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Fuzzy Analytic Hierarchy Process (FAHP) Based performance Assessment of Textile Industry in Tirupur

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Abstract
This study investigates the application of the Fuzzy Analytic Hierarchy Process (FAHP) to evaluate and prioritize key decision criteria in supply chain management within the textile industry of the Tirupur district. A structured questionnaire was developed and validated by industry experts possessing over 30 years of professional experience. The study employs pairwise comparisons to assess four major criteria: cost (C1), quality (C2), total cost of ownership (TCO) (C3), and financial stability (C4). By incorporating fuzzy logic into the traditional AHP framework, FAHP effectively addresses uncertainty and subjectivity in expert judgments. The results provide a systematic and reliable approach for enhancing decision-making in textile supply chain operations and support improved management and optimization of supply chain processes.

Keywords: *Fuzzy Analytic Hierarchy Process (FAHP), Textile Industry, Decision-Making, Criteria*

1. Introduction

Supply chain management (SCM) plays a crucial role in enhancing competitiveness, efficiency, and sustainability in the textile industry, particularly in highly dynamic and cost-sensitive markets. The textile cluster in the Tirupur district is one of the largest knitwear manufacturing hubs in India, contributing significantly to exports and employment. However, the industry faces persistent challenges related to cost control, quality assurance, supplier reliability, and financial stability, all of which directly impact supply chain performance. Effective evaluation and prioritization of these factors are essential for informed decision-making and long-term competitiveness. Traditional decision-making approaches often struggle to address the inherent uncertainty and subjectivity associated with complex supply chain criteria. The Analytic Hierarchy Process (AHP) is widely used for multi-criteria decision-making, but it relies on precise judgments, which may not accurately reflect real-world ambiguity. To overcome this limitation, the Fuzzy Analytic Hierarchy Process (FAHP) integrates fuzzy logic with AHP, enabling more realistic modeling of human judgment and uncertainty.

This study applies FAHP to evaluate and prioritize key supply chain criteria—cost, quality, total cost of ownership (TCO), and financial stability—within the textile industry of the Tirupur district. Expert opinions were collected through a structured questionnaire and analyzed using pairwise comparisons under a fuzzy environment. The objective of this research is to provide a systematic and reliable decision-support framework that enhances supply chain management practices in the textile sector.

2. Literature review

The implementation of the Fuzzy Analytic Hierarchy Process (FAHP) for supplier selection in the textile industry aims to address the uncertainty and subjectivity inherent in evaluating complex and often conflicting criteria such as cost, quality, and sustainability. FAHP enhances decision-making by employing fuzzy numbers to represent the imprecision of human judgments, thereby enabling more flexible, realistic, and accurate pairwise comparisons among evaluation criteria. The foundational work of Chang (1996) introduced FAHP by integrating fuzzy logic into the traditional AHP framework to effectively manage uncertainty in multi-criteria decision-making. Building on this approach, numerous studies have demonstrated the applicability of FAHP in textile and manufacturing contexts. Kannan et al. (2016) applied FAHP to sustainable supplier selection in the Indian textile industry, emphasizing the trade-offs between cost efficiency, product quality, and environmental impact. Similarly, Bhattacharya and Sarkar (2017) employed FAHP to evaluate suppliers based on environmental performance, reflecting the growing

importance of sustainability in supply chain decisions. Several researchers have extended FAHP by integrating it with other multi-criteria decision-making (MCDM) techniques. Mangla et al. (2017) combined FAHP with hybrid MCDM methods to assess green suppliers in the textile dyeing industry, incorporating criteria such as cost, quality, and environmental impact. Luthra and Mangla (2018) reviewed hybrid FAHP-based models, including integrations with TOPSIS and VIKOR, highlighting their effectiveness in strengthening decision-making robustness. Wang and Lee (2009) also proposed a hybrid FAHP framework that remains influential in contemporary supplier selection research.
Further advancements include the integration of FAHP with optimization and goal-oriented approaches. Govindan and Chaudhuri (2019) combined FAHP with goal programming to select suppliers that align with specific sustainability and performance objectives. Case studies by Yazdani and Hashemkhani Zolfani (2017) and Ho and Xu (2019) demonstrated FAHP's effectiveness in textile supplier selection across different national and multinational contexts, accounting for regulatory and performance requirements. Kumar and Sharma (2020) further validated FAHP in the Indian textile sector by prioritizing suppliers based on quality, delivery performance, and cost. The applicability of FAHP to sustainability-driven supplier evaluation has been widely acknowledged. Govindan, Khodaverdi, and Jafarian (2016) highlighted FAHP's capability to handle both qualitative and quantitative sustainability criteria, while Kumar and Vrat (2018) focused on green supplier selection in textile dyeing industries, incorporating factors such as energy consumption and waste management. Earlier contributions by Chan and Kumar (2007) laid the groundwork for sustainability-oriented supplier selection models using FAHP.

Recent studies have explored the integration of emerging technologies with FAHP. Bag and Pretorius (2019) examined the role of digital technologies and big data analytics in enhancing FAHP-based supplier selection. Additionally, Mikhailov and Singh (1999) developed fuzzy ranking methods that provided a theoretical foundation for later FAHP applications involving complex evaluation criteria. Garg and Sharma (2021) discussed future research directions, emphasizing the incorporation of artificial intelligence and machine learning techniques to address increasingly complex supplier selection problems.Overall, the extensive literature demonstrates that FAHP is a powerful and flexible decision-support tool for supplier selection in the textile industry. By balancing conflicting criteria and incorporating qualitative factors such as environmental impact and sustainability, FAHP significantly enhances the quality and reliability of supplier selection decisions in modern textile supply chains.

3. 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).

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

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).

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

3.1. Case study

The numerical experimental data was collected from one place such that tirupur. After that, the questionnaire was reviewed by the Experts more than 30 years' textile industries experience and to make the pairwise comparison of the matrix. This study considered the various types of criteria such as cost (C1), quality (C2), **Total Cost of Ownership (TCO)** (C3), and **Financial Stability** (C4).

. The above criteria we considered to determine the weight of the criteria by using Fuzzy AHP. The FAHP value are shows in Table 1.

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

Criteria	C_1	C_2	C_3	C_4
Fuzzy Weights	0.1704	0.1860	0.1641	0.1537
Rank	2	1	3	4

4. Conclusion

This study demonstrates the effectiveness of the Fuzzy Analytic Hierarchy Process (FAHP) as a robust decision-making tool for evaluating and prioritizing critical supply chain criteria in the textile industry of the Tirupur district. By incorporating fuzzy logic into the traditional AHP framework, the proposed approach successfully addresses the uncertainty and subjectivity inherent in expert judgments. The analysis highlights the relative importance of cost, quality, total cost of ownership, and financial stability, offering valuable insights for supply chain managers and decision-makers. The findings emphasize the need for a balanced evaluation of both financial and operational factors when selecting suppliers and formulating supply chain strategies. The FAHP-based framework provides a structured and transparent method that can support improved decision-making, risk reduction, and performance optimization in textile supply chains. Moreover, the methodology can be adapted and extended to other industrial sectors or integrated with additional criteria for more comprehensive analysis. Future research may focus on incorporating sustainability, environmental impact, and technological capabilities as additional criteria, as well as applying hybrid decision-making models to further enhance supply chain resilience and competitiveness.

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