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# Optimizing Supplier Selection using Fuzzy MCDM

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***Abstract: This study explores the supplier selection problem within technology manufacturing by employing the Fuzzy Analytic Hierarchy Process (FAHP). Data was collected from a technology manufacturing company, and expert evaluations were sought from professionals with over 10 years of experience in the industry. The criteria considered for supplier selection included profitability of the supplier (C1), relationship closeness (C2), technological capability (C3), conformance quality (C4), and conflict (C5). The FAHP results indicated that relationship closeness (C2) ranked highest among the criteria, highlighting its significance in the supplier selection process, while conflict (C5) received the lowest ranking. These findings emphasize the importance of nurturing strong relationships with suppliers and vendors to enhance overall supply chain performance. The proposed FAHP model effectively addresses the complexities and uncertainties inherent in supplier evaluation, offering a robust decision-making tool tailored to the specific needs of technology manufacturing companies.***
***Keywords: Fuzzy Analytic Hierarchy Process (FAHP), Supplier Selection, Decision-Making, Technology Manufacturing***

## I. INTRODUCTION

In the modern business landscape, supply chain management is a critical factor for success, with supplier selection emerging as a key strategic decision. The performance of suppliers directly impacts a company's operational efficiency, influencing essential aspects such as product quality, cost control, and delivery reliability. Selecting the right suppliers, however, is a complex process that involves evaluating multiple criteria. Factors such as price, quality, delivery performance, and flexibility must all be considered, and these factors often involve both quantitative metrics and qualitative judgments, adding layers of complexity to the decision-making process. Traditional supplier selection methods typically rely on precise numerical data, but in reality, many decisions are influenced by uncertain or subjective information. Decision-makers often assess suppliers using linguistic terms like "good," "average," or "poor," reflecting subjective opinions rather than hard data. Such vagueness and uncertainty make it difficult to apply conventional methods that depend on crisp values. This is where fuzzy set theory becomes particularly useful, as it allows for the modeling of imprecise information and accommodates the subjective nature of human judgment, making it an ideal tool for addressing real-world supplier selection challenges. In this paper, we propose a fuzzy multi-criteria decision-making (MCDM) model that integrates fuzzy set theory with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. This model uses linguistic values, represented as trapezoidal or triangular fuzzy numbers, to evaluate both qualitative and quantitative factors in the supplier selection process. By calculating the closeness coefficient, which measures the proximity of each supplier to both the fuzzy positive-ideal solution (FPIS) and the fuzzy negative-ideal solution (FNIS), the proposed method provides a clear ranking of suppliers. The effectiveness of the model is demonstrated through a practical example, showing its suitability as a decision-making tool for supply chain systems.

## II. LITERATURE REVIEW

Supplier selection is a critical part of supply chain management and can significantly impact operational performance. Numerous studies have explored various models to address this complex problem, including multi-criteria decision-making (MCDM) techniques like the Analytic Hierarchy Process (AHP) and its fuzzy variant (FAHP). These methods have been found effective in handling both qualitative and quantitative criteria simultaneously (Rashidi & Cullinane, 2019).

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Fuzzy AHP has been widely used to deal with the uncertainty inherent in decision-making processes. Unlike traditional AHP, FAHP incorporates fuzzy set theory to handle vague or imprecise judgments, making it suitable for industries like technology manufacturing where uncertainty is prevalent (Kahraman et al., 2014).Supplier profitability has been identified as a fundamental criterion in various industries, including manufacturing, where it directly impacts cost savings and business performance. Researchers have emphasized the need to integrate profitability into multi-criteria decision frameworks to enhance supplier evaluation (Amindoust et al., 2012).Close relationships between suppliers and buyers foster long-term collaboration and improved performance. Several studies have highlighted relationship closeness as an essential qualitative factor in supplier evaluation models, particularly in industries with complex supply chains (Sarkis & Talluri, 2002).Technological capability is often used as a criterion to ensure that suppliers can meet current and future product development needs. Fuzzy AHP has been applied in numerous studies to weigh the technological capabilities of suppliers, especially in high-tech sectors (Chen & Huang, 2007).Quality conformance is a vital criterion when selecting suppliers, as it affects the overall performance and reliability of the supply chain. Research on FAHP highlights its effectiveness in assessing the quality standards maintained by suppliers (Ho, 2008).Conflict between suppliers and buyers can jeopardize supply chain efficiency, making it an important criterion to consider in evaluations. Studies have demonstrated the ability of FAHP to address conflict and manage its impact on decision-making processes (Demirtas & Üstün, 2008).Fuzzy AHP has been applied extensively in the technology manufacturing sector to optimize supplier selection processes. The integration of fuzzy logic allows decision-makers to better handle the complexity and uncertainty inherent in evaluating suppliers (Chan & Kumar, 2007).MCDM models like FAHP offer a systematic approach to supplier selection by addressing various conflicting criteria. This approach has been validated in multiple industries, including technology manufacturing, where complex trade-offs between criteria are common (Govindan et al., 2015).Numerous studies have compared different supplier selection methods, including AHP, FAHP, and TOPSIS. FAHP has been found particularly effective when dealing with imprecise or uncertain data, making it highly suitable for dynamic environments like manufacturing (Chou et al., 2011).Fuzzy logic has been extensively used in supply chain management to manage uncertainty and vagueness in data. Fuzzy AHP, in particular, has emerged as a robust tool for supplier selection, ensuring that both subjective and objective criteria are considered (Zimmermann, 2001).The integration of AHP with fuzzy logic has proven successful in addressing supplier selection challenges. Research shows that this combined approach enhances decision accuracy by accounting for uncertainty in expert judgments (Buyukozkan & Cifci, 2012).In high-tech industries, supplier selection requires the consideration of multiple criteria, including innovation capability and product development potential. Fuzzy AHP is often applied to these complex decision-making scenarios, where uncertainty plays a major role (Wang et al., 2009).Fuzzy set theory has been increasingly applied in decision-making frameworks like FAHP, particularly for scenarios involving vague information. It allows for more nuanced evaluations of criteria, which is essential in supplier selection (Zadeh, 1965).FAHP has been effectively used in the performance evaluation of suppliers, allowing decision-makers to weigh multiple performance metrics. This technique has been applied in industries ranging from manufacturing to service (Mendoza et al., 2008).Risk is an important consideration in supplier selection, particularly in industries with complex supply chains. Fuzzy AHP helps incorporate risk-related factors like financial stability and conflict potential into supplier evaluation models (Tsai et al., 2010).Studies have applied FAHP to supplier selection in emerging markets, where data uncertainty and lack of transparency often complicate decision-making. Expert judgment plays a significant role in FAHP applications, especially when dealing with qualitative criteria. Research shows that incorporating expert knowledge

### *A. Research Gap*

Despite extensive use of Fuzzy AHP for supplier selection, its application in technology manufacturing remains underexplored, particularly in addressing the industry's dynamic conditions and innovation requirements. Additionally, there is a lack of integration of sustainability and conflict management in FAHP models for this sector. Future research should focus on incorporating real-time data, balancing qualitative and quantitative factors, and leveraging advanced computational tools like AI for improved decision-making.

## III. FUZZY ANALYTIC HIERARCHY PROCESS (FUZZY AHP)

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty in 1980, organizes complex decisions into a hierarchical structure and uses pairwise comparisons to derive priority scales. Incorporating fuzziness, the method is extended with Triangular Fuzzy Numbers (TFN) to model uncertainty in judgments.

*1) Developing a fuzzy comparison matrix*

First the scale of linguistics is determined. The scale used is the TFN scale from one to nine are shows in Table 1.

Table 1. Scale of Interest

| Scale of Interest | Linguistic Variable | Membership Function |
|---|---|---|
| 1 | Equally important | (1,1,1) |
| 3 | Weakly important | (2,3,4) |
| 5 | Strongly more important | (4,5,6) |
| 7 | Very strongly important | (6,7,8) |
| 9 | Extremely important | (8,9,10) |

Then, using the TFN to make pair-wise comparison matrix for the main criteria and sub-criteria.
Equation (1) shows the form of fuzzy comparison matrix.

$$\bar{\mathcal{A}} = \begin{bmatrix} 1 & \cdots & \overline{a_{1n}} \\ \vdots & \ddots & \vdots \\ \overline{a_{n1}} & \cdots & 1 \end{bmatrix} \quad (1)$$

*2) Define Fuzzy Geometric Mean*

The fuzzy geometric mean is then calculated using Equation (2)[13]:

$$\bar{x_i} = \left(\bar{a}_{(i1)} \otimes \bar{a}_{(i2)} \otimes \ldots \otimes \bar{a}_{(in)}\right)^{\frac{1}{n}} \quad (2)$$

Where $\tilde{a}_{in}$ is a value of fuzzy comparison matrix from criteria I to n. Result from the fuzzy geometric mean will be referred to later as local fuzzy number.

*3) Calculate the weight of fuzzy of each dimension*

The next step is to calculate the global fuzzy number for each evaluation dimension with Equation (3).

$$\tilde{w}_i = \tilde{x}_1 \otimes (\tilde{x}_1 \oplus \tilde{x}_1 \oplus \ldots \oplus \tilde{x}_1)^{-1} \quad (3)$$

*4) Define the best non fuzzy performance (BNP)*

The global fuzzy number is then converted to crisp weight value using the Centre of Area (COA) method to find the value of best BNP from the fuzzy weight in each dimension, calculated using Equation (4).

$$BNP_{wi} = \frac{[(u_{wi} - l_{wi}) + (m_{wi} - l_{wi})]}{3} + l_{wi} \quad (4)$$

*A. Case Study*

The numerical experimental data was collected from a single source, specifically a technology manufacturing company. Afterward, the questionnaire was carefully reviewed by experts with over 10 years of experience in the technology manufacturing sector, who also contributed to the pairwise comparison matrix. This study considered several key criteria, including supplier profitability (C1), relationship closeness (C2), technological capability (C3), conformance quality (C4), and conflict (C5). These criteria were then used to determine their respective weights through the Fuzzy Analytic Hierarchy Process (FAHP). The FAHP results are displayed in Table 1.

Table 1:Determining the weights of the criteria by FAHP Approach

| Criteria | $C_1$ | $C_2$ | $C_3$ | $C_4$ | C5 |
|---|---|---|---|---|---|
| Fuzzy Weights | 0.1804 | 0.1954 | 0.1740 | 0.1837 | 0.1730 |
| Rank | 3 | 1 | 4 | 2 | 5 |

## IV. CONCLUSION

In conclusion, this research underscores the pivotal role of various criteria in the supplier selection process within the technology manufacturing sector. Using the Fuzzy Analytic Hierarchy Process (FAHP), we evaluated five critical criteria: profitability of the supplier (C1), relationship closeness (C2), technological capability (C3), conformance quality (C4), and conflict (C5). The results indicated that relationship closeness (C2) emerged as the most significant criterion, emphasizing its importance in establishing effective supplier partnerships. Conversely, conflict (C5) was ranked the lowest, suggesting that minimizing conflicts is essential but secondary to building strong relationships. These findings highlight the necessity for technology manufacturing companies to focus on nurturing supplier relationships to enhance operational efficiency and competitiveness. For future work, research should explore the integration of sustainability and environmental considerations into the FAHP model. Additionally, the development of dynamic supplier selection frameworks that utilize real-time data and machine learning algorithms could further improve decision-making processes. By incorporating these elements, future studies can provide a more comprehensive approach to supplier evaluation, ensuring adaptability and resilience in an ever-evolving marketplace.

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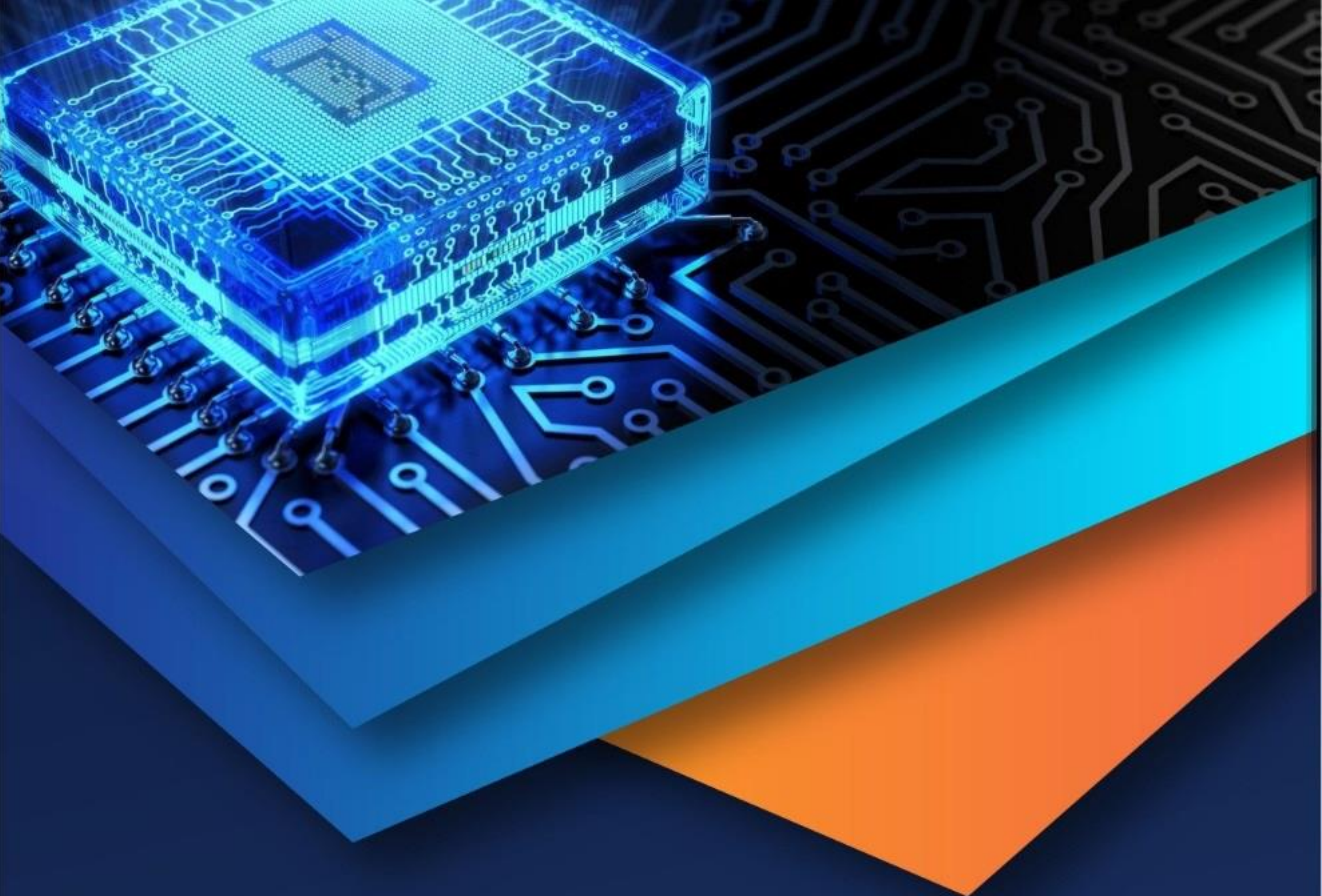


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