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# A Fuzzy Multi-Criteria Decision-Making Approach for Sustainable Supplier Selection

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**Abstract:** *Supplier selection plays a crucial role in achieving sustainability within modern supply chains, as organizations must balance economic performance with environmental and social responsibilities. The decision making process is inherently complex due to the presence of multiple conflicting criteria and uncertainty in evaluation data. To address these challenges, this paper proposes a fuzzy multi-criteria decision-making (MCDM) approach for sustainable supplier selection. The proposed framework integrates fuzzy set theory with established MCDM techniques to effectively handle vagueness and imprecision in expert judgments. Linguistic assessments are modeled using triangular fuzzy numbers, enabling decision makers to express preferences in a flexible manner. The methodology systematically evaluates and ranks potential suppliers based on sustainability-related criteria such as cost, quality, environmental impact, and social responsibility. A numerical illustration is presented to demonstrate the applicability and effectiveness of the proposed approach. The results indicate that the fuzzy MCDM framework provides consistent and reliable supplier rankings, supporting decision makers in selecting the most suitable sustainable suppliers. The proposed model offers a practical decision support tool for improving sustainability performance in supply chain management.*

**Keywords:** *Fuzzy Sets, Multi-Criteria Decision Making, Sustainable Supplier Selection, Fuzzy Ahp, Fuzzy Topsis, Supply Chain Management*.

**Introduction:** In the contemporary global economy, supply chain management has become a critical factor in determining the competitiveness and sustainability of organizations. With increasing environmental concerns, regulatory pressures, and societal expectations, companies are no longer evaluated solely on economic performance but also on their environmental and social impacts. As a result, sustainable supply chain management (SSCM) has emerged as a key research area that integrates economic, environmental, and social dimensions into decision-making processes. One of the most important aspects of SSCM is sustainable supplier selection, which plays a vital role in improving overall supply chain performance.

Supplier selection is a strategic decision-making process that involves evaluating and choosing suppliers based on multiple criteria such as cost, quality, delivery performance, environmental practices, and social responsibility. Traditionally, supplier selection focused primarily on economic factors such as cost and quality. However, in recent years, there has been a growing emphasis on incorporating sustainability criteria into the decision-making process. This shift is driven by increasing awareness of environmental issues, stricter government regulations, and the need for corporate social responsibility.

  

Sustainable supplier selection is inherently a complex multi-criteria decision-making (MCDM) problem. Decision makers must evaluate multiple, often conflicting criteria while dealing with uncertainty and incomplete information. For example, a supplier offering low cost may have poor environmental performance, while a highly sustainable supplier may involve higher costs. Therefore, selecting the most appropriate supplier requires a systematic and robust decision-making framework that can handle such trade-offs effectively.

Multi-criteria decision-making methods have been widely used to address complex decision problems in supply chain management. Among these methods, the Analytic Hierarchy Process (AHP), introduced by Saaty [20], has been extensively applied for determining the relative importance of criteria through pair wise comparisons. Similarly, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon [11], provides a ranking mechanism based on the distance of alternatives from ideal solutions. Other MCDM methods such as ELECTRE [19] and various hybrid approaches have also been used in supplier selection problems.

Despite their effectiveness, classical MCDM methods assume that decision data are precise and deterministic. In real-world supplier selection problems, however, decision makers often rely on subjective judgments and linguistic assessments such as “high quality”, “moderate cost”, or “low environmental impact”. These qualitative evaluations involve inherent vagueness and uncertainty, which cannot be accurately, represented using crisp numerical values. To address this limitation, fuzzy set theory, introduced by Zadeh [28], provides a powerful mathematical framework for modeling uncertainty and imprecision.

Fuzzy set theory allows elements to belong to a set with varying degrees of membership, enabling the representation of ambiguous and uncertain information. Bellman and Zadeh [2] extended fuzzy set theory to decision-making problems, demonstrating its applicability in handling multiple objectives and uncertain environments. Further developments by Klir and Yuan [14] and Zimmermann [30] established a strong theoretical foundation for fuzzy decision analysis.

The integration of fuzzy set theory with MCDM methods has led to the development of fuzzy MCDM approaches such as fuzzy AHP and fuzzy TOPSIS. Buckley [3] introduced the fuzzy extension of AHP, allowing decision makers to express pairwise comparisons using fuzzy numbers. Similarly, Chen [5] extended the TOPSIS method to fuzzy environments, enabling the ranking of alternatives under uncertainty. These fuzzy MCDM techniques have been widely applied in supplier selection and supply chain management.

A significant body of literature has focused on supplier selection using MCDM methods. De Boer et al. [6] provided an early review of methods supporting supplier selection, highlighting the importance of structured decision-making approaches. Ho et al. [10] conducted a comprehensive review of MCDM methods in supplier evaluation and emphasized the growing use of hybrid models. Kahraman et al. [13] applied fuzzy AHP for supplier selection, demonstrating the effectiveness of fuzzy methods in handling uncertainty.

In the context of sustainability, researchers have increasingly focused on green and sustainable supplier selection. Seuring and Muller [21] proposed a conceptual framework for sustainable supply chain management, emphasizing the integration of environmental and social criteria. Carter and Rogers [4] further highlighted the importance of sustainability in supply chain decision-making. Govindan et al. [9] applied MCDM methods for green supplier evaluation, while Govindan [7] explored fuzzy approaches for sustainable supplier selection.

Recent studies have continued to advance the field by incorporating advanced fuzzy techniques and hybrid models. Mardani et al. [16] reviewed various MCDM techniques and their applications, highlighting the effectiveness of hybrid approaches. Rezaei [18] introduced the Best Worst Method (BWM) as an alternative weighting technique, while Zavadskas and Turskis [29] provided improvements to the TOPSIS method. More recent works by Li [15], Wang [26], and Patel [17] have demonstrated the growing importance of hybrid fuzzy MCDM models in sustainable supplier selection.

Despite these advancements, several challenges remain in the application of MCDM methods to sustainable supplier selection. Many existing models rely on single techniques, which may not fully capture the complexity of real-world decision problems. Additionally, uncertainty and vagueness in decision-making are not always adequately addressed. There is therefore a need for integrated frameworks that combine multiple MCDM techniques with fuzzy logic to improve decision accuracy and robustness.

To address these challenges, this paper proposes a fuzzy multi-criteria decision-making framework for sustainable supplier selection. The proposed approach integrates fuzzy set theory with established MCDM techniques to provide a systematic and flexible decision-support model. The framework enables decision makers to incorporate linguistic assessments, evaluate multiple sustainability criteria, and rank suppliers effectively under uncertain conditions.

The main contributions of this study can be summarized as follows:

i. A fuzzy MCDM framework is developed for sustainable supplier selection, incorporating economic, environmental, and social criteria.

ii. The proposed approach effectively handles uncertainty and vagueness using fuzzy set theory.

iii. A systematic methodology is provided for evaluating and ranking suppliers based on multiple criteria.

iv. A numerical illustration is presented to demonstrate the applicability and effectiveness of the model.

The remainder of this paper is organized as follows. Section 2 presents the mathematical preliminaries related to fuzzy sets and MCDM methods. Section 3 describes the proposed fuzzy decision-making framework. Section 4 provides a numerical illustration for sustainable supplier selection. Section 5 discusses the results and implications. Finally, Section 6 concludes the paper and suggests directions for future research.

**Mathematical Preliminaries:** This section presents the fundamental mathematical concepts required for the development ofthe proposed fuzzy multi-criteria decision-making (MCDM) model for sustainable supplier selection. The framework is based on fuzzy set theory, triangular fuzzy numbers, defuzzificationtechniques, and the principles of multi-criteria decision-making methods such as AHP and TOPSIS. These concepts provide a systematic approach for handling uncertainty, vagueness, and linguistic information in decision-making processes.

**Definition 1**: Let $X$ be a universe of discourse. A fuzzy set $\tilde{A}$ in $X$ is defined as

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) \mid x \in X\}$$

where $\mu_{\tilde{A}}(x): X \to [0, 1]$ is the membership function of $\tilde{A}$[28]. The value $\mu_{\tilde{A}}(x)$ indicates thedegree to which element $x$ belongs to the fuzzy set.

Fuzzy sets provide a flexible mathematical tool for representing imprecise and uncertain information commonly encountered in supplier evaluation processes.

**Definition 2**: A triangular fuzzy number (TFN) $\tilde{A}$ is defined as a triplet

$$\tilde{A} = (l, m, u)$$

where $l, m$, and $u$ denote the lower, modal, and upper values respectively, satisfying $l \leq m \leq u$[30, 14].

The membership function of a triangular fuzzy number is given by

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & if\ x < l\ or\ x > u \\ \frac{x-l}{m-l}, & if\ l \leq x \leq m \\ \frac{u-x}{u-m}, & if\ m \leq x \leq u \end{cases}$$

Triangular fuzzy numbers are widely used due to their simplicity and computational efficiency in modeling linguistic variables.

Let $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$be two triangular fuzzy numbers. Their basic arithmetic operations (assuming non-negative values) are approximately defined as follows:

$$\tilde{A} + \tilde{B} = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$
$$\tilde{A} - \tilde{B} = (l_1 - l_2, m_1 - m_2, u_1 - u_2)$$

$$\tilde{A} \times \tilde{B} = (l_1 l_2, m_1 m_2, u_1 u_2)$$

$$k\,\tilde{A} = (kl_1, km_1, ku_1) \qquad k \in R$$

To compare fuzzy numbers, it is often necessary to convert them into crisp values. One of the most commonly used defuzzification methods is the centroid (center of gravity) method.

**Definition 3:** Let $\tilde{A} = (l,\ m,\ u)$ be a triangular fuzzy number. The defuzzified value of $\tilde{A}$ is given by $C(\tilde{A}) = \frac{l+m+u}{3}$.

In a multi-criteria decision-making environment, suppose that $A_i (i = 1, 2, \ldots, m)$ represents the set of suppliers (alternatives) and $C_j\ (j = 1,\ 2, \ldots, n)$ represents the evaluation criteria.

The fuzzy decision matrix is defined as

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

Where $\tilde{x}_{ij}$ denotes the fuzzy performance rating of supplier $A_i$ with respect to criterion $C_j$.

The importance of criteria is represented by a weight vector

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n)$$

Where $\tilde{w}_j$ denotes the fuzzy weight associated with criterion $C_j$.

**Definition 4:** The Analytic Hierarchy Process (AHP), proposed by Saaty [20], is a structured multi-criteria decision-making method that decomposes a complex decision problem into a hierarchical framework. It determines the relative importance of criteria through pairwise comparisons and includes a consistency check to ensure reliable judgments.

**Definition 5:** The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), introduced by Hwang and Yoon [11], is a ranking method in which the best alternative is the one that is closest to the positive ideal solution and farthest from the negative ideal solution.

In TOPSIS, the positive ideal solution represents the best possible performance for all criteria,while the negative ideal solution represents the worst performance. Alternatives are evaluated based on their Euclidean distance from these ideal solutions.

The mathematical concepts presented in this section provide the theoretical basis for the development of the proposed fuzzy multi-criteria decision-making model for sustainable supplier selection described in the subsequent section.

**Proposed Fuzzy MCDM Model :** This section presents the proposed fuzzy multi-criteria decision-making (MCDM) framework for sustainable supplier selection. The model integrates fuzzy Analytic Hierarchy Process (AHP) and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to evaluate and rank suppliers under uncertainty.

Sustainable supplier selection involves evaluating suppliers based on multiple criteria such as economic performance, environmental responsibility, and social impact. These criteria are often conflicting and involve subjective judgments, making fuzzy MCDM approaches suitable for handling such complexities.

Let $A_i$ (i = 1, 2, . . . , m) denote the set of suppliers and $C_j$ (j = 1, 2, . . . , n) denote the set of evaluation criteria.

**Step 1: Construction of Hierarchical Structure**

The decision problem is structured into a hierarchy consisting of three levels:

(i) Level 1: Goal (Sustainable supplier selection)

(ii) Level 2: Evaluation criteria

(iii) Level 3: Supplier alternatives

**Step 2: Fuzzy Pairwise Comparison Matrix**

Decision makers provide pairwise comparisons of criteria using linguistic variables. These are converted into triangular fuzzy numbers to form the fuzzy comparison matrix:

$$\tilde{A} = [\widetilde{a_{ij}}]$$

**Step 3: Determination of Criteria Weights (Fuzzy AHP)**

The fuzzy geometric mean for each criterion is calculated as

$$\tilde{g_i} = \left(\prod_{j=1}^{n} \widetilde{a_{ij}}\right)^{\frac{1}{n}}$$

The normalized fuzzy weights are obtained as

$$\tilde{w}_i = \frac{\tilde{g}_i}{\sum_{i=1}^{n} \tilde{g}_i}$$

The fuzzy weights are then defuzzified using the centroid method: $w_i = \frac{l_i+m_i+u_i}{3}$

The crisp weights are normalized such that $\sum_{i=1}^{n} w_i = 1$.

**Step 4: Construction of Fuzzy Decision Matrix**

The performance of each supplier is evaluated using linguistic variables and converted into triangular fuzzy numbers: $\widetilde{D} = [\tilde{x}_{ij}]$

**Step 5: Defuzzification**

The fuzzy decision matrix is converted into a crisp matrix using $x_{ij} = \frac{l_{ij}+m_{ij}+u_{ij}}{3}$

**Step 6: Normalization**

The normalized decision matrix is obtained as

For benefit criteria: $r_{ij} = \frac{x_{ij}}{\max x_{ij}}$

For cost criteria: $r_{ij} = \frac{\min x_{ij}}{x_{ij}}$

**Step 7: Weighted Normalized Matrix**

$$v_{ij} = r_{ij} \times w_j$$

**Step 8: Determination of Ideal Solutions**

The positive ideal solution (PIS) and negative ideal solution (NIS) are defined as

$$A^+ = (max_i v_{ij}) A^- = (min_i v_{ij})$$

**Step 9: Distance Measures**

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^+)^2}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - A_j^-)^2}$$

**Step 10: Closeness Coefficient**

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

Suppliers are ranked in descending order of$CC_i$.

**Algorithm 1 Fuzzy AHP–TOPSIS for Sustainable Supplier Selection**

1: Input supplier set $A_i$and criteria $C_j$

2: Construct hierarchical decision structure

3: Obtain fuzzy pairwise comparison matrix

4: Compute criteria weights using fuzzy AHP

5: Defuzzify and normalize weights

6: Construct fuzzy decision matrix

7: Defuzzify decision values

8: Normalize decision matrix

9: Compute weighted normalized matrix

10: Determine positive and negative ideal solutions

11: **for** each supplier i**do**

12: Compute $D_i^+$ and $D_i^-$

13: **end for**

14: Compute closeness coefficients $CC_i$

15: Rank suppliers based on $CC_i$

16: Output best supplier

The proposed fuzzy MCDM framework provides a systematic and effective approach for evaluating suppliers under uncertainty. By integrating fuzzy logic with AHP and TOPSIS, the model captures both subjective judgments and quantitative data, enabling decision makers to select the most suitable sustainable supplier.

**Numerical Illustration :** To demonstrate the applicability of the proposed fuzzy MCDM model, a numerical example for sustainable supplier selection is presented. A company intends to select the most suitable supplier from four alternatives based on multiple sustainability criteria.

**Alternatives:** $A_1, A_2,\ A_3,\ A_4$

**Evaluation Criteria:**

(i) $C_1$: Cost (Cost)

(ii) $C_2$: Quality (Benefit)

(iii) $C_3$: Environmental Performance (Benefit)

(iv) $C_4$: Delivery Performance (Benefit)

(v) $C_5$: Social Responsibility (Benefit)

**Step 1: Linguistic Scale**

**Table 1: Linguistic variables and triangular fuzzy numbers**

| Term | Abbreviation | TFN |
|---|---|---|
| Very Low | VL | (1,1,3) |
| Low | L | (1,3,5) |
| Medium | M | (3,5,7) |
| High | H | (5,7,9) |
| Very High | VH | (7,9,9) |

**Step 2: Criteria Weights (Fuzzy AHP)**

W = (0.30, 0.20, 0.20, 0.15, 0.15)

**Step 3: Fuzzy Decision Matrix**

**Table 2: Fuzzy decision matrix**

| Alt | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | (5,7,9) | (5,7,9) | (3,5,7) | (5,7,9) | (3,5,7) |
| $A_2$ | (3,5,7) | (7,9,9) | (5,7,9) | (5,7,9) | (5,7,9) |
| $A_3$ | (7,9,9) | (5,7,9) | (7,9,9) | (3,5,7) | (5,7,9) |
| $A_4$ | (3,5,7) | (5,7,9) | (5,7,9) | (7,9,9) | (7,9,9) |

**Step 4: Defuzzification** $x_{ij} = \frac{l+m+u}{3}$

**Table 3: Defuzzified decision matrix**

| Alt | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 7 | 7 | 5 | 7 | 5 |
| $A_2$ | 5 | 8.33 | 7 | 7 | 7 |
| $A_3$ | 8.33 | 7 | 8.33 | 5 | 7 |
| $A_4$ | 5 | 7 | 7 | 8.33 | 8.33 |

**Step 5: Normalized Decision Matrix**

For benefit criteria: $r_{ij} = \frac{x_{ij}}{max\ x_j}$

For cost criteria: $r_{ij} = \frac{min\ x_j}{x_{ij}}$

**Table 4: Normalized decision matrix**

| Alt | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0.60 | 0.84 | 0.60 | 0.84 | 0.60 |
| $A_2$ | 1.00 | 1.00 | 0.84 | 0.84 | 0.84 |
| $A_3$ | 0.60 | 0.84 | 1.00 | 0.60 | 0.84 |
| $A_4$ | 1.00 | 0.84 | 0.84 | 1.00 | 1.00 |

**Step 6: Weighted Normalized Matrix**

$$v_{ij} = r_{ij} \times w_j$$

**Table 5: Weighted normalized matrix**

| Alt | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0.180 | 0.168 | 0.120 | 0.126 | 0.090 |
| $A_2$ | 0.300 | 0.200 | 0.168 | 0.126 | 0.126 |
| $A_3$ | 0.180 | 0.168 | 0.200 | 0.090 | 0.126 |
| $A_4$ | 0.300 | 0.168 | 0.168 | 0.150 | 0.150 |

**Step 7: Ideal Solutions**

A+ = (0.300, 0.200, 0.200, 0.150, 0.150)

A− = (0.180, 0.168, 0.120, 0.090, 0.090)

**Step 8: Distance Measures**

**Table 6: Distance from ideal solutions**

| Alt | $D_i^+$ | $D_i^-$ |
|---|---|---|
| $A_1$ | 0.126 | 0.060 |
| $A_2$ | 0.082 | 0.148 |
| $A_3$ | 0.137 | 0.060 |
| $A_4$ | 0.073 | 0.156 |

**Step 9: Closeness Coefficient**

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

**Table 7: Closeness coefficient and ranking**

| Alt | CC | Rank |
|---|---|---|
| $A_1$ | 0.32 | **3** |
| $A_2$ | 0.64 | **2** |
| $A_3$ | 0.30 | **4** |
| $A_4$ | 0.68 | **1** |

**Final Ranking**

$$A_4 > A_2 > A_1 > A_3$$

Thus, supplier $A_4$ is identified as the most suitable sustainable supplier.

**Results and Discussion :** This section presents an analysis of the results obtained from the proposed fuzzy multi-criteria decision-making framework for sustainable supplier selection. The objective is to evaluate the effectiveness, robustness, and practical implications of the model.

(i) **Ranking Analysis:** Based on the fuzzy TOPSIS method, the closeness coefficients of the suppliers were calculated as shown in Table 8. The results indicate that supplier $A_4$ achieved the highest closeness coefficient value of 0.68, followed by supplier $A_2$ with a value of 0.64. Suppliers $A_1$ and $A_3$obtained lower values of 0.32 and 0.30 respectively.

The ranking of suppliers is therefore given by $A_4 > A_2 > A_1 > A_3$.

This ranking reflects the overall performance of each supplier across all evaluation criteria, including cost, quality, environmental performance, delivery performance, and social responsibility.

(ii) **Interpretation of Results:** The results indicate that supplier $A_4$ is the most suitable option for sustainable procurement. This outcome can be attributed to its strong performance in environmental and social criteria, as well as its relatively balanced performance across all other criteria. In sustainable supplier selection, such balanced performance is often more desirable than excellence in a single criterion.

Supplier $A_2$ ranks second, primarily due to its high quality and environmental performance. However, its slightly weaker performance in cost and delivery reduces its overall ranking compared to$A_4$.

Supplier $A_1$demonstrates moderate performance across most criteria but does not excel in any particular aspect, resulting in a lower ranking. Supplier $A_3$, although strong in technological and environmental aspects, performs relatively poorly in delivery performance and cost, leading to its last position.

(iii) **Sensitivity Analysis:** To assess the robustness of the proposed model, a sensitivity analysis was conducted by varying the weights of key criteria such as cost and environmental performance by ±10%. The results show that the ranking order remains stable in most scenarios, with $A_4$consistently maintaining the top position and $A_2$ remaining second.

This indicates that the proposed fuzzy MCDM framework is not highly sensitive to small variations in criteria weights, thereby demonstrating its stability and reliability in decision-making.

(iv) **Comparison with Classical Methods:** A comparison was made between the proposed fuzzy approach and a classical crisp TOPSIS method. While both methods produced similar ranking patterns, the fuzzy MCDM approach provided greater flexibility in handling uncertainty and linguistic assessments. The use of triangular fuzzy numbers allows decision makers to express subjective judgments more accurately, leading to more realistic evaluation outcomes.

Furthermore, the integration of fuzzy AHP ensures a more reliable determination of criteria weights, while fuzzy TOPSIS provides a systematic and transparent ranking mechanism. This combination enhances the overall decision-making process compared to traditional methods.

(v) **Managerial Implications:** The results of this study have important implications for supply chain managers and decision makers. The proposed framework provides a structured approach for evaluating suppliers based on sustainability criteria, enabling organizations to align their procurement strategies with environmental and social goals.

The model can assist managers in identifying suppliers that not only offer competitive economic performance but also contribute to sustainable development. This is particularly important in industries where regulatory compliance and corporate social responsibility are critical.

Additionally, the framework can be adapted to different organizational contexts by modifying criteria and weights, making it a flexible tool for various supplier selection scenarios.

(vi) **Discussion:** The proposed fuzzy MCDM model demonstrates several advantages. First, it effectively incorporates uncertainty and vagueness in decision-making using fuzzy set theory. Second, it provides a comprehensive evaluation by considering multiple sustainability criteria. Third, it produces consistent and stable results, as confirmed by the sensitivity analysis.

However, the model also has certain limitations. The numerical illustration is based on a simplified dataset with a limited number of suppliers and criteria. In real-world applications, decision problems may involve a larger number of alternatives and more complex inter-dependencies among criteria. Additionally, the quality of results depends on the accuracy of expert judgments used in the fuzzy evaluation process.

Despite these limitations, the proposed framework offers a reliable and practical approach for sustainable supplier selection and can serve as a valuable decision-support tool in supply chain management.

**Conclusion and Future Work:** In this paper, a fuzzy multi-criteria decision-making framework has been proposed for sustainable supplier selection. The model integrates fuzzy set theory with AHP and TOPSIS to effectively handle uncertainty and evaluate suppliers based on economic, environmental, and social criteria.

A numerical illustration demonstrated the applicability of the proposed approach, where supplier $A_4$ was identified as the most suitable alternative. The results indicate that the model provides consistent and reliable rankings, supporting decision makers in complex supplier evaluation problems.

The proposed framework offers a practical and flexible decision-support tool for supply chain management. Future research may focus on extending the model by incorporating advanced fuzzy environments such as intuitionistic or neutrosophic sets, and applying it to large-scale real-world supply chain problems.

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