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Halal sustainable supplier selection using an integrated F-AHP and F-TOPSIS approach: A case study in the meat supply chain in Malang

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ABSTRACT
The halal meat supply chain faces unique challenges, including strict halal certification requirements, sustainability concerns, and the need for advanced traceability systems. Small and medium-sized enterprises (SMEs) frequently struggle to comply owing to financial and technological constraints. This study aims to construct a structured decision-making framework for selecting halal sustainable meat suppliers by combining the Fuzzy Analytical Hierarchy Process (F-AHP) and the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS). F-AHP is used to define the evaluation criteria, build the hierarchical structure, and compute the relative weights using expert pairwise comparisons. Moreover, F-TOPSIS is used to evaluate suppliers, normalize the decision matrix, discover positive and negative ideal solutions, and compute the closeness coefficient to produce the final ranking. The results show that halal compliance is the most critical factor in supplier selection, with halal certification and product quality as the top priorities. The proposed framework provides a systematic approach to integrating halal and sustainability principles in supplier evaluation, supporting supply chain managers in making informed decisions while upholding worldwide halal and ecological requirements.

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F-AHP, F-TOPSIS, Halal compliance, Halal sustainable supply chain, Meat industry, Supplier selection.

INTRODUCTION

The global demand for halal meat products has been continuously increasing due to the growing Muslim population and growing awareness of ethical and sustainable food choices (Rahman et al., 2024). The halal meat supply chain has special characteristics since it must adhere to not only fundamental sustainability principles but also stringent halal certification standards (Bachtiar et al., 2024). The halal meat certification ensures that the product complies with Islamic laws governing permissibility, hygiene, and ethical treatment (Rahman et al., 2024). However, halal sustainable meat suppliers have distinct challenges that distinguish ahead from the conventional counterparts. As an instance, businesses must ensure animal welfare through following traditional Islamic slaughtering practices, which require the animal to be healthy, slaughtered by a qualified individual, and processed in a manner that minimizes suffering (Pozzi et al., 2015). Furthermore, halal products must be separate from non-halal items throughout the supply chain, including transportation, storage, and processing (Falahudin et al., 2025). Traceability systems are crucial for maintaining segregation and adhering to halal standards. Furthermore, sustainability issues such as reducing greenhouse gas emissions from livestock production, minimizing waste generated during meat processing, and ensuring effective water and energy usage are becoming increasingly important (Sakadevan & Nguyen, 2017). Suppliers must also navigate complex regulatory preferences to combine international halal certification requirements with regional sustainability standards. The growing consumer preference for ethical and environmentally friendly products puts further pressure on suppliers to embrace cutting-edge practices like renewable energy use and waste recycling initiatives.

Halal laws for small and medium-sized meat enterprises (SMEs) may necessitate significant investments in training, infrastructure, and certification processes (Ariffin et al., 2023; Luthfiya et al., 2024). SMEs may also have challenges in obtaining the technology needed for advanced traceability systems, as well as the financial means to engage in sustainable practices. Despite these hurdles, meeting both criteria offers significant benefits, including access to high-value markets, increased customer trust, and alignment with global environmental goals. Both limits and opportunities make selecting halal sustainable beef suppliers an important feature of supply chain management. The study's limitation is the lack of integration of halal compliance and sustainability principles into supplier selection frameworks, particularly for meat providers, where issues such as traceability, animal welfare, and environmental effect are commonly disregarded in prior research.

The complexity of incorporating halal and environmental considerations into supplier selection emphasizes the necessity for structured decision-making techniques. Fuzzy AHP and Fuzzy TOPSIS are two complementary approaches used extensively in the food industry to prioritize criteria and rate alternatives under uncertainty. Fuzzy AHP is primarily focused on organizing complex decision problems into hierarchical frameworks and determining the relative weights of criteria and sub-criteria via pairwise comparisons. Expert opinions are represented linguistically and then transformed into fuzzy numbers, allowing decision-makers to better understand the imprecision inherent in qualitative assessments (Herrera-Viedma et al., 2021). Fuzzy AHP has been used to prioritize factors like food safety (Yadav et al., 2023), nutritional quality (Lakshmi et al., 2023), sustainability attributes (Rehman et al., 2019), and halal assurance (Wijaya & Widodo, 2023).

Furthermore, fuzzy TOPSIS ranks options based on their distance from a Fuzzy Positive Ideal Solution (FPIS) and a Fuzzy Negative Ideal Solution (FNIS). This strategy assumes that the optimal alternative should be as close as feasible to the ideal solution while being as far away from the least desirable one (Çelikbilek & Tüysüz, 2020). In food-related applications, Fuzzy TOPSIS has been used to evaluate sustainable packaging choices (Hajiaghaei-Keshteli et al., 2023), assessing food supplier performance under uncertainty (Mohammed, 2020), and ranking environmentally friendly production alternatives (Goyal et al., 2021). Its capacity to integrate several opposing aspects makes it particularly useful in the food business, where cost efficiency, product quality, halal compliance, and sustainability must all be balanced. The combination of Fuzzy AHP and Fuzzy TOPSIS creates a more robust framework for making decisions in the food business. While Fuzzy AHP determines the relative importance of assessment criteria, Fuzzy TOPSIS ranks the available options based on these weighted criteria.

This study bridges the gap by providing a framework for halal sustainable supplier selection based on an integrated Fuzzy AHP and Fuzzy TOPSIS. The study aims to: (1) identify and prioritize criteria that reflect halal and sustainable principles in the meat supply chain; and (2) evaluate and rank halal meat providers using Fuzzy AHP - Fuzzy TOPSIS. Through merging the Fuzzy AHP and Fuzzy-TOPSIS, the proposed framework offers a structured and adaptive decision-making approach that contributes to the understanding of halal and sustainable supply chains. This paper is structured as follows: Section 2 describes the research methodology, including the creation of the integrated Fuzzy AHP and Fuzzy TOPSIS framework and data gathering procedures. The results and analysis are presented in Section 3, which uses a case study of halal meat vendors to demonstrate the framework's implementation. Section 4 summarizes the study's findings. Section 6 concludes by summarizing the research, limitations of the study, and suggestions for future research.

RESEARCH METHOD

The methodology of this study consists of two phases. In the first phase, Fuzzy AHP is employed to break down the decision-making problem into a hierarchical structure for the prioritization of criteria based on expert evaluation. In the second phase, Fuzzy TOPSIS is applied to rank suppliers while

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incorporating the uncertainty inherent in subjective assessments. The research was conducted in Malang, Indonesia, focusing on a medium-sized meat logistics company that supplies both local markets and regional distributors.

Fuzzy Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a decision-making method developed by Prof. Thomas. L. Saaty in the 1970s. The AHP concept is based on the theory of hierarchical structure, prioritization, and reasonable consistency (Saaty, 2008). However, the classic AHP has several shortcomings, including an imbalanced rating scale and imprecise rankings that do not accurately transform the judgment into numerical values. Subjective impressions have a considerable influence on AHP outcomes (Zuo & Wang, 2020). To address these challenges, researchers used fuzzy theory with AHP. The steps of the fuzzy AHP are as follows:

1. Step 1: Define the Criteria and Sub-Criteria

   The first step is to establish the criteria and sub-criteria relevant to halal sustainable supplier selection based on a literature review and expert opinions, including supply chain managers, quality assurance specialists, and purchasing officers.

2. Step 2: Construct the Matrix of Pairwise Comparison

   Experts provide pairwise comparisons of criteria using a linguistic scale, which is then converted into fuzzy triangular numbers. The linguistic scale is defined as Table 1, follows:

Table 1. Linguistic scale.

Linguistic Scale	Fuzzy Number (Triangular Form)
Perfect (P)	(8, 9, 10)
Absolute (A)	(7, 8, 9)
Very good (VG)	(6, 7, 8)
Fairly good (FG)	(5, 6, 7)
Good (G)	(4, 5, 6)
Preferable (P)	(3, 4, 5)
Not bad (NB)	(2, 3, 4)
Weak advantage (WA)	(1, 2, 3)
Equal (E)	(1, 1, 1)

3. Step 3: Compute the Fuzzy Synthetic Extent Values

   The fuzzy synthetic extent method is used to derive the relative weights of each criterion. The synthetic extent value is computed as:

$$S_i = \sum_{j=1}^{n} M_{ij} \times \left(\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right)^{-1} \qquad (1)$$

   where represents M_{ij} the fuzzy comparison value.

4. Step 4: Compute the Degree of Possibility

   The degree of possibility for a fuzzy number S_i to be greater than another fuzzy number S_j is defined as:

$$V(S_i \geq S_j) = \frac{(l_j - u_i)}{(m_i - u_i) - (m_j - l_j)} \qquad (2)$$

   where l, m, u are the lower, middle, and upper values of the fuzzy number.

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5. Step 5: Normalize the Weight Values
   The final weight of each criterion is obtained to normalize the fuzzy weights as:

$$W_i = \frac{S_i}{\sum S_i} \tag{3}$$

Step Fuzzy TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a technique that evaluates alternatives based on their relative similarity to an ideal solution (Uzun et al., 2021). The approach assumes that the best alternative has the shortest distance from the Positive Ideal Solution (PIS) and the greatest distance from the Negative Ideal Solution (NIS). However, in real-world decision-making, precise numerical values are often difficult to obtain, leading to the use of fuzzy logic to handle uncertainty and vagueness (Sahoo & Goswami, 2023). The Fuzzy TOPSIS method follows these steps:

1. Step 1: Develop the Decision Matrix
   Each supplier is evaluated against the criteria using a linguistic scale converted into fuzzy numbers.

2. Step 2: Construct the Normalized Decision Matrix.
   The normalized fuzzy decision matrix $\tilde{x}_{ij}$ is computed using:

$$\tilde{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{4}$$

3. Step 3: Determine the Weighted Normalized Matrix
   The weighted normalized values $\tilde{v}_{ij}$ are computed as:

$$\tilde{v}_{ij} = \tilde{x}_{ij} \times W_j \tag{5}$$

   where $\tilde{v}_{ij}$ is the weight of the criteria from Fuzzy AHP.

4. Step 4: Identify the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS)
   The determination of FPIS and FNIS can be expressed as follows:

$$A^+ = \left(\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+\right) \tag{6}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-\right) \tag{7}$$

   where:
   A^+ represents the maximum fuzzy value for each criterion.
   A- represents the minimum fuzzy value for each criterion.

5. Step 5: Determine Each Alternative's Distance from FPIS and FNIS
   The Euclidean separation of each alternative from both FPIS and FNIS is obtained using the following equations:

$$D_i^+ = \sum_{j=1}^{n} d\left(\tilde{x}_{ij}, \tilde{v}_j^+\right) \tag{8}$$

$$D_i^- = \sum_{j=1}^{n} d\left(\tilde{x}_{ij}, \tilde{v}_j^-\right) \tag{9}$$

   where $d\left(\tilde{x}_{ij}, \tilde{v}_j\right)$ is the distance measure between fuzzy numbers.

6. Step 6: Obtain the Closeness-to-Ideal Index for Each Decision Alternative
   The relative closeness coefficient is determined using:

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$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{10}$$

where C_i is the closeness coefficient of the supplier i. Suppliers are ranked based on the highest C_i values.

RESULT AND DISCUSSION

This study was conducted in a medium-sized meat logistics company located in Malang, Indonesia, which specializes in the distribution of halal-certified beef. Evaluations and insights were provided by industry experts, including supply chain managers, quality assurance specialists, and purchasing officers. The first analysis employed the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) to calculate the weights of the criteria and sub-criteria involved in halal sustainable supplier selection. The initial step was to establish the relevant criteria and sub-criteria based on literature review and expert consultation, followed by the development of the AHP hierarchy structure as illustrated in Figure 1. Subsequently, expert evaluations were carried out using pairwise comparisons, and the resulting weights of the criteria and sub-criteria are presented in Table 2.

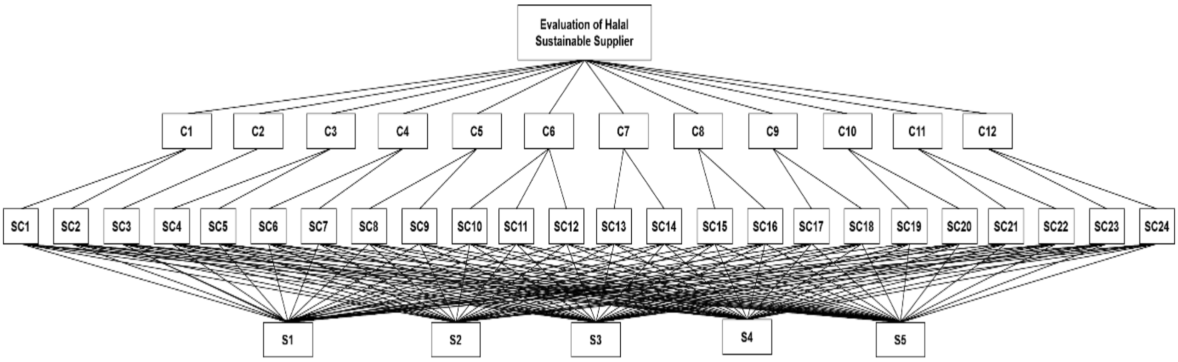

Figure 1. AHP hierarchy for meat supplier selection.

Table 2. Calculation results of Fuzzy AHP.

Dimension	Criteria	Weight	Sub-Criteria	Weight	Final Weight
Environmental Sustainability (Yu & Su, 2017)	Emissions Reduction (C1)	0.0474	Carbon footprint minimization (SC1)	0.7664	0.0363
			Greenhouse gas emissions control (SC2)	0.2659	0.0126
	Waste Management (C2)	0.0346	Proper disposal of by-products (SC3)	1.0000	0.0346
	Resource Efficiency (C3)	0.0265	Water usage optimization (SC4)	0.7664	0.0203
			Energy consumption efficiency (SC5)	0.2659	0.0070
Social Responsibility (Vörösmarty, 2025)	Labor Practices (C4)	0.0142	Compliance with labor laws (SC6)	0.7664	0.0109
			Safe and healthy working conditions (SC7)	0.2659	0.0038

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Dimension	Criteria	Weight	Sub-Criteria	Weight	Final Weight
	Community Engagement (C5)	0.0185	Transparency in supplier operations (SC8)	0.7664	0.0142
			Corporate social responsibility initiatives (SC9)	0.2659	0.0049
Economic Viability (Pourmohammadreza et al., 2025)	Cost (C6)	0.139	Competitive pricing (SC10)	0.5916	0.0822
			Cost stability over time (SC11)	0.2922	0.0406
			Flexibility in payment terms (SC12)	0.1444	0.0201
	Delivery (C7)	0.1373	On-time delivery performance (SC13)	0.7664	0.1052
			Lead time optimization (SC14)	0.2659	0.0365
	Flexibility (C8)	0.0618	Responsiveness to order changes (SC15)	0.7664	0.0474
			Adaptability to supply chain disruptions (SC16)	0.2659	0.0164
	Quality (C9)	0.1528	Product consistency (SC17)	0.7664	0.1171
			Adherence to quality standards (SC18)	0.2659	0.0406
Halal Compliance (Ali et al., 2017)	Halal Certification (C10)	0.1822	Possession of a valid halal certification (SC19)	0.7664	0.1396
			Certification from a recognized authority (SC20)	0.2659	0.0484
	Traceability (C11)	0.0806	Assurance of halal status across the supply chain (SC21)	0.7664	0.0618
			Preventing cross-contamination with non-halal products (SC22)	0.2659	0.0214
	Cleanliness and Purity (C12)	0.1052	Compliance with Islamic standards for hygiene (SC23)	0.7664	0.0806
			Regular audits for cleanliness and purity (SC24)	0.2659	0.0280

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The Halal Compliance dimension was identified as the most essential, while Halal Certification (C10) holds the highest criterion weight as 0.1822. Among its sub-criteria, the halal certification (SC19) was also the highest important with a global weight of 0.1396. The findings indicating the highest global weight in halal certification are consistent with the basic significance of halal assurance in supplier selection, as noted by Wijaya & Widodo (2023). Similarly, Dashti et al. (2024) emphasize that halal certification not only ensures compliance with Shariah principles but also enhances consumer confidence and facilitates market access in both Muslim-majority and global markets. The Certification from a recognized authority (SC20), although less important with a global weighting of 0.0484, is also aligned with global halal trade standards that further emphasize the importance of compliance and recognition in establishing consumer trust (Yadav et al., 2023).

Within the Economic dimension, Quality (C9) was the most significant criterion, given the greatest weight of 0.1528, led by the sub-criterion Product consistency (SC17), which had the second highest sub-criterion weight (0.1171). The result validates a prior study by Okpala & Korzeniowska (2023), who identified consistency in product quality as critical for supplier competitiveness, particularly in industries subject to strict safety and quality regulations such as meat processing. This view is further corroborated by Wu et al. (2021) who argue that quality consistency in food production not only meets regulatory requirements but also strengthens consumer trust and brand reputation in increasingly competitive markets.

Additionally, another key criterion identified was cost (C6), which was heavily influenced by competitiveness (SC10). The results demonstrated that while cost competitiveness remains crucial, achieving high-quality standards is furthermore required for developing long-term supplier partnerships and meeting consumer expectations. However, price competition is still important; the findings show that meeting high-quality standards is also critical for developing long-term supplier relationships and meeting consumer expectations. This is consistent with the arguments of Jena & Singhal (2023), who state that in sustainable supply chains, competitive prices must be balanced with value creation through quality, safety, and compliance. Furthermore, Berti & Mulligan (2016) argue that in food supply chains, providers who combine affordable pricing with consistent quality are more likely to form strategic alliances and retain market viability.

Furthermore, although Environmental Sustainability did not receive the highest rating, it indicated the growing relevance of sustainable practices. Emissions Reduction (C1) and Resource Efficiency (C3) were substantial, with sub-criteria such as Carbon footprint minimization (SC1) and water consumption optimization (SC4) performing important functions. The findings are congruent with those provided by Emenike & Falcone (2020), who highlight emissions control and resource efficiency as critical for decreasing environmental impact in supply chains. Furthermore, in terms of Social Responsibility, Community Engagement (C5) ranked higher than Labor Practices (C4). Sub-criteria such as Transparency in supplier operations (SC8) emphasize the importance of open communication and ethical behavior, which is consistent with Vörösmarty (2025) identification of transparency as a critical component of social sustainability in supply chains. However, the observation has a lower total weight than other sub-criteria, implying that social responsibility is still considered a secondary issue among meat supply business decision makers.

Table 3. Calculation results of Fuzzy TOPSIS.

Halal Sustainable Supplier Alternative	CC_i	Rank
Supplier A1 (S1)	0.5071	2
Supplier B1 (S2)	0.3239	4
Supplier C1 (S3)	0.5404	1
Supplier D1 (S4)	0.3145	5
Supplier E1 (S5)	0.3265	3

Furthermore, to discover the relative weights of criteria and sub-criteria with Fuzzy AHP and Fuzzy TOPSIS were used to evaluate five potential suppliers based on their performance across the defined criteria. Table 3 shows the findings of the Fuzzy TOPSIS study. Supplier C1 (S3) obtained an amazing score based on the closeness coefficient CC_i values due to its strong performance across critical

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characteristics, especially Halal Compliance and Economic Viability. S3's ability to exhibit strong halal certification standards and consistent product quality certainly contributed to its excellent score. The findings are consistent with previous research by Tieman & Ghazali (2014), which emphasized the importance of certification and quality assurance in establishing consumer trust and preserving market competitiveness in halal supply chains.

CONCLUSION

This study presented an integrated F-AHP and F-TOPSIS approach for halal sustainable supplier selection in the meat supply chain. The findings show that halal certification is the most critical factor, followed by product quality and economic viability. Within halal compliance, possession of a valid certification emerged as the most decisive sub-criterion. For economic aspects, product consistency and competitive pricing were the main drivers of supplier performance. Environmental and social responsibility also appeared, but they were considered secondary compared to halal and economic factors. The main novelty of this research is the simultaneous integration of halal compliance and sustainability in supplier selection. Previous studies have mostly focused on either halal assurance or sustainability alone. This study is among the first to combine both dimensions in a unified framework. The application in a medium-sized halal meat logistics company in Indonesia further strengthens its practical contribution. The model offers a structured tool for decision-making under uncertainty and supports managers in aligning with global halal and sustainability standards. Future research could extend this framework with additional sustainability metrics and test its applicability in other halal industries such as pharmaceuticals and cosmetics.

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