iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IX Month of publication: September 2025

DOI: https://doi.org/10.22214/ijraset.2025.74274

Application of Fuzzy Multi-Criteria Decision Making in Entrepreneurial Venture Evaluation

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Abstract: This study investigates vendor selection criteria within the framework of supply chain management using the Fuzzy Analytic Hierarchy Process (FAHP). To ensure reliability, expert insights were obtained from two industry professionals, each with over 30 years of experience. Six key criteria were evaluated: Quality (C1), Cost and Value (C2), Delivery and Logistics (C3), Customer Service and Support (C4), Security and Risk Management (C5), and Technical Expertise and Capabilities (C6). The FAHP approach was applied to determine the relative importance of these factors. The analysis showed that Cost and Value (C2) emerged as the most critical consideration, while Quality (C1) ranked lowest in priority. These results offer valuable guidance for organizations, highlighting the need to prioritize cost efficiency and value creation when formulating vendor selection strategies.
Keywords: Vendor Selection, Supply Chain Management, Fuzzy Analytic Hierarchy Process (FAHP), Customer Service and Support

I. INTRODUCTION

In today's highly competitive and dynamic business environment, supply chain management (SCM) has emerged as a strategic function that directly influences organizational performance, customer satisfaction, and long-term sustainability. Among the critical decisions within SCM, vendor selection is of paramount importance. Vendors are not only providers of raw materials, products, or services but also strategic partners whose performance directly impacts cost structures, product quality, delivery efficiency, and the overall resilience of the supply chain. Choosing the right vendor strengthens competitiveness and operational efficiency, whereas poor vendor selection can result in delays, increased costs, reputational risks, and in some cases, total supply chain failure. Traditionally, vendor selection has been based on simple measures such as cost and quality. While these factors remain important, modern supply chains have grown increasingly complex and interdependent, requiring decision-makers to consider a broader range of evaluation criteria. Delivery performance, customer service, security and risk management, technical capabilities, and long-term value creation are now equally significant in determining the suitability of a vendor. Furthermore, globalization, digitalization, and disruptive events such as pandemics or geopolitical tensions have added layers of uncertainty and volatility, making vendor selection more challenging than ever before. This complexity has positioned vendor selection as a classic multi-criteria decision-making (MCDM) problem. Unlike traditional single-criterion approaches, MCDM techniques allow organizations to evaluate multiple, often conflicting, factors simultaneously. However, a significant limitation of many classical models is their inability to adequately handle the uncertainty and subjectivity inherent in human judgments. Vendor evaluation often involves qualitative assessments—such as reliability, responsiveness, or innovation—which decision-makers tend to express in linguistic terms like "high," "moderate," or "low." Translating these qualitative perceptions into precise numerical values is problematic, and conventional methods may oversimplify or distort expert opinions.

To address these challenges, fuzzy set theory has been increasingly adopted in decision-making models. Fuzzy logic provides a mathematical framework for representing vague or imprecise information, allowing decision-makers to express their judgments more naturally and realistically. One of the most widely used methods that integrates fuzzy logic into MCDM is the Fuzzy Analytic Hierarchy Process (FAHP).

FAHP is an extension of the traditional Analytic Hierarchy Process (AHP), which is well known for structuring complex decision problems into a hierarchy of criteria and alternatives, followed by pairwise comparisons to determine relative importance.

By incorporating fuzzy numbers into the pairwise comparison process, FAHP enables decision-makers to capture the uncertainty and vagueness of their judgments, thus producing more reliable and consistent results. The application of FAHP in vendor selection has been widely documented in the literature. Researchers have employed FAHP to evaluate suppliers in manufacturing, healthcare, construction, and IT services, among others. Studies have demonstrated its effectiveness in capturing subjective expert opinions, aggregating preferences, and generating priority weights for diverse criteria. For example, FAHP has been applied to sustainable supplier evaluation, green procurement, risk assessment, and vendor performance monitoring. These applications highlight its flexibility and robustness in supporting strategic procurement decisions. However, despite the growing body of research, most studies treat vendor selection as a static decision-making process—evaluating vendors at a single point in time without considering how vendor performance or organizational priorities may change over multiple periods. In reality, vendor selection is often a dynamic and continuous process. A supplier that performs well today may fail to meet requirements in the future due to changes in market conditions, financial stability, technology, or service levels. Similarly, organizational priorities may evolve, requiring re-evaluation of vendors across different time horizons. Yet, the majority of existing models neglect this time axis and focus on one-off evaluations. This creates a significant research gap: the need for a vendor selection model that incorporates both uncertainty in human judgment and the dynamic, time-based nature of vendor performance.

This study seeks to address this gap by proposing a vendor selection framework that integrates FAHP with a time-based evaluation model. Unlike traditional approaches that ignore the planning horizon, the proposed framework allows organizations to assess vendors across multiple periods, capturing changes in performance and aligning selection decisions with evolving strategic objectives. By combining the strengths of fuzzy logic and hierarchical structuring, the model provides a systematic, flexible, and practical tool for vendor evaluation under uncertainty. The purpose of this paper is therefore twofold. First, it aims to extend existing vendor selection research by introducing a dynamic FAHP-based model that incorporates the time axis into the evaluation framework. Second, it seeks to demonstrate the practical utility of FAHP in capturing the uncertainties associated with expert opinions and providing consistent, data-driven vendor rankings across multiple periods. By doing so, the study contributes both to theory and practice. From a theoretical standpoint, it enriches the literature on MCDM applications in supply chain management by bridging the gap between static evaluation models and dynamic, time-based approaches. From a practical standpoint, it provides supply chain managers and procurement professionals with an efficient decision-support tool that improves the accuracy, transparency, and robustness of vendor selection decisions. The findings of this research are expected to provide meaningful insights for both researchers and practitioners. By offering a step-by-step procedure for applying FAHP in a dynamic, time-based context, the study demonstrates a simple yet powerful method for enhancing vendor evaluation. Organizations adopting this approach will be better positioned to respond to uncertainty, adapt to evolving conditions, and strengthen long-term vendor relationships. Moreover, the model's adaptability ensures that it can be applied across industries and contexts, making it a valuable contribution to the broader field of supply chain management.

A. Literature Review

The development of supplier selection methods has evolved significantly over the past decades, drawing from multiple disciplines such as operations research, fuzzy set theory, and decision sciences. Early studies emphasized traditional multi-criteria decision-making techniques, while later research incorporated more sophisticated approaches, including fuzzy logic, stochastic programming, and hybrid optimization models. During the 1990s, several studies explored supplier evaluation from both conceptual and empirical perspectives. For instance, Verma and Pullman (1998) examined discrepancies between managers' stated importance of supplier attributes and their actual supplier choices in experimental settings. Boer et al. (1998) demonstrated that outranking approaches could be effectively applied in supplier selection decisions, while O'Brien and Ghodsypour (1998) integrated the Analytic Hierarchy Process (AHP) with linear programming to capture both tangible and intangible supplier factors. Similarly, Ganeshan et al. (1999) investigated cost economics when sourcing from reliable versus unreliable suppliers, highlighting the role of logistics and inventory dynamics. Parallel to these advancements, scholars investigated supplier relations in international and strategic contexts. Motwani et al. (1999) developed a sourcing and purchasing model tailored to developing countries, and Ittner et al. (1999) explored how supplier monitoring practices influence organizational performance. Earlier, Dowlatshahi (2000) proposed a framework for integrating supplier relations across strategic, tactical, and operational planning horizons, presenting nine propositions for effective interface management. Masella and Rangone (2000) further contributed by categorizing vendor selection systems (VSSs) into short-term versus long-term, and logistic versus strategic approaches.

With the expansion of quantitative techniques, the 2000s saw the introduction of new models and methodologies. Liu et al. (2000) and Braglia & Petroni (2000) applied Data Envelopment Analysis (DEA) to compare suppliers and support performance improvement. Ghodsypour and O'Brien (2001) advanced this work by presenting a mixed-integer nonlinear programming model for multi-sourcing that accounted for logistics costs, budget constraints, and service quality. Feng et al. (2001) incorporated stochastic integer programming to optimize supplier and tolerance selection simultaneously using quality loss functions and process capability indices. In a parallel stream, Boer et al. (2001) conducted a comprehensive review of decision-making methods for supplier selection, consolidating earlier findings.

Fuzzy set theory and its extensions began to play a stronger role during this era. Cebeci and Kahraman (2002), and Cebeci (2001), for example, applied the Fuzzy Analytic Hierarchy Process (FAHP) to measure customer satisfaction in Turkish catering service companies. Choy and Lee (2002) introduced a Case-Based Supplier Management Tool (CBSMT) using Case-Based Reasoning (CBR), providing an intelligent supplier selection and management framework that outperformed traditional approaches. Earlier foundational studies also contributed critical insights. Noci (1997) emphasized supplier selection from an environmental performance perspective, while Choi and Hartley (1996) compared supplier practices across auto industry tiers. Mummalaneni et al. (1996) examined trade-offs made by Chinese managers among six supplier attributes, and Swift (1995) analyzed sourcing preferences for single versus multiple suppliers. Going further back, Chao et al. (1993) identified six key supplier selection criteria in China, while Weber and Ellram (1993) applied multi-objective programming to Just-in-Time (JIT) supplier selection. Partovi et al. (1990) reviewed AHP applications in supplier evaluation, and Willis & Huston (1990) proposed dimensional analysis for JIT purchasing systems. Together, these studies demonstrate the gradual evolution of supplier selection research: from traditional cost- and quality-based evaluation to integrated, fuzzy, and hybrid decision-making models that account for uncertainty, environmental concerns, and strategic partnerships.

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II. FUZZY ANALYTIC HIERARCHY PROCESS (FUZZY AHP)

The Analytic Hierarchy Process (AHP), introduced by Thomas L. Saaty in 1980, simplifies complex decision-making by structuring it into a hierarchical model and employing pairwise comparisons to establish priority scales. To address the uncertainty in judgments, this method has been enhanced with Triangular Fuzzy Numbers (TFNs), allowing for a more flexible and nuanced evaluation.

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).

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

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) Quality

Quality refers to the standard of products or services delivered by the vendor. A reliable vendor should consistently provide goods or services that meet or exceed the required specifications, standards, and regulatory guidelines. High quality ensures fewer defects, reduced rework, improved customer satisfaction, and long-term reliability. Quality is often verified through certifications (e.g., ISO 9001), inspection reports, and past performance records.

b) Cost and Value

Cost is not only about the initial purchase price but also the total cost of ownership (TCO), which includes shipping, maintenance, installation, operational costs, and potential downtime. Value refers to the balance between cost and benefits received. A vendor offering the lowest price may not always provide the best value if the quality, durability, or after-sales service is poor. The ideal vendor provides competitive pricing while maximizing value through efficiency, innovation, and reliability.

c) Delivery and Logistics

This criterion evaluates the vendor's ability to deliver products or services on time, in the right quantity, and to the correct location. It includes aspects such as lead time, flexibility in handling urgent orders, global reach, and supply chain reliability. Efficient logistics reduce delays, minimize inventory costs, and enhance operational flow. Vendors with strong logistics networks and proven track records are preferred, especially in industries where timing is critical.

d) Customer Service and Support

Customer service encompasses how well a vendor supports clients before, during, and after the purchase. This includes responsiveness to inquiries, complaint handling, availability of technical support, training, and warranty services. Vendors with excellent customer service help maintain smooth operations, minimize downtime, and build long-term partnerships. Effective communication channels, quick problem resolution, and proactive support are crucial evaluation points.

e) Security and Risk Management

Vendors must demonstrate their ability to safeguard sensitive data, maintain regulatory compliance, and minimize risks such as fraud, supply disruptions, or cyber threats. This criterion is especially important when dealing with IT vendors, financial services, or critical supply chains. Risk management also involves contingency planning, disaster recovery, financial stability, and adherence to environmental and legal standards. A vendor's ability to mitigate risks ensures business continuity and reduces vulnerability.

f) Technical Expertise and Capabilities

This evaluates whether the vendor has the necessary knowledge, skills, technology, and infrastructure to deliver on requirements. Technical expertise is critical in industries such as IT, engineering, manufacturing, and healthcare. Vendors with advanced tools, innovation capacity, R\&D facilities, and skilled personnel are more capable of meeting evolving demands. Their ability to upgrade, customize, and innovate adds long-term value to the partnership.

A. Case Study

In this study, data were collected based on expert opinions. The industrial experts consulted possess more than 30 years of experience in the field of supply chain management, ensuring credibility in the evaluation process. The study considered six key criteria: Quality (C1), Cost and Value (C2), Delivery and Logistics (C3), Customer Service and Support (C4), Security and Risk Management (C5), and Technical Expertise and Capabilities (C6). The Fuzzy Analytic Hierarchy Process (FAHP) was then employed to determine the relative importance weights of these criteria, with the results presented in Table 1.

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

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
Fuzzy Weights	0.1033	0.1858	0.1850	0.1537	0.1417	0.1191
Rank	6	1	2	3	4	5

B. Results and Discussion

"From Table 1, the results indicate that Cost and Value (C2) secured the first rank according to the FAHP analysis. This was followed by Delivery and Logistics (C3), Customer Service and Support (C4), Security and Risk Management (C5), and Technical Expertise and Capabilities (C6), which were ranked second, third, fourth, and fifth, respectively. Quality (C1) received the lowest rank among the six criteria. These results provide valuable insights for vendor selection, as they highlight that cost efficiency and value creation are considered the most critical factors by experts, while quality, though important, is relatively less prioritized in this evaluation framework. This prioritization can assist decision-makers in aligning vendor strategies with organizational objectives, ensuring better resource allocation and improved supply chain performance."

III. CONCLUSION

This study examined the evaluation of vendor selection criteria in supply chain management using the Fuzzy Analytic Hierarchy Process (FAHP). By consulting two highly experienced industry experts, six key criteria—Quality, Cost and Value, Delivery and Logistics, Customer Service and Support, Security and Risk Management, and Technical Expertise and Capabilities—were assessed for their relative importance. The findings indicate that Cost and Value is the most significant factor in vendor selection, whereas Quality holds the lowest priority among the evaluated criteria. These results emphasize the importance of aligning vendor selection strategies with practical organizational priorities, particularly focusing on cost efficiency and value creation. The study demonstrates that FAHP provides a systematic and reliable approach for quantifying expert judgments under uncertainty, offering actionable insights for supply chain decision-makers. Future research may extend this framework to include dynamic, time-based evaluations or integrate additional sustainability and risk-related criteria to further enhance decision-making accuracy and strategic alignment.

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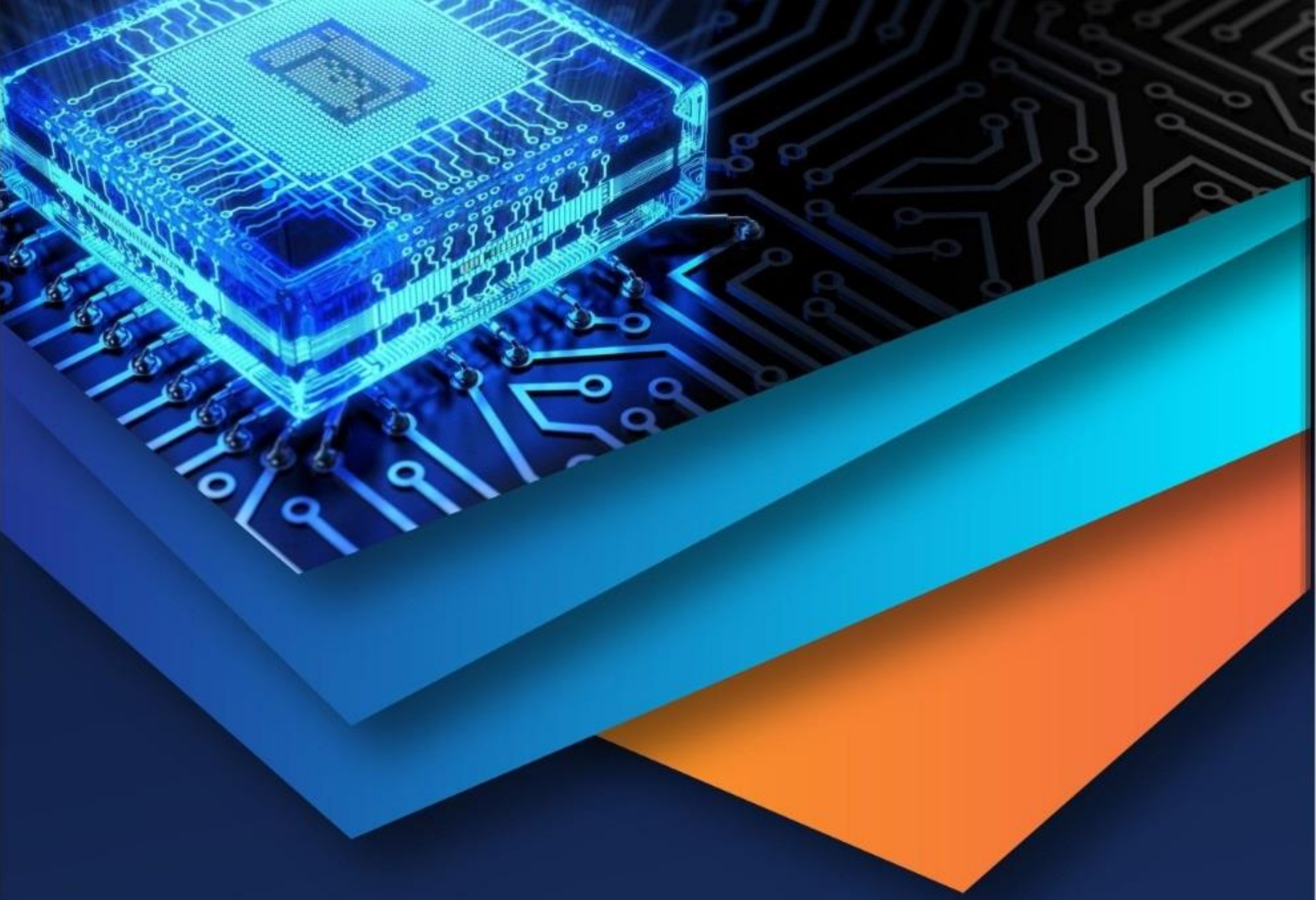

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