

# Supplier Selection in Supply Chain Management using Intuitionistic Trapezoidal Fuzzy Numbers, Earth Mover's Distance and Fuzzy TOPSIS

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## Article History:

**Received:** 12-11-2024

**Revised:** 17-12-2024

**Accepted:** 06-01-2025

## Abstract:

Supplier selection is a critical decision-making process in supply chain management, significantly impacting operational efficiency and cost-effectiveness. Traditional methods often struggle to handle the inherent uncertainty and vagueness involved in evaluating supplier criteria. This paper proposes a novel approach for supplier selection using Intuitionistic Trapezoidal Fuzzy Numbers (ITFNs), combined with Earth Mover's Distance (EMD) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), to effectively model and address these uncertainties. ITFNs allow for the representation of both membership and non-membership degrees, enhancing the ability to capture imprecision in supplier evaluations. The Earth Mover's Distance, a powerful metric from transportation theory, is employed to rank the intuitionistic trapezoidal fuzzy numbers and compare suppliers based on multiple criteria using fuzzy TOPSIS. The proposed model is demonstrated through a case study, showcasing its ability to provide more flexible and accurate supplier rankings compared to conventional methods. This approach offers valuable insights for decision-makers aiming to optimize supplier selection in complex and uncertain environments, contributing to more resilient supply chains.

**Keywords:** Supplier selection; Supply Chain Management; Transportation problem; Earth Mover's Distance; Decision making; Intuitionistic Trapezoidal Fuzzy Number

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## Introduction

In real life, hurdles often involve uncertainties that classical operation research theories cannot effectively report. To implement issues with fuzzy or ambiguous information, Lotfi Zadeh proposed fuzzy set theory in 1965 [1]. This innovative concept relies on membership values to represent uncertainty. However, in many cases, decisions based on existing information require higher correctness. To associate this gap, various higher-order fuzzy sets were developed, including Atanassov's Intuitionistic Fuzzy Sets (IFS) in 1986 [2]. IFS extends traditional fuzzy sets by incorporating both membership and non-membership values, enabling more effective handling of imprecise information [3]. As a result, both fuzzy and intuitionistic fuzzy set theories have been successfully applied to numerous real-world decision-making problems. Effective supplier selection is

vital at the supply chain's source. De Boer et al. [4] investigated this complex process, identifying key factors such as issue characterization, performance requirements, and supplier credentials. Five widely used Multi Criteria Decision Making (MCDM) tools are Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination Et Choix Traduisant la Realite (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Vise Criterion Optimization and Compromise Solution in Serbian (VIKOR). TOPSIS, developed by Hwang and Yoon [5] (1981), is employed in the second phase to select the best supplier. Various studies [6-11] have adapted TOPSIS for fuzzy data. Research on supplier selection methods has been extensively reviewed, revealing various classification approaches. Studies by various researchers [12- 16] identified common methods including linear weighting models, mathematical programming, statistical models, and artificial intelligence-based techniques. Notably, AHP emerged as the most widely used method, employed in approximately 25% of reviewed articles, followed by TOPSIS (14.6%). This review synthesizes existing research on supplier selection criteria, building upon previous comprehensive reviews [17-22]. To provide a foundational framework for various sectors, this study focuses on two primary sources : review articles and empirical surveys of business practitioners. The objective is to compile an exhaustive list of supplier selection criteria, serving as a starting point for industries to tailor their specific requirements. To ensure broad applicability, this review prioritizes studies examining a diverse range of industries, while studies focused on a single industry or sector are excluded to maintain generalizability. Kahraman et al. [23] introduced a circular intuitionistic fuzzy TOPSIS method utilizing vague membership functions for supplier selection applications.

This paper is organized as follows: Section 2 provides preliminaries on fuzzy concepts, including intuitionistic trapezoidal fuzzy numbers and Earth Mover's Distance. Section 3 explains and ranking intuitionistic trapezoidal fuzzy numbers. A new methodology for solving supplier selection using TOPSIS using Earth Mover's distance with intuitionistic trapezoidal fuzzy numbers is presented in section 4. Section 5 illustrates a numerical example applying this methodology to supplier selection with intuitionistic trapezoidal fuzzy numbers using EMD. The paper concludes with results and discussion in Section 6.

## 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  $f_A: U \rightarrow [0,1]$ , 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 :  $0 \leq f_A(x) + g_A(x) \leq 1$ , for all  $x \in U$ .

**Definition 2.3 : Intuitionistic Fuzzy Number**

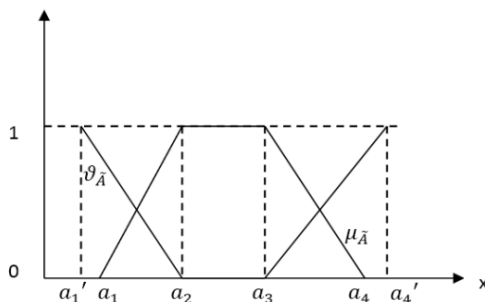
An intuitionistic fuzzy set  $A = \{(x, f_A(x), g_A(x))/x \in U\}$  is called an intuitionistic fuzzy number on real line  $\mathbf{R}$  if it satisfies

- (i) Intuitionistic fuzzy normality ( $\exists z \in \mathbf{R}, f_A(z) = 1$  and  $g_A(z) = 0$ ),
- (ii) Intuitionistic fuzzy convexity ( $f_A(\lambda x + (1 - \lambda)y) \geq \text{Min}(f_A(x), f_A(y))$  and  $g_A(\lambda x + (1 - \lambda)y) \leq \text{Max}(g_A(x), g_A(y))$ ), 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

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



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

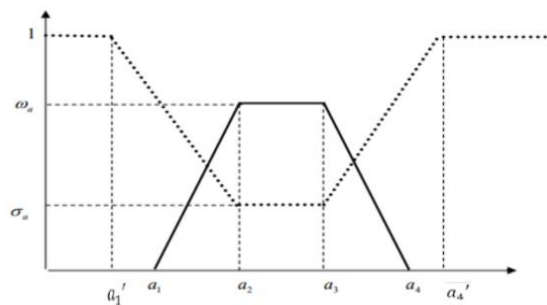
**Definition 2.5: Generalized ITFN (Figure 2)**

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

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

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



**Figure 2 : Generalized ITFN**

**Definition 2.6 Arithmetic operations of generalized intuitionistic trapezoidal fuzzy numbers**

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:

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

(ii) Subtraction:

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

(iii) Scalar Multiplication:

$$k \otimes A = \left\{ \begin{aligned} & (ka_1, ka_2, ka_3, ka_4; \omega_a)(ka'_1, ka_2, ka_3, ka'_4; \sigma_a) \text{ if } k \geq 0 \\ & (ka_4, ka_3, ka_2, ka_1; \omega_a)(ka'_4, ka_3, ka_2, ka'_1; \sigma_a) \text{ if } k < 0 \end{aligned} \right\}$$

**Definition 2.7 : Earth Mover’s Distance (EMD)**

EMD between two ITFN’s A and B can be calculated as follows :

1. Compute membership function and non-membership function for both A and B.

2. Compute cumulative distribution functions for both  $\mu_A$  and  $\nu_A$  and  $\mu_B$  and  $\nu_B$

i.e.,  $F_{\mu_A}(x)$  and  $F_{\nu_A}(x)$

$F_{\mu_B}(x)$  and  $F_{\nu_B}(x)$

3. Compute EMD for both A and B

$$EMD_{\mu}(A, B) = \int_{-\infty}^{\infty} |F_{\mu_A}(x) - F_{\mu_B}(x)| dx$$

$$EMD_{\nu}(A, B) = \int_{-\infty}^{\infty} |F_{\nu_A}(x) - F_{\nu_B}(x)| dx$$

4. Total EMD is calculated as 
$$EMD(A,B) = \frac{EMD_{\mu}(A,B) + EMD_{\nu}(A,B)}{2}$$

In the context of supplier selection, EMD can be employed to measure the dissimilarity between (i) supplier and Intuitionistic Trapezoidal Fuzzy Positive Ideal Solution (ITFPIS) and (ii) supplier and Intuitionistic Trapezoidal Fuzzy Negative Ideal Solution (ITFNIS). EMD is particularly useful when dealing with fuzzy numbers, as it can effectively handle the inherent uncertainty and variability.

**Definition 2.8 : Supply Chain Network (Figure 2):** In general, instead of allowing direct transport of goods from manufacturers to customers, a supply chain network (SCN) involves the transportation of goods with potential stakeholders, such as suppliers, wholesalers, distributors, retailers, and customers (De et al., 2020 [4]).



**Figure 2 : Supply Chain Network**

### 3. Existing Generalized ITFN Ranking Method [ 24 ]

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 to Select Supplier Using TOPSIS**

Let  $A_i, i = 1, 2, \dots, n$  be the set of suppliers and  $C_j, j = 1, 2, \dots, m$  be the set of criteria.

**Step 1:** Define an assessment matrix  $P$  for  $n$  suppliers under  $m$  criteria, with the performance of each supplier and criteria as  $p_{ij}$  and the matrix given as

$$P = \begin{bmatrix} p_{11} & \dots & p_{1m} \\ \vdots & \ddots & \vdots \\ p_{1n} & \dots & p_{nm} \end{bmatrix}$$

Each entry is represented by generalized intuitionistic trapezoidal fuzzy number  $(a_1, a_2, a_3, a_4; \omega_a)(a'_1, a_2, a_3, a'_4; \sigma_a)$  with membership grade  $\omega_a$  and non-membership grade  $\sigma_a$

**Step 2:** Using the normalization method, the matrix  $P = [p_{ij}]_{n \times m}$  is normalized to form the  $N = [r_{ij}]_{n \times m}$ , where  $r_{ij} = \frac{p_{ij}}{\max(p_{ij})}$ . Here, each GITFN is ranked using Section 3.

**Step 3:** Compute the weighted normalised decision matrix  $[d_{ij}]_{n \times m}$

where  $d_{ij} = r_{ij} \cdot w_j$ , and  $w_j$  - weight of the  $j$ th criterion such that  $\sum_{j=1}^n w_j = 1$ .

**Step 4:** Determine positive and negative ideal solutions.

$$ITFPIS = \{ \langle \max(d_{ij})/j \in J_- \rangle, \langle \min(d_{ij})/j \in J_+ \rangle \} = \{ d_{pj}/j = 1, 2, \dots, m \}$$

= Maximum value across each criteria

$$ITFNIS = \{ \langle \min(d_{ij})/j \in J_- \rangle, \langle \max(d_{ij})/j \in J_+ \rangle \} = \{ d_{nj}/j = 1, 2, \dots, m \}$$

= Minimum value across each criteria

where,  $J_+$  associated to benefit criteria,  $J_-$  associated to cost criteria,

ITFPIS means Intuitionistic Trapezoidal Fuzzy Positive Ideal Solution, and

ITFNIS means Intuitionistic Trapezoidal Fuzzy Negative Ideal Solution

**Step 5:** Evaluate the separation measures.

The distance between each supplier and the ITFPIS using EMD

and the distance between each supplier and the ITFNIS using EMD

**Step 6:** Determine the relative closeness by

$$R_{in} = \frac{d_{ip}}{d_{in} + d_{ip}}, 0 \leq R_{in} \leq 1 \text{ and } i = 1, 2, \dots, n$$

**Step 7:** Rank the suppliers according to relative closeness,  $R_{in}, i = 1, 2, \dots, n$ .

The supplier with the highest Relative Closeness value is considered the best supplier.

### 5. Illustrative Example

This example considers five suppliers, each assessed based on six evaluation criteria.

**Step 1 :** The assessment matrix P utilizes linguistic terms from Table 1 and Table 2 to evaluate five suppliers across 6 criteria. Each entry in the table is represented by a generalized intuitionistic trapezoidal fuzzy number, denoted as  $(a_1, a_2, a_3, a_4; \omega_a)(a'_1, a'_2, a'_3, a'_4; \sigma_a)$  where  $\omega_a$  and  $\sigma_a$  signify membership and non-membership grades, respectively, as presented in Table 3.

**Table 1 : Linguistic Terms and Corresponding Intuitionistic Trapezoidal Fuzzy Numbers [25]**

Linguistic Term	Intuitionistic Trapezoidal Fuzzy Number
Very Low (VL)	$(0.0, 0.0, 0.0, 0.0; 0.2) (0.0, 0.0, 0.0, 0.0; 0.3)$
Low (L)	$(0.0, 0.1, 0.2, 0.3; 0.3) (0.0, 0.1, 0.2, 0.3; 0.5)$
Medium Low (ML)	$(0.1, 0.2, 0.3, 0.4; 0.4) (0.0, 0.2, 0.3, 0.5; 0.3)$
Medium (M)	$(0.3, 0.4, 0.5, 0.6; 0.5) (0.2, 0.4, 0.5, 0.7; 0.4)$
Medium High (MH)	$(0.5, 0.6, 0.7, 0.8; 0.6) (0.4, 0.6, 0.7, 0.9; 0.3)$
High	$(0.7, 0.8, 0.9, 1.0; 0.7) (0.7, 0.8, 0.9, 1.0; 0.1)$
Very High	$(1.0, 1.0, 1.0, 1.0; 0.8) (1.0, 1.0, 1.0, 1.0; 0.1)$

**Table 2 : Evaluation from DM1 [25] for Intuitionistic Trapezoidal Fuzzy Numbers**

Suppliers	Quality (C <sub>1</sub> )	Price (C <sub>2</sub> )	Technological Capability (C <sub>3</sub> )	Partnership (C <sub>4</sub> )	On-time delivery (C <sub>5</sub> )
S <sub>1</sub>	VL	ML	MH	H	MH
S <sub>2</sub>	L	MH	M	H	M
S <sub>3</sub>	MH	ML	H	M	VL
S <sub>4</sub>	H	H	MH	ML	VH
S <sub>5</sub>	M	M	MH	H	VH
S <sub>6</sub>	ML	ML	H	H	L

**Table 3 : Representation of Evaluation Matrix using GITFN**

Suppliers	Quality (C1)	Price (C2)	Technological Capability (C3)	Partnership (C4)	On-time delivery (C5)
S <sub>1</sub>	(0.0, 0.0,0.0,0.0; 0.2 ) (0.0, 0.0,0.0,0.0;0.3 )	(0.1, 0.2,0.3,0.4;0.4 ) (0.0, 0.2,0.3,0.5;0.3)	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)
S <sub>2</sub>	(0.0, 0.1,0.2,0.3; 0.3) (0.0, 0.1,0.2,0.3; 0.5 )	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)	(0.3, 0.4,0.5,0.6;0.5 ) (0.2, 0.4,0.5,0.7;0.4)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.3, 0.4,0.5,0.6;0.5 ) (0.2, 0.4,0.5,0.7;0.4)
S <sub>3</sub>	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)	(0.1, 0.2,0.3,0.4;0.4 ) (0.0, 0.2,0.3,0.5;0.3)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.3, 0.4,0.5,0.6;0.5 ) (0.2, 0.4,0.5,0.7;0.4)	(0.0, 0.0,0.0,0.0; 0.2) (0.0, 0.0,0.0,0.0;0.3 )
S <sub>4</sub>	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)	(0.1, 0.2,0.3,0.4;0.4 ) (0.0, 0.2,0.3,0.5;0.3)	(1.0, 1.0,1.0,1.0; 0.8 ) (1.0, 1.0,1.0,1.0;0.1)
S <sub>5</sub>	(0.3, 0.4,0.5,0.6;0.5 ) (0.2, 0.4,0.5,0.7;0.4)	(0.3, 0.4,0.5,0.6;0.5 ) (0.2, 0.4,0.5,0.7;0.4)	(0.5, 0.6,0.7,0.8; 0.6) (0.4, 0.6,0.7,0.9;0.3)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(1.0, 1.0,1.0,1.0; 0.8 ) (1.0, 1.0,1.0,1.0;0.1)
S <sub>6</sub>	(0.1, 0.2,0.3,0.4;0.4 ) (0.0, 0.2,0.3,0.5;0.3)	(0.1, 0.2,0.3,0.4;0.4 ) (0.0, 0.2,0.3,0.5;0.3)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.7, 0.8,0.9,1.0; 0.7 ) (0.7, 0.8,0.9,1.0; 0.1)	(0.0, 0.1,0.2,0.3; 0.3) (0.0, 0.1,0.2,0.3; 0.5 )

**Step 2 :** Each GITFN is ranked according to Section 3 and then normalized using the formula outlined in Step 2, with the results presented in Table 4.

**Table 4 : Normalized Matrix**

Suppliers	Quality (C1)	Price (C2)	Technological Capability (C3)	Partnership (C4)	On-time delivery (C5)
S <sub>1</sub>	0/0.35 = <b>0</b>	0.1/0.35= <b>0.29</b>	0.26/0.35= <b>0.74</b>	0.27/0.35= <b>0.77</b>	0.26/0.35= <b>0.74</b>
S <sub>2</sub>	0.08/0.35= <b>0.22</b>	0.26/0.35= <b>0.74</b>	0.21/0.35= <b>0.6</b>	0.27/0.35= <b>0.77</b>	0.21/0.35= <b>0.6</b>
S <sub>3</sub>	0.26/0.35= <b>0.74</b>	0.1/0.35= <b>0.29</b>	0.27/0.35= <b>0.77</b>	0.21/0.35= <b>0.6</b>	0/0.35= <b>0</b>
S <sub>4</sub>	0.27/0.35= <b>0.77</b>	0.27/0.35= <b>0.77</b>	0.26/0.35= <b>0.74</b>	0.1/0.35= <b>0.29</b>	0.35/0.35= <b>1</b>
S <sub>5</sub>	0.21/0.35= <b>0.6</b>	0.21/0.35= <b>0.6</b>	0.26/0.35= <b>0.74</b>	0.27/0.35= <b>0.77</b>	0.35/0.35= <b>1</b>
S <sub>6</sub>	0.1/0.35= <b>0.29</b>	0.1/0.35= <b>0.29</b>	0.27/0.35= <b>0.77</b>	0.27/0.35= <b>0.77</b>	0.08/0.35= <b>0.22</b>

**Step 3 :** Each criterion is assigned a weight ( $w_1, w_2, w_3, w_4,$  and  $w_5$ ), and the sum of the weights equals one. The weighted normalized decision matrix values are obtained by multiplying these weights with the elements in Table 4 and presented in Table 5.

**Table 5 : Weighted Normalised Decision Matrix**

Suppliers	Quality (C1) $w_1 = 0.2$	Price (C2) $w_2 = 0.2$	Technological Capability (C3) $w_3 = 0.3$	Partnership (C4) $w_4 = 0.1$	On-time delivery (C5) $w_5 = 0.2$
S <sub>1</sub>	0	0.058	0.222	0.077	0.148
S <sub>2</sub>	0.044	0.148	0.18	0.077	0.12
S <sub>3</sub>	0.148	0.058	0.231	0.06	0
S <sub>4</sub>	0.154	0.154	0.222	0.029	0.2
S <sub>5</sub>	0.12	0.12	0.222	0.077	0.2
S <sub>6</sub>	0.058	0.058	0.231	0.077	0.044

**Step 4 :** Determine the positive ideal solution (ITFPIS) and negative ideal solutions ITFNIS using Step 4.

$$\text{ITFPIS} = (0.154, 0.231, 0.222, 0.077, 0.2)$$

$$\text{ITFNIS} = (0, 0.058, 0.22, 0.0029, 0.044)$$

**Step 5 :** Calculate the EMD between each supplier and the ITFPIS and ITFNIS as described in section 2, with results presented in Table 6.

**Table 6 : Earth Mover’s Distance Calculation**

Suppliers	ITFPIS	ITFNIS
S <sub>1</sub>	0.231	0.191
S <sub>2</sub>	0.201	0.166
S <sub>3</sub>	0.181	0.208
S <sub>4</sub>	0.145	0.243
S <sub>5</sub>	0.129	0.226
S <sub>6</sub>	0.223	0.159

**Step 6 :** The Relative Closeness of each supplier is calculated using the distances from Table 6 and presented in Table 7.

**Table 7 : Relative Closeness of each Supplier**

Suppliers	Relative Closeness
S <sub>1</sub>	0.449
S <sub>2</sub>	0.452
S <sub>3</sub>	0.535
S <sub>4</sub>	0.626
S <sub>5</sub>	0.637
S <sub>6</sub>	0.416

**Step 7 :** Rank the suppliers based on their relative closeness values as presented in Table 8. The supplier with the highest Relative Closeness value is deemed the best supplier, which in this case is S<sub>5</sub>.

**Table 8 : Ranks of Suppliers**

Suppliers	Rank
S <sub>1</sub>	5
S <sub>2</sub>	4
S <sub>3</sub>	3
S <sub>4</sub>	2
S <sub>5</sub>	1
S <sub>6</sub>	6

## 6. Results and Discussion

Supplier selection plays a pivot role in supply chain management, impacting the overall performance, effectiveness, and profitability of an organization or industry. Due to the inherent uncertainty and

fuzziness in decision-making , supply chains require robust evaluation and selection of optimal suppliers. This study proposes a supplier selection methodology, integrating intuitionistic trapezoidal fuzzy numbers, Earth Mover's Distance (EMD), and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS). The EMD accurately measures distance between intuitionistic trapezoidal fuzzy numbers, while fuzzy TOPSIS facilitates efficient supplier ranking. This research investigates the application of the proposed model in real-world supply chain scenarios.

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