-13,-4,4,13;0.6) (-17,-4,4,17;0.3) | (-44,-15,15,44;0.5) (-57,-15,15,57;0.3) | 25 |
| $S_2$ | (-8,-3,3,8;0.6) (-11,-3,3,11;0.2) | (-38,-12,14,45;0.4) (-49,-12,14,62;0.3) | 30 |
| $S_3$ | (-8,-1,5,11;0.5) (-11,-1,5,15;0.3) | (-27,-8,12,34;0.5) (-35,-8,12,47;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | **95** |

**Step 5 :** Table 7 presents the iterative assignment results obtained using the proposed method described in Section 4.

**Table 7 : New reduced table**

| Destinations → Sources ↓ | $D_1$ | $D_2$ | Supply $s_i$ |
|---|---|---|---|
| $S_1$ | (-13,-4,4,13;0.6) (-17,-4,4,17;0.3) | (-44,-15,15,44;0.5) (-57,-15,15,57;0.3) | 25 |
| $S_2$ | (-8,-3,3,8;0.6) (-11,-3,3,11;0.2) | (-38,-12,14,45;0.4) (-49,-12,14,62;0.3) | 30 |
| $S_3$ | (-19,-6,6,19;0.5) (-26,-6,6,26;0.3) | (-31,-13,13,42;0.5) (-50,-13,13,58;0.3) | 40 |
| Demand $d_j$ | 35 | 45 | **95** |

**Step 6:** The optimum solution and Generalized Intuitionistic Trapezoidal Fuzzy Optimal Value are presented in Table 8, which also illustrates the obtained allocation.

**Table 8 : Optimal Solution by Step 6**

| Destinations → Sources ↓ | $D_1$ | $D_2$ | $D_3$ | Supply $s_i$ |
|---|---|---|---|---|
| $S_1$ | (2,4,8,15;0.6) (1,4,8,18;0.3) | (3,5,7,12; 0.5) (1,5,7,15;0.3) **(25)** | (2,5,9,16;0.7) (1,5,9,18;0,3) | 25 |
| $S_2$ | (2,5,8,10;0.6) (1,5,8,12;0.2) **(30)** | (4,8,10,13;0.4) (3,8,10,15,0.3) | (4,8,10.13;0.4) (3,8,10,15;0.3) | 30 |
| $S_3$ | (2,7,11,15;0.5) (1,7,11,18;0.3) **(5)** | (5,9,12,16;0.7) (3,9,12,19;0.2) **(20)** | (4,6,8,10;0.6) (3,6,8,12;0.3) **(15)** | 40 |
| Demand $d_j$ | 35 | 45 | 15 | **95** |

$x_{12} = 25$ , $x_{21} = 30$ , $x_{31} = 5$ , $x_{32} = 20$, $x_{33} = 15$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} \otimes x_{ij} = c_{12} \otimes x_{12} \oplus c_{21} \otimes x_{21} \oplus c_{31} \otimes x_{31} \oplus c_{32} \otimes x_{32} \oplus c_{33} \otimes x_{33}$$

= (3,5,7,12; 0.5)(1,5,7,15;0.3) ⊗ 25 ⊕ (2,5,8,10;0.6) (1,5,8,12;0.2)⊗ 30 ⊕ (2,7,11,15;0.5)(1,7,11,18;0.3)⊗ 5 ⊕ (5,9,12,16;0.7) (3,9,12,19;0.2)⊗ 20 ⊕ (4,6,8,10;0.6)(3,6,8,12;0.3)⊗ 15

= ( 305,580,830,1145;0.5) (165,580,830,1385;0.3)

## 6. COMPARATIVE STUDY

The fuzzy optimal cost obtained using the proposed method and the method by Indira and Shankar [28] are identical. A comparative study is presented in Table 9.

**Table 9: Comparative Table**

| Example | Ranking Procedure | Fuzzy Transportation Method | Fuzzy Optimal Cost |
|---|---|---|---|
| Agarwal et al.[27] | Pardha Saradhi et al. [28] | Indira and Shankar [26] | (305,580,830,1145;0.5) (165,580,830,1385;0.3) |
| Agarwal et al.[27] | Gani and Mohammed [25] | Proposed | (305,580,830,1145;0.5) (165,580,830,1385;0.3) |

## 7. RESULTS AND DISCUSSION

The proposed optimization method using Generalized Intuitionistic Trapezoidal Fuzzy Numbers (GITFNs) was applied to transportation problem. A comparative study was conducted to evaluate transportation costs using the proposed method and existing methodology. The results showed identical outcomes for both methods. These findings demonstrate the effectiveness and validity of the proposed GITFN-based optimization method in solving transportation problems.

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