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Fuzzy analytic hierarchy process for analysis of barriers to halal supply chain adoption in Indonesia

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ABSTRACT

The increasing awareness of the importance of halal certification has prompted companies to evaluate the barriers to adopting the halal supply chain. While this adoption has the potential for significant benefits, various barriers must be investigated. This study examines the barriers to adopting halal supply chains in small and medium-sized food enterprises (SMEs). The fuzzy analytical hierarchy process (fuzzy AHP) assesses and weighs the 30 identified barriers. The results showed that the main barriers to adopting a halal supply chain include understanding and awareness of the importance of halal certification, support from the government and related institutions, and companies' internal readiness to implement halal standards. In addition, other significant barriers were high certification costs, lack of funds to promote the halal industry, lack of willingness to adopt and implement halal in the supply chain, and lack of technology costs to manage supply chain processes by halal standards. The implications of this study suggest the need for better support strategies from the government and relevant agencies, as well as awareness and understanding-raising efforts among SMEs to overcome these barriers and facilitate the adoption of halal supply chains.

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1. INTRODUCTION

In recent years, adopting the halal supply chain in small and medium-sized food enterprises (SMEs) has become a key focus in improving business performance and ensuring product halalness [1], [2]. Adopting a halal supply chain is essential for food SMEs to improve their operational performance and ensure their products comply with established halal standards [3], [4]. By Islamic law, every Muslim must ensure that the food consumed is completely halal [5]. Therefore, food SMEs must ensure that the entire process of producing, shipping, and storing their products complies with applicable halal standards [6], [7]. Implementing the halal supply chain can help SMEs manage the supply chain effectively while increasing consumer confidence in the halal products they offer [8]. Thus, adopting the halal supply chain is an important strategy to improve business performance and ensure that the products sold meet halal criteria [9].

Identifying the barriers that hinder the adoption of halal supply chains among SMEs in Indonesia is essential as it can improve the halal integrity of food products [10]. The demand for halal food has increased domestically and internationally in recent years [11]. However, many SMEs still experience difficulties integrating halal principles into their supply chains, which can raise doubts regarding the quality and halalness of the products [3]. Therefore, conducting an in-depth analysis of the barriers hindering halal supply chain adoption in SMEs is necessary. This analysis aims to increase SMEs' awareness and ability to

manage the halal supply chain [12]. Without implementing a halal supply chain, there is no guarantee that products claimed to be halal meet these standards when consumed [13]. Therefore, manufacturers must maintain halal integrity throughout the supply chain [14], [15].

Previous research shows various aspects of adopting and implementing halal supply chains in multiple contexts. Ngah *et al*. [14] conducted an exploratory study on the adoption of a halal supply chain among Malaysian halal manufacturers, which provides initial insights into the challenges and opportunities faced by Malaysian halal manufacturers. Next, Haleem *et al*. [16] used interpretive structural modeling (ISM) techniques to assess barriers to adopting and implementing halal practices in logistics operations. In Indonesia, Susanty *et al*. [17] mapped barriers to implementing halal logistics in food, beverage, and ingredient companies using ISM, providing a deeper understanding of local challenges. Lestari *et al*. [18] identify barriers and drivers of halal supply chain adoption in small and medium enterprises in Indonesia, while Ardiantono *et al*. [19] offer obstacle maps and strategic solutions using analytic network processes for SMEs. In addition, Khan *et al*. [20] analyze barriers in halal supply chain management using the best-worst method (BWM). Khan *et al*. [21] evaluate obstacles in adopting halal certification with a fuzzy DEMATEL approach that significantly contributes to understanding the challenges faced in the halal certification and adoption process.

While there are various studies on halal supply chain adoption, there are still significant gaps in the literature related to ranking halal supply chain adoption, especially in uncertain or fuzzy data. Most previous studies focus on exact data information. In contrast, studies exploring aspects of uncertainty in halal supply chain adoption are rarely investigated. Therefore, this research aims to fill the gap by assessing the barriers to halal supply chain adoption in food SMEs using the fuzzy analytic hierarchy process (fuzzy AHP) method. This method was chosen for its ability to handle uncertainty and subjectivity in judgment and provide a more accurate weighting of the various obstacles encountered. With this approach, this research can be a strong foundation for building strategies and policies to increase SMEs' awareness and understanding of halal products. In addition, this research is expected to positively contribute to the advancement of food SMEs by providing deeper insights into halal supply chain adoption challenges and strategic solutions to overcome them.

2. METHOD

2.1. Proposal procedure

To determine the prioritized barriers to halal supply chain adoption, this study proposes a framework consisting of three main stages as shown in Figure 1. The first stage is identifying and selecting barriers, where various barriers that may interfere with adopting the halal supply chain are identified and selected based on the literature and expert input. The second stage involves the pairwise comparison of barriers, where the chosen barriers are compared in pairs to determine their relative importance. This process ensures that the difference between barriers can be systematically measured. The third stage is the assessment of obstacle weights using the fuzzy AHP, where the fuzzy AHP method is applied to give weight to each obstacle based on the results of pairwise comparisons [22], [23]. This method allows for a more flexible assessment of uncertainty and subjectivity in decisions, resulting in a more accurate ranking of the prioritization of constraints [24], [25].

This research uses the fuzzy AHP method proposed by Chang [26] to prioritize the barriers to halal supply chain adoption. The fuzzy AHP procedure starts by constructing a pairwise comparison matrix of the obstacles that have been identified. Each element in this matrix is scored using fuzzy numbers, usually expressed as triangular fuzzy numbers (TFN), to capture the uncertainty and subjectivity in the scoring [27]. The TFN variables of this study are shown in Table 1.

In the fuzzy AHP method, the first step is to create a pairwise comparison matrix of linguistic variables converted into TFN, which can be seen in (1). Matrix operations in fuzzy AHP are formulated in (2) and (3). The equation holds if there are two fuzzy numbers M_1=(l_1, m_1, u_1) and M_2=(l_2, m_2, u_2).

Figure 1. Framework prioritized barriers to halal supply chain adoption

Table 1. Linguistic and triangular variables

Linguistic variables (VL)	Code VL	Triangular fuzzy numbers	Reciprocal
Both elements are equally important	EI	1, 1, 1	1, 1, 1
Element one intermediate preference	IP	1, 2, 3	1/3, 1/2, 1
Element one is moderately more important	MI	2, 3, 4	1/4, 1/3, 1, 2
Element one intermediate preference	IE	3, 4, 5	1/5, 1/4, 1/3
Element one is strongly more important	SMI	4, 5, 6	1/6, 1/5, 1/4
Element one: intermediate preference	IF	5, 6, 7	1/7, 1/6, 1/5
Element one: very strong more important	VI	6, 7, 8	1/8, 1/7, 1/6

$$\bar{A} = \begin{bmatrix} 1 & \bar{a}_{12} & \dots & \bar{a}_{1n} \\ \bar{a}_{21} & 1 & \dots & \bar{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{a}_{n1} & \bar{a}_{n2} & \dots & 1 \end{bmatrix} \quad (1)$$

$$M_1 \oplus M_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$M_1 \otimes M_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 \, x \, l_2, m_1 \, x \, m_2, u_1 \, x \, u_2) \quad (3)$$

Next, the synthesis value is determined, which is described in (4). The sum of the values in the columns of each matrix row is defined in (5), with j as the column index and i as the row index. The TFN number is denoted as M, with m representing the number of indicators and g as the TFN parameter. The next step is to perform the mathematical operation modeled in (6) to obtain the inverse of (4). After that, the level between fuzzy numbers for each indicator is determined using (7), which results in a fuzzy convection sum with $M_1 \geq M_2$.

$$Si = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]\text{-}1 \quad (4)$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj \quad (5)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \frac{1}{\sum_{j=1}^{m} uj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} lj} \quad (6)$$

$$(M_2 \geq M_1) = \begin{cases} 1; if \; m_2 \geq m_1 \\ 0; if \; l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - u_1)}; other \; condition \end{cases} \quad (7)$$

In the defuzzification stage, Equation (8) is used to assess the defuzzification model based on certain assumptions, where the weight vector value is calculated using (9). The weight normalization is formulated in (10). This process generates prioritized weights that enable more informed and systematic decision-making under conditions of uncertainty.

$$V(M \geq M_1, M_2, \dots, M_k = V(M \geq M_1), V(M \geq M_2), \dots V(M \geq M_k) \\ = (min \, V(M \geq M_1), \text{i=1,2,…,k} \quad (8)$$

$$W' = (d'(A_1), d'(A_2), \dots, d'(A_n))^T \quad (9)$$

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (10)$$

2.2. Data and case study

This study focuses on prioritizing barriers to halal supply chain adoption conducted on food (SMEs) in Malang City, Indonesia. Malang City was chosen as the research location because it is a center of rapidly growing food SME activities and needs to implement halal standards in local products. In this study, five experts were engaged to provide a comprehensive insight into the barriers faced by the following. The five experts consist of two experienced SME practitioners, two halal experts with in-depth knowledge of halal certification and standards, and an academic with expertise in the halal supply chain. The selection of five experts aims to obtain diverse and in-depth perspectives so that the identification of barriers and comparison of pairs of barriers can be done thoroughly. The identification of obstacles faced in adopting a halal supply chain has been presented in Table 2. A pairwise comparison of barriers to halal supply chain adoption can be

seen in Tables 3 and 4. The table presents pairwise comparison data in the analysis of halal supply chain barriers that illustrate the comparison of each barrier. This shows the level of significance of each barrier, making evaluating barriers to halal supply chain adoption more objective and able to identify the most critical barriers to be addressed immediately. This also helps generate more targeted strategic recommendations to increase halal supply chain adoption.

Table 2. List of barriers to Halal supply chain adoption

Code	Barriers	Reference
B1	Lack of management commitment to HSCM	Ngah *et al*. [28]
B2	Lack of change management towards HSCM	Tieman *et al*. [29]
B3	Lack of leadership towards HSCM	Talib *et al*. [30]
B4	Lack of willingness to adopt and implement halal in the supply chain	Khan *et al*. [20]
B5	Incapability of hazard control blocks (HCBs)	Hoon *et al*. [31]
B6	The poor response rate of HCBs	Talib *et al*. [32]
B7	Standardization and harmonization issues in the supply chain	Haleem and Khan [33]
B8	Lack of research and development of halal products	Haleem *et al*. [34]
B9	Issues with fake halal logos	
B10	Lack of trust and commitment among halal supply chain partners	
B11	Lack of resource sharing among halal supply chain partners	
B12	Supplier certification issues	
B13	Lack of coordination and collaboration	
B14	Lack of information exchange between supply chain partners	
B15	Lack of logistics infrastructure for halal products	
B16	lack of halal professionals	
B17	Lack of testing infrastructure	
B18	Lack of training and human resource development	
B19	Lack of halal product suppliers in the supply chain	
B20	Lack of traceability system for halal products	
B21	Lack of information sharing	
B22	Lack of convenience in product testing halal products	
B23	Lack of technology costs in managing supply chain processes that comply with halal standards	
B24	Data integrity in the halal supply chain	
B25	Lack of motivation and rewards	
B26	Lack of funding for halal industry promotion	
B27	Lack of policies and directives	
B28	Lack of mindset for halal products	
B29	Lack of trust in the halal logo	
B30	Unwillingness to pay for halal products	

3. RESULTS AND DISCUSSION

3.1. Research results

The research results on the priority weighting of barriers to adopting the halal supply chain are shown in Figure 2. The three highest-weighted barriers were identified as the main barriers to this adoption. The obstacle with the highest weight of 0.0681 is the "lack of funds for the promotion of the halal industry". It suggests that the high promotion cost or lack of funds is the main factor hindering SMEs from adopting a halal supply chain. Furthermore, the obstacle of the criterion "lack of willingness to adopt and implement halal in the supply chain" also has a significant weight of 0.0679. These barriers relate to the difficulties in dealing with halal supply chain registration and implementation procedures, including the large amount of paperwork and complex verification processes, which reduce the willingness of SME owners to adopt and implement halal standards. The criterion "lack of technology costs in managing supply chain processes that comply with halal standards" is the next barrier, weighing 0.0637. These barriers indicate that a traceability system for halal products is also a significant barrier to managing food SMEs.

The results of this study reveal that the main barriers to adopting halal supply chains in food SMEs are closely related to limited funds, willingness to adopt and implement halal standards, and technology costs. The obstacle with the highest weight, namely "lack of funds for the promotion of the halal industry", is in line with the findings of Azam and Abdullah [35], which also highlighted financial limitations as a significant constraint in adopting halal practices in the SME sector. High promotion costs and lack of funds hinder SMEs' efforts to increase market awareness and demand for halal products. Furthermore, the bottleneck "lack of willingness to adopt and implement halal in the supply chain" reflects difficulties in bureaucratic procedures and complex documentation, which the participants also found Iberahim *et al*. [36] in their research on bureaucratic obstacles in implementing halal logistics. The complexity of the procedures and the required paperwork discourage SME owners from getting up and running with the adoption process. Finally, the bottleneck "lack of technology costs in managing supply chain processes compliant with halal standards" suggests that adequate technology and traceability systems are critical to ensure compliance with

halal standards, as discussed by Arshad *et al*. [13]. Lack of investment in technology leads to difficulties in managing efficient and transparent supply chains. Thus, this study confirms the importance of financial support, simplified registration procedures, and increased technology investment to encourage wider adoption of the halal supply chain in the food SME sector.

Table 3. Pairwise comparison of barriers B1-B15

Barriers	Pairwise comparisons														
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
B1	EI	IP	MI	1/MI	IP	IE	1/IE	IP	1/MI	1/MI	1/IE	IP	1/IE	1/IE	IE
B2		EI	IE	1/IP	MI	IP	IP	1/MI	1/IE	1/IP	1/MI	MI	1/IE	1/MI	MI
B3			EI	1/IP	IE	MI	MI	IE	IP	MI	IE	IE	IP	MI	IP
B4				EI	IP	MI	MI	MI	MI	MI	MI	IP	IP	IP	MI
B5					EI	IP	1/IP	1/MI	1/IP	1/MI	1/IE	IP	1/IP	1/MI	IP
B6						EI	1/IE	1/IP	1/MI	1/IE	1/IP	1/IP	1/MI	1/MI	1/EI
B7							EI	MI	IP	IP	IP	IE	IE	1/IP	IP
B8								EI	IP	IP	MI	IP	IP	1/MI	MI
B9									EI	MI	MI	MI	IP	MI	IP
B10										EI	IE	IP	MI	1/IP	MI
B11											EI	MI	IE	1/IE	IP
B12												EI	1/IE	1/MI	MI
B13													EI	1/MI	MI
B14														EI	MI
B15															EI

Table 4. Pairwise comparison of barriers B16-B30

Barriers	Pairwise comparisons														
	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30
B1	1/MI	1/IP	1/MI	1/MI	1/IP	1/IP	1/MI	1/IE	1/IP	1/MI	1/MI	1/MI	1/MI	MI	1/IP
B2	1/MI	1/MI	1/MI	1/IE	1/IP	1/IE	1/MI	1/IE	1/MI	1/IE	IP	IP	1/IP	1/MI	1/MI
B3	1/IP	1/MI	1/MI	1/IE	1/IP	1/IE	1/MI	1/IP	1/IE	1/IP	1/IE	1/IP	1/MI	1/MI	1/IE
B4	1/IP	IP	EI	IE	MI	EI	IE	IP	MI	MI	1/IE	MI	1/MI	1/IP	MI
B5	1/MI	1/MI	1/MI	1/IP	1/MI	1/IE	1/IP	1/MI	1/IP	1/MI	MI	1/IE	1/IP	1/IP	1/IP
B6	1/MI	1/IE	1/MI	1/IP	1/MI	1/IP	1/IE	1/MI	1/IE	1/MI	1/IE	1/IP	IP	1/IP	1/IP
B7	1/IP	MI	1/MI	IP	IP	1/IP	MI	IP	1/MI	1/IP	1/MI	1/IP	1/IE	IP	MI
B8	1/IP	IP	1/MI	MI	MI	1/IP	IE	MI	IE	1/IP	IE	1/IE	1/IE	1/IE	1/MI
B9	1/IP	MI	1/MI	IE	IE	1/IP	IP	IE	1/MI	1/MI	1/MI	IE	1/IP	IP	1/IE
B10	1/IP	IE	1/MI	IP	MI	1/IP	MI	IE	1/MI	1/IP	1/MI	IE	IP	1/MI	MI
B11	1/IP	IP	1/MI	1/MI	1/IP	1/IP	IE	IP	1/IP	1/MI	1/MI	IP	IP	1/MI	IE
B12	1/MI	1/IP	1/MI	1/MI	1/IE	1/IE	1/MI	1/IE	1/IP	1/MI	1/MI	1/IE	IE	1/MI	IP
B13	1/IP	IP	1/MI	IE	IP	1/IE	IP	MI	1/IE	1/IP	IP	MI	MI	1/MI	MI
B14	1/IP	MI	1/MI	IP	IE	1/IE	IP	MI	IE	IP	MI	MI	IP	IE	IE
B15	1/MI	1/IP	1/MI	1/MI	1/IE	1/IP	1/IP	1/MI	1/IP	1/MI	IE	1/MI	MI	1/IP	1/MI
B16	EI	IP	IP	MI	MI	IP	MI	IP	IP	IP	IP	1/IP	IE	1/IE	IP
B17		EI	1/MI	IP	MI	1/IE	IP	IE	1/IE	1/IP	IP	1/IE	IE	1/IE	MI
B18			EI	MI	MI	IP	IP	MI	IP	MI	1/IP	1/IE	1/IP	1/IE	IE
B19				EI	IE	1/IE	MI	IP	1/MI	1/IE	MI	EI	1/IP	1/IE	MI
B20					EI	1/IP	IE	MI	1/IP	1/MI	IP	1/IE	1/IP	1/IP	1/IP
B21						EI	MI	IE	MI	IP	IP	1/IP	1/IP	IP	1/IE
B22							EI	IE	1/MI	1/IE	IP	1/IP	1/IP	1/IE	IP
B23								EI	1/IE	1/IE	1/IE	1/IP	1/MI	IE	IE
B24									EI	MI	1/IP	MI	1/IE	1/IP	1/IE
B25										EI	1/IP	1/MI	1/IE	1/IP	MI
B26											EI	1/MI	IP	IE	MI
B27												EI	MI	IP	MI
B28													EI	1/MI	IE
B29														EI	MI
B30															EI

3.2. Theoretical and managerial implications

This research aims to make a significant theoretical contribution by identifying and prioritizing barriers to halal supply chain adoption using the fuzzy AHP method. The finding that the main barriers are lack of funding for halal industry promotion (B26), Lack of willingness to adopt and implement halal in the supply chain (B4), and lack of technology costs in managing supply chain processes that comply with halal standards (B23) with code third elements are equally important (EI) are limited funds, lack of willingness to adopt, and technology costs provide a deep insight into the critical factors hindering adoption in the food

SME sector. Accordingly, the bar chart above shows the results of prioritizing the weights of each barrier. These weights are based on the pairwise comparison results, which indicate each barrier's relative importance in halal supply chain adoption. Barriers with the highest weights (such as B26, B4, and B23) have the most significant importance, while barriers with the lowest weights (such as B1 and B6) have less significant importance in the halal supply chain adoption process using the fuzzy AHP method. Theoretically, this study extends the literature on halal supply chain adoption by highlighting the importance of an approach that considers uncertainty and ambiguity in the data, which is often overlooked in previous studies that focus more on complex data.

From a managerial perspective, the results of this study provide practical guidance for stakeholders in the food SME sector to overcome critical barriers in adopting a halal supply chain. SME managers and owners can use these findings to plan more effective budget allocations, particularly for halal industry promotion and investment in supply chain technology. In addition, simplifying registration procedures and increasing support from the government and relevant agencies may increase the willingness of SMEs to adopt and implement halal standards. These implications suggest that with the right strategies, SMEs can improve their business performance while meeting the growing market demand for halal products.

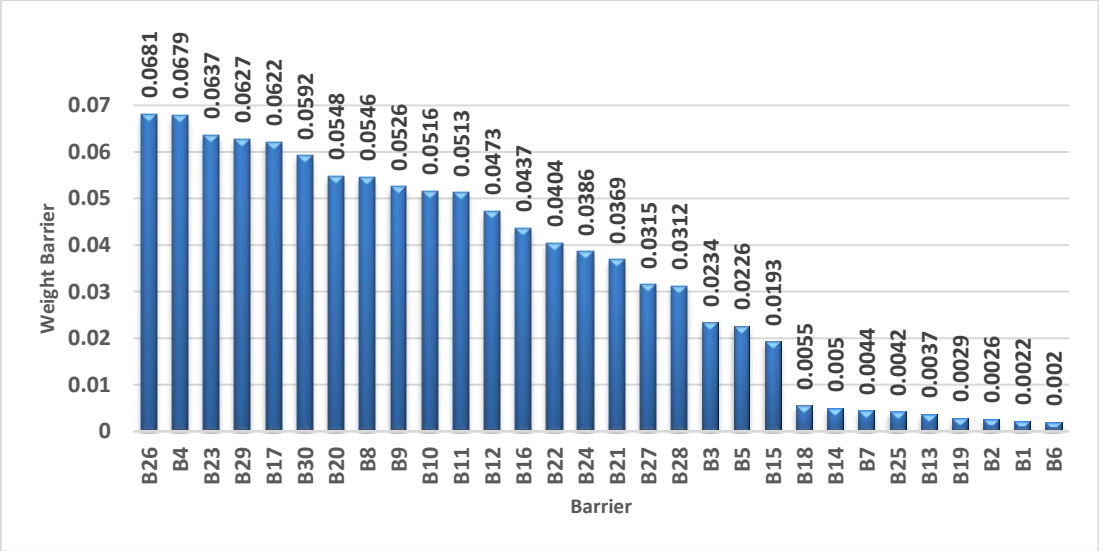

Figure 2. Priority weighting results of barriers to halal supply chain adoption

4. CONCLUSION

This study concludes that applying the fuzzy AHP method is essential in overcoming barriers to halal supply chain adoption in food SMEs. The results identified several priority barriers, including the lack of a traceability system for halal products, the high technology cost of implementing a halal supply chain, and the lack of funds for halal industry promotion. While this research provides valuable insights, some limitations need to be noted. The study was limited to a specific geographical location, namely Malang City. It involved only five experts whose perspectives may not fully represent the entire context of food SMEs in Indonesia. In addition, the fuzzy AHP methodology still has limitations in handling complex uncertainties. For future research, expanding the geographical coverage and number of respondents and incorporating other methodological approaches is recommended to gain a more comprehensive understanding of the barriers to halal supply chain adoption. Further research could also explore practical solutions and implementation strategies to overcome the identified barriers and examine the impact of halal supply chain adoption on the performance and growth of food SMEs.

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