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Research Article

Intuitionistic Fuzzy Supplier Selection using Signed Distance and Fuzzy TOPSIS

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ABSTRACT

This research proposes a novel supplier selection approach using Intuitionistic Trapezoidal Fuzzy Numbers (ITFNs), Signed Distance(SD),and Fuzzy TOPSIS. The Signed Distance, a robust metric for measuring the distance between intuitionistic fuzzy sets, is employed to rank ITFNs and compare suppliers based on multiple criteria using Fuzzy TOPSIS. The proposed model effectively handles uncertainty and vagueness in supplier evaluations, providing more flexible and accurate supplier rankings. The supplier selection process is demonstrated with a numerical example.

Keywords: Supplier selection; Intuitionistic Trapezoidal Fuzzy Number; Supply Chain Management; Signed Distance; Decision making

1. Introduction

Uncertainties in real-life decision-making often cannot be effectively addressed by classical operation research theories. Lotfi Zadeh invented fuzzy set theory in 1965 [1] to address such concerns. However, in many cases, higher correctness is required, leading to the development of higher-order fuzzy sets, 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.

Effective supplier selection is crucial in supply chain management. Various Multi-Criteria Decision-Making (MCDM) tools, such as TOPSIS, have been adapted for fuzzy data [3-8]. By generating a detailed inventory of supplier selection criteria, this study intends to present a comprehensive basis for supplier selection. A novel methodology is proposed to solve supplier selection problems using TOPSIS with sign distance and intuitionistic trapezoidal fuzzy numbers. This review integrates existing research on supplier selection criteria, expanding upon prior comprehensive reviews [11-16]. To establish a foundational framework applicable across various sectors, this study draws from two primary sources: review articles and empirical surveys of business practitioners. The primary objective is to compile an exhaustive and industry-agnostic list of supplier selection criteria, providing a starting point for organizations to tailor their specific requirements. To ensure broad applicability, this review prioritizes studies examining diverse industries, excluding those focused on a single industry or sector to maintain generalizability. Notably, Kahraman et al. [23] developed a leveraging vague membership functions and circular intuitionistic fuzzy TOPSIS method for supplier selection applications.

The organization of this paper is as follows: An overview of fuzzy notions and Earth Mover's Distance is given in Section 2. Section 3 explains ranking intuitionistic trapezoidal fuzzy numbers using signed distance, and Section 4 presents the new methodology. A numerical example is illustrated in Section 5, and in Section 6, the study presents results and discussions.

2. Preliminaries

As stated above, this section includes a number of basic descriptions.

Definition 2.1: Fuzzy Set

Assume U is a universal set. A membership function $\mathrm{f_A}: \mathrm{U} \rightarrow [0,1]$ defines a fuzzy set A of U, where $\mathrm{f_A}(a)$ is the degree of membership of a in A. $\mathrm{A} = \{(a, \mathrm{f_A}(a))/a \in \mathrm{U}\}$ is the representation of the fuzzy set A.

Definition 2.2 : Intuitionistic Fuzzy Set (IFS)

Let $\mathrm{f_A}$, and $\mathrm{g_A}$ are functions from U to $[0, 1]$ that reflect the degree of membership and non-membership of a in U, respectively, and therefore $0 \le \mathrm{f_A}(a) + \mathrm{g_A}(a) \le 1$ for any $a \in U$, A= $\{(a, f_A(a), g_A(a))/a \in U\}$ defines an IFS of A in U.

Definition 2.3 : Intuitionistic Fuzzy Number

An intuitionistic fuzzy number on the real line $\boldsymbol{R}$ is defined as an intuitionistic fuzzy set

$\mathrm{A} = \{(a, f_A(a), g_A(a))/a \in U\}$ if it satisfies

Intuitionistic fuzzy normality ($\exists\, z \in \boldsymbol{R}$, $\mathrm{g}_A(\mathrm{z}) = 0$ and $\mathrm{f_A}(\mathrm{z}) = 1$), (ii) Intuitionistic fuzzy convexity $g_A(\lambda a + (1-\lambda)b) \le Max\,(g_A(a), g_A(b))$, $(f_A(\lambda a + (1-\lambda)b) \ge Min\,(f_A(a), f_A(b))$ where $a, b \in U, \lambda \in [0,1]$, (iii) The real-valued functions $g_A(a)$ and $f_A(a)$ are piecewise continuous, and (iv) A's support is bounded.

Definition 2.4 : Intuitionistic Trapezoidal fuzzy number (ITFN)

An intuitionistic fuzzy number A is said to be ITFN and is represented as $\mathrm{A} = (\alpha'_1, \alpha_2, \alpha_3, \alpha'_4); (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ with membership and non-membership function f_A and g_A (Figure 1).

$$f_A = \begin{cases} 0, & a < \alpha_1 \\ \frac{a-\alpha_1}{\alpha_2-\alpha_1}, & \alpha_1 \le a \le \alpha_2 \\ 1, & \alpha_2 \le a \le \alpha_3 \\ \frac{a-\alpha_4}{\alpha_3-\alpha_4}, & \alpha_3 \le a \le \alpha_4 \\ 0, & \alpha_4 < a \end{cases} \quad \text{and} \quad g_A = \begin{cases} 0, & a < \alpha'_1 \\ \frac{a-\alpha_2}{\alpha'_1-\alpha_2}, & \alpha'_1 \le a \le \alpha_2 \\ 1, & \alpha_2 \le a \le \alpha_3 \\ \frac{a-\alpha_3}{\alpha'_4-\alpha_3}, & \alpha_3 \le a \le \alpha'_4 \\ 0, & \alpha'_4 < a \end{cases}$$

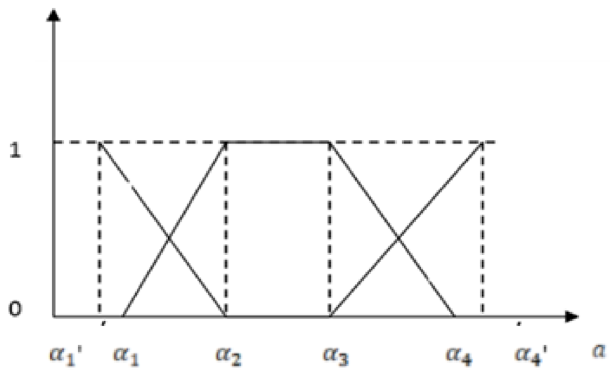

Figure 1: Intuitionistic Trapezoidal Fuzzy Number (ITFN)

Definition 2.6 Arithmetic operations of intuitionistic trapezoidal fuzzy numbers (ITFN)

Let $A = \langle (\alpha'_1, \ \alpha_2, \ \alpha_3, \ \alpha'_4)(\alpha_1, \ \alpha_2, \ \alpha_3, \ \alpha_4)\rangle$ and $B = \langle (\beta'_1, \ \beta_2, \ \beta_3, \ \beta'_4)(\beta_1, \ \beta_2, \ \beta_3, \ \beta_4)\rangle$ be ITFN. Then the arithmetic operations are

(i) Addition:

$$A \oplus B = \begin{Bmatrix} (\alpha'_1 + \beta'_1, \alpha_2 + \beta_2, \alpha_3 + \beta_3, \alpha'_4 + \beta'_4) \\ (\alpha_1 + \beta_1, \ \alpha_2 + \beta_2, \ \alpha_3 + \beta_3, \ \alpha_4 + \beta_4) \end{Bmatrix}$$

(ii) Subtraction:

$$A \Theta B = \begin{Bmatrix} (\alpha'_1 - \beta'_4, \alpha_2 - \beta_2, \alpha_3 - \beta_3, \alpha'_4 - \beta'_1) \\ (\alpha_1 - \beta_4, \alpha_2 - \beta_2, \alpha_3 - \beta_3, \alpha_4 - \beta_1) \end{Bmatrix}$$

(iii) Scalar Multiplication:

$$k \otimes A = \begin{Bmatrix} (k\alpha_4, k\alpha_3, k\alpha_2, k\alpha_1)(k\alpha'_4, k\alpha_3, k\alpha_2, k\alpha'_1) \ if \ k < 0 \\ (k\alpha_1, k\alpha_2, k\alpha_3, k\alpha_4)(k\alpha'_1, k\alpha_2, k\alpha_3, k\alpha'_4) \ if \ k \geq 0 \end{Bmatrix}$$

Definition 2.7 : Earth Mover's Distance (EMD)

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

1. Compute membership and non-membership function for both A and B.
2. Compute cumulative distribution functions for both μ_A and ν_A and μ_B and ν_B i.e., $F_{\mu_A}(a)$ and $F_{\nu_A}(a)$
   $F_{\mu_B}(a)$ and $F_{\nu_B}(a)$
3. Compute EMD for both A and B

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

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

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): Supply chain networks (SCNs) generally comprise the transportation of goods with prospective stakeholders, such as wholesalers, suppliers, retailers, distributors, and consumers, rather than enabling the direct transportation of goods from producers to consumers [10].

Figure 2 : Supply Chain Network

3. Signed Distance Ranking Method [9]

Let A = $(\alpha'_1, \alpha_2, \alpha_3, \alpha'_4)(\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ and B = $(\beta'_1, \beta_2, \beta_3, \beta'_4)(\beta_1, \beta_2, \beta_3, \beta_4)$ be two ITFN. Let O = (0,0,0,0) (0,0,0,0) be the fuzzy origin.

The shortest distance from A to the fuzzy Origin is

$$\text{SD}(A, O) = \frac{(\alpha_1 + \alpha_4) + 4(\alpha_2 + \alpha_3) + (\alpha'_1 + \alpha'_4)}{24}$$

The shortest distance from B to the fuzzy Origin is

$$\text{SD}(B, O) = \frac{(\beta_1 + \beta_4) + 4(\beta_2 + \beta_3) + (\beta'_1 + \beta'_4)}{24}$$

SD(A,B) is the difference between the two signed distances of the two intuitionistic trapezoidal fuzzy numbers from fuzzy origin.

Comparisons:

SD (A, B) < 0 iff SD (A,O) < SD (B,O), which implies A < B
SD (A, B) > 0 iff SD (A,O) > SD (B,O) , which implied A > B
SD (A, B) = 0 iff SD (A,O) = SD (B,O) , which implies 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

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

Each entry is represented by intuitionistic trapezoidal fuzzy number $(\alpha'_1, \alpha_2, \alpha_3, \alpha'_4)(\alpha_1, \alpha_2, \alpha_3, \alpha_4)$.

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 ITFN is ranked using signed distance ranking in Section 3.

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

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

Step 4: Find negative and positive ideal solutions.

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

= Minimum value across each criteria

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

= Maximum value across each criteria

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

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

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

Step 7: Rank the suppliers based on 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 an ITFN and is represented as $(\ \alpha_1',\ \alpha_2,\ \alpha_3,\ \alpha_4')(\ \alpha_1,\ \alpha_2,\ \alpha_3,\ \alpha_4)$ and presented in Table 3.

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

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

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

Suppliers	Quality (C_1)	Partnership (C_2)	Technological Capability (C_3)	Price (C_4)	On-time delivery (C_5)
S_1	VL	H	MH	ML	MH
S_2	L	H	M	MH	M
S_3	MH	M	H	ML	VL
S_4	H	ML	MH	H	VH
S_5	M	H	MH	M	VH
S_6	ML	H	H	ML	L

Table 3 : Representation of Evaluation Matrix using ITFN

Suppliers	Quality (C_1)	Partnership (C_2)	Technological Capability (C_3)	Price (C_4)	On-time delivery (C_5)
S_1	(0.0, 0.0,0.0,0.0) (0.0, 0.0,0.0,0.0)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)	(0.1, 0.2,0.3,0.4) (0.0, 0.2,0.3,0.5)	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)
S_2	(0.0, 0.1,0.2,0.3) (0.0, 0.1,0.2,0.3)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.3, 0.4,0.5,0.6) (0.2, 0.4,0.5,0.7)	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)	(0.3, 0.4,0.5,0.6) (0.2, 0.4,0.5,0.7)

S_3	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)	(0.3, 0.4,0.5,0.6) (0.2, 0.4,0.5,0.7)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.1, 0.2,0.3,0.4) (0.0, 0.2,0.3,0.5)	(0.0, 0.0,0.0,0.0) (0.0, 0.0,0.0,0.0)
S_4	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.1, 0.2,0.3,0.4) (0.0, 0.2,0.3,0.5)	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(1.0, 1.0,1.0,1.0) (1.0, 1.0,1.0,1.0)
S_5	(0.3, 0.4,0.5,0.6) (0.2, 0.4,0.5,0.7)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.5, 0.6,0.7,0.8) (0.4, 0.6,0.7,0.9)	(0.3, 0.4,0.5,0.6) (0.2, 0.4,0.5,0.7)	(1.0, 1.0,1.0,1.0) (1.0, 1.0,1.0,1.0)
S_6	(0.1, 0.2,0.3,0.4) (0.0, 0.2,0.3,0.5)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.7, 0.8,0.9,1.0) (0.7, 0.8,0.9,1.0)	(0.1, 0.2,0.3,0.4) (0.0, 0.2,0.3,0.5)	(0.0, 0.1,0.2,0.3) (0.0, 0.1,0.2,0.3)

Step 2 : Each ITFN is ranked according to Signed Distance (Section 3) and then normalized using the formula outlined in Step 2, with the outcomes depicted in Table 4.

Table 4 : Normalized Matrix

Suppliers	Quality (C_1)	Partnership (C_2)	Technological Capability (C_3)	Price (C_4)	On-time delivery (C_5)
S_1	0/0.5 = **0**	0.425/0.5=**0.85**	0.325/0.5=**0.65**	0.125/0.5=**0.25**	0.325/0.5=**0.65**
S_2	0.075/0.5=**0.15**	0.425/0.5=**0.85**	0.225/0.5=**0.45**	0.325/0.5=**0.65**	0.225/0.5=**0.45**
S_3	0.325/0.5=**0.65**	0.225/0.5=**0.45**	0.425/0.5=**0.85**	0.125/0.5=**0.25**	0/0.5= **0**
S_4	0.27/0.5=**0.77**	0.125/0.5=**0.25**	0.325/0.5=**0.65**	0.425/0.5=**0.85**	0.5/0.5=**1**
S_5	0.225/0.5=**0.45**	0.425/0.5=**0.85**	0.325/0.5=**0.65**	0.225/0.5=**0.45**	0.5/0.5=**1**
S_6	0.125/0.5=**0.25**	0.425/0.5=**0.85**	0.425/0.5=**0.85**	0.125/0.5=**0.25**	0.075/0.5=**0.15**

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. These weights are multiplied by the elements in Table 4 to get the weighted normalised decision matrix values, which are then displayed in Table 5.

Table 5 : Weighted Normalised Decision Matrix

Suppliers	Quality (C_1) W_1=0.2	Partnership (C_4) W_2 =0.1	Technological Capability (C_3) W_3 =0.3	Price (C_2) W_4 =0.2	On-time delivery (C_5) W_5=0.2
S_1	0	0.085	0.195	0.05	0.13
S_2	0.03	0.085	0.135	0.13	0.09
S_3	0.13	0.045	0.255	0.05	0
S_4	0.154	0.025	0.195	0.17	0.2
S_5	0.09	0.085	0.195	0.09	0.2
S_6	0.05	0.085	0.255	0.05	0.03

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

ITFPIS = (0.154,0.085,0.255,0.17,0.2)

ITFNIS = (0,0.025,0.135,0.05,0)

Step 5 : Calculate the EMD between each supplier and the ITFPIS and ITFNIS as specified in section 2, the findings are displayed in Table 6.

Table 6 : Earth Mover's Distance Calculation

Suppliers	ITFPIS	ITFNIS
S_1	0.421	0.853
S_2	0.351	0.651
S_3	0.482	0.951
S_4	0.201	0.351
S_5	0.312	0.551
S_6	0.541	0.851

Step 6 : The distances from Table 6 are used to calculate each supplier's relative proximity, which is then displayed in Table 7.

Table 7 : Relative Closeness of each Supplier

Suppliers	Relative Closeness
S_1	0.330
S_2	0.350
S_3	0.336
S_4	0.385
S_5	0.362
S_6	0.389

Step 7 : Rank the suppliers based on their relative closeness values as presented in Table 8. The supplier with the greatest Relative Closeness value is deemed the best supplier, which in this case is S_6.

Table 8 : Ranks of Suppliers

Suppliers	Rank
S_1	6
S_2	4
S_3	5
S_4	2
S_5	3
S_6	1

Results and Discussion

Selecting a supplier is an essential part of supply chain management, significantly influencing an organization's overall performance, effectiveness, and profitability. However, decision-making in supply chains is often plagued by uncertainty and fuzziness. To address this challenge, this study established a new supplier selection methodology that integrates ITFN with Signed Distance(SD) ranking, Earth Mover's Distance (EMD), and Fuzzy TOPSIS. By leveraging EMD to accurately measure distances between ITFN and fuzzy TOPSIS for efficient supplier ranking, this research aims to provide a robust evaluation and selection framework for optimal suppliers. The invented model is tested in real-world supply chain scenarios to demonstrate its practical applicability.

References

[1] L.A.Zadeh, “Fuzzy Sets,” Information and Control, Vol.8, no.3, pp. 338-352,1965

[2] K.T.Atanassov, “ Intuitionistic fuzzy sets,” Fuzzy sets and Systems, Vol.20, no.1, pp.87-96,1986.

[3] Tsaur, S. H., Chang, T. Y., & Yen, C. H. (2002). The evaluation of airline service quality by fuzzy MCDM. Tourism management, 23(2), 107-115.

[4] Chu, T. C. (2002). Selecting plant location via a fuzzy TOPSIS approach. The International Journal of Advanced Manufacturing Technology, 20(11), 859-864.

[5] Chen, M. F., & Tzeng, G. H. (2004). Combining grey relation and TOPSIS concepts for selecting an expatriate host country. Mathematical and computer modelling, 40(13), 1473-1490.

[6] Byun, H. S., & Lee, K. H. (2005). A decision support system for the selection of a rapid prototyping process using the modified TOPSIS method. The International Journal of Advanced Manufacturing Technology, 26(11), 1338-1347.

[7] Chen, Chen-Tung, Ching-Torng Lin, and Sue-Fn Huang. "A fuzzy approach for supplier evaluation and selection in supply chain management." *International journal of production economics* 102.2 (2006): 289-301.

[8] Boran FE , GençS , Kurt M , Akay D . A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. Expert Syst Appl 2009;36:11363–8 .

[9] B. Abirami, V.Vimitha, S. Rajaram, A New Approach for solving Trapezoidal Intuitionistic Fuzzy Transportation Problem, Advances in Mathematics: Scientific Journal 9 (11), (2020) , 9149-9159.

[10] De Boer, Luitzen, Eva Labro, and Pierangela Morlacchi. "A review of methods supporting supplier selection." European journal of purchasing & supply management 7.2 (2001): 75-89.

[11] Wang, Gang, et al. "Big data analytics in logistics and supply chain management: Certain investigations for research and applications." *International journal of production economics* 176 (2016): 98-110.

[12] Pournader, Mehrdokht, et al. "Artificial intelligence applications in supply chain management." *International Journal of Production Economics* 241 (2021): 108250.

[13] Ecer, Fatih, and Dragan Pamucar. "Sustainable supplier selection: A novel integrated fuzzy best worst method (F-BWM) and fuzzy CoCoSo with Bonferroni (CoCoSo’B) multi-criteria model." *Journal of cleaner production* 266 (2020): 121981.

[14] Münch, Christopher, Lukas Alexander Benz, and Evi Hartmann. "Exploring the circular economy paradigm: A natural resource-based view on supplier selection criteria." *Journal of Purchasing and Supply Management* 28.4 (2022): 100793.

[15] Naz, Farheen, et al. "Is artificial intelligence an enabler of supply chain resiliency post COVID-19? An exploratory state-of-the-art review for future research." *Operations Management Research* 15.1 (2022): 378-398.

[16] Lin, Song-Shun, Annan Zhou, and Shui-Long Shen. "Safety assessment of excavation system via TOPSIS-based MCDM modelling in fuzzy environment." *Applied Soft Computing* 138 (2023): 110206.