Evaluation Supplier Involve on Food Safety and Halal Criteria using Fuzzy AHP: A Case Study in Indonesia

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ABSTRACT

Selecting or evaluating reliable suppliers is essential to business, and the food industry is no exception. Business operations are at serious risk if suppliers are not properly selected. One of the risks that occur is the risk of food safety and halal. Not many studies have explored this topic, even though this issue is crucial for the Muslim community. This research aims to Evaluate Supplier Involve in Food Safety and Halal Criteria using Fuzzy AHP. It can help food manufacturers decide based on food safety and halal criteria during the supplier selection. The case study is applied to a food industry in Indonesia that produces biscuits. Eight criteria and 17 sub-criteria based on economic, social, and environmental dimensions were used to evaluate suppliers. The results show that the Halal certification system (HP) and product compliance with specifications (Q2) are the most important factors to consider. Third and fourth places are product price criteria (C1) and food safety management system certifications (FS2). Weighted evaluations of food industry suppliers are also possible with Fuzzy AHP.

1. Introduction

Supply chains in the food industry have changed dramatically in recent years into complex networks involving multiple suppliers [1]. In the food industry, a good supply chain is not just for cost-effectiveness, longevity, and efficiency [2]. Food safety hazards in the supply chain can cause compensation issues and difficult-to-fix problems [3]. Thus, in the food industry as a whole, the supply chain is the most critical procedure [4]. Therefore, Selecting food industry suppliers requires a holistic understanding of the criteria [5]. The issue of supplier selection has been recognized as an essential issue in companies to maintain their competitive position [6].

In supplier evaluation and selection, many factors contribute to the complexity of problem-solving, such as the large number of stakeholders involved [7], the combination of quantitative and qualitative selection criteria [8], and the large number and variety of suppliers throughout the supply chain. Companies prefer collaborating with suppliers who can guarantee the highest possible performance level [9-11]. However, deciding which suppliers to work with is becoming increasingly important and challenging, given the

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dynamics of customer needs and increasing quality standards. Supplier selection is an essential part of the halal supply chain network in the food industry because it impacts food safety. Wrong decisions lead to food safety risks that have a significant impact on the company, especially business operations are disrupted. Therefore, it is crucial to establish best practices and determine appropriate evaluation criteria for supplier selection in the food industry.

In some literature, suppliers can be selected using various qualitative and quantitative criteria weighted according to each company's unique priorities [12]. Quality, cost, and timeliness are the three most studied aspects in the initially proposed supplier selection criteria [13, 14]. However, in recent years, new criteria, such as environmental sustainability and social responsibility, have been introduced into the literature to complement these generally accepted criteria [15]. Some criteria are widely used by researchers, and some conflict with each other. Therefore, Multi-Criteria Decision Making (MCDM) approaches are widely offered to solve supplier selection and evaluation [16]. Recently, businesses have used MCDM to choose suppliers because it allows simultaneous consideration of multiple factors to make the best choice [17]. Although the MCDM approach can simplify decision-making [18, 19], it is not easy to apply when there are fewer certain factors for decision-making. Therefore, the principles of fuzzy logic in MCDM are needed to make the right decision in complex situations with a high degree of uncertainty [20].

In the problem of selecting or evaluating suppliers in the food industry, several procedures with fuzzy data characteristics have been proposed. Several procedures have been offered, including the fuzzy analytic hierarchy process (AHP)-Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [21] and the fuzzy Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) [22]. Fuzzy Grey Relational Analysis (GRA) [2] and Fuzzy AHP-Višekriterijumsko Kompromisno Rangiranje (VIKOR) [23] have also been proposed. Thanh and Lan [24] proposed Fuzzy AHP-Combined Compromise Solution (CoCoSo), and Singh, et al. [25] offered Fuzzy AHP-decision-making trial and evaluation laboratory (DEMATEL) and TOPSIS. Interpretive structural modeling (ISM)- fuzzy VIKOR was applied by Khan and Ali [26], and Başaran and Çakir [27] implemented fuzzy Complex Proportional Assessment (COPRAS). Other procedures were also applied, including TOPSIS and Best Worst Method (BWM) [28], Fuzzy ANP-Fuzzy VIKOR [29], Fuzzy AHP- Data Envelopment Analysis (DEA) [30], and interval-valued intuitionistic uncertain linguistic sets (IVIULSs)-GRA-TOPSIS [31]. Most studies ignore food safety and halal criteria in supplier selection. Only a few studies involve food safety and halal criteria. One of the studies involving these criteria was investigated by Başaran and Çakir [27].

Food safety is usually considered secondary after price and quality criteria in selecting a supplier [32]. However, products with food safety risks are not favored by customers and consumers, even though they can be sold at a lower price. This causes the company to experience a decline in trust which results in financial performance in the long term [33]. As a result, food safety should be a determining factor for overall quality. Several studies presented by Lau, et al. [34] and Govindan, et al. [35] state that food safety should be treated as a supplier selection and evaluation criterion. In addition, traceability is another widely discussed aspect of food safety; it is essential to maintaining food safety [36]. Companies can do a lot to improve their image regarding food safety by adopting systematic approaches such as HACCP or ISO 22000 certification [37].

Meanwhile, as the halal food supply chain becomes globalized, consumers are becoming more concerned about the products' safety [38]. Many Muslims are concerned about whether the food they buy is appropriately prepared for consumption [39]. A few

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suppliers utilize ingredients prohibited in Islam in food products even though no such ingredients are on their product labels [40]. This results in products being consumed that are not Halal. Halal denotes food allowed by Muslims according to their religious teachings. Therefore, food must comply with the ingredients, production methods, and transportation provisions to be considered Halal. Otherwise, the food is considered haram. Businesses that want halal certification must ensure that all businesses in their supply chain, starting with suppliers, follow halal management system standards and have halal certification.

Based on the description above, it is clear that there is very little research on supplier evaluation involving Food Safety, traceability, and Halal Criteria. Only Başaran and Çakir [27] involve Food Safety, traceability, and Halal Criteria in supplier evaluation with COPRAS fuzzy procedures in Turkey. Slightly different from Başaran and Çakir [27], this research proposes a fuzzy AHP procedure to solve the supplier selection evaluation problem implemented in Indonesia. In addition, the dimension of environmental criteria is also considered in this research, which is different from the research conducted by Başaran and Çakir [27]. Thus, this research aims to evaluate suppliers by involving food safety and halal criteria using fuzzy AHP. This research enriches science, especially supplier evaluation, by involving food safety and halal criteria.

2. Literature review

This section outlines a literature review of supplier evaluation or selection research for the food industry. Some research related to supplier evaluation or selection for the food industry is presented in Table 1. The results show that various procedures for solving deterministic data problems have been proposed, such as AHP [41], PROMETHEE [42], and TODIM [43]. Some integration procedures are also offered, including DEMATEL-QFD-COPRAS [44], ANP-QFD [45], Delphi-DEA [46], GRA-BWM [47], TOPSIS-VIKOR-GRA [6], and SWARA-LBWA- MARCOS [9]. Meanwhile, the fuzzy AHP is a popular procedure applied to fuzzy-type data. This procedure effectively solves supplier evaluation or selection problems for the food industry. Most studies focus on solving problems in the economic and environmental dimensions. A few research consider social issues. In addition, very few studies address food safety and halal criteria.

3. Methods

3.1 Stages of supplier evaluation

This section presents the proposed stages in supplier evaluation. These are (1). Identification of criteria and sub-criteria for supplier evaluation, (2). Weighting criteria and sub-criteria with fuzzy AHP, and (3). Weighting and ranking suppliers with fuzzy AHP.

The first stage in evaluating suppliers in the food industry is determining criteria and sub-criteria. Criteria and sub-criteria related to supplier evaluation in the food industry are identified through literature reviews and opinions of experts and practitioners. The criteria and sub-criteria consider economic, social, and environmental dimensions. Furthermore, the selected criteria and sub-criteria are weighted using the Fuzzy AHP method. The sub-criteria weights are also used for weighting and ranking suppliers with the Fuzzy AHP method.

In 1996, Chang [48] proposed the fuzzy AHP procedure. The AHP method proposed by Saaty [49] forms the basis of this approach. Using this technique, multi-criteria problems are broken down into more straightforward and more manageable sub-

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problems. Fuzzy AHP is more superficial than traditional AHP because it can compensate for its predecessor's weaknesses, especially its reliance on grey information. This investigation converts linguistic variables into fuzzy triangular numbers (TFN) for use in Fuzzy AHP evaluation. Table 2 displays some linguistic variables and TFN fuzzy numbers.

Table 1. Research in food industry supplier selection and evaluation

Authors	Year	Approaches	Dimension					Data Type	
			Economic	Environment	Social	Food Safety	Halal Criteria	Deterministic	Fuzzy
Banaeian, et al. [46]	2014	Delphi-DEA	V	V	-	-	-	V	-
Banaeian, et al. [2]	2015	Fuzzy GRA	V	V	-	-	-	-	V
Govindan, et al. [42]	2017	PROMETHEE	V	V	-	-	-	V	-
Yazdani, et al. [44]	2017	COPRAS	V	V	-	-	-	V	-
Tavana, et al. [45]	2017	ANP-QFD	V	V	V	-	-	V	-
Banaeian, et al. [6]	2018	TOPSIS-VIKOR-GRA	V	V	-	-	-	V	-
Tian, et al. [28]	2018	TOPSIS-BWM	V	V	-	-	-	-	V
Wang, et al. [30]	2018	Fuzzy AHP-DEA	V	V	V	-	-	-	V
Singh, et al. [25]	2018	Fuzzy AHP, DEMATEL and TOPSIS	V	V	-	-	-	-	V
Liu, et al. [21]	2019	fuzzy AHP-TOPSIS	V	V	V	-	-	-	V
Wan, et al. [22]	2019	fuzzy PROMETHEE	V	V	-	-	-	-	V
Nie, et al. [43]	2019	TODIM	V	V	-	-	-	V	-
Ikinci and Tipi [41]	2021	AHP	V	V	-	-	-	V	-
Nguyen, et al. [23]	2021	Fuzzy AHP-VIKOR	V	V	-	-	-	-	V
Khan and Ali [26]	2021	ISM- fuzzy VIKOR	V	V	V	-	-	-	V
Başaran and Çakir [27]	2021	fuzzy COPRAS	V	-	V	V	V	-	V
Yazdani, et al. [9]	2022	SWARA- LBWA-MARCOS	V	V	V	-	-	V	-
Thanh and Lan [24]	2022	Fuzzy AHP- CoCoSo	V	V	V	-	-	-	V
Ada [29]	2022	Fuzzy ANP-Fuzzy VIKOR	V	V	V	-	-	-	V
This research	2022	Fuzzy AHP	V	V	V	V	V	-	V

The initial step in fuzzy AHP involves converting linguistic variables into Tringual Fuzzy Numbers (TFN) to create a pairwise comparison matrix. To see the pairwise comparison matrix, see Equation (1). The matrix operations in Equation (1) are expressed in Equations (2) and (3), which are characteristics of fuzzy AHP. The second step is calculating the fuzzy synthesis value (Si) in Equation (4). $\sum_{j=1}^{m} M_{gi}^{j}$ represents the total values in each matrix column defined by Equation (5). The column index is denoted by j, and the row index by i. In Matrix M, m is the total number of indicators, and g is the TFN parameter. Meanwhile, it is also possible to model the process of finding the inverse of Equation (4) using Equation (6).

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Table 2. Linguistic Variables and Triangular Fuzzy Number Fuzzy AHP

Linguistic Variable	Code	Triangular Fuzzy Numbers	Reciprocal
Both elements are Equal Important	EI	(1; 1; 3)	(1; 1; 1/3)
Element one Moderately important	MI	(1; 3; 5)	(1; 1/3; 1/5)
Element one is Strongly important	SI	(3; 5; 7)	(1/3; 1/5; 1/7)
Element one Very strong	VS	(5; 7; 9)	(1/5; 1/7; 1/9)
Element one Extremely strong	ES	(7; 9; 9)	(1/7; 1/9; 1/9)

The next step is calculating the degree of probability between the fuzzy numbers of each comparison. Equation (7) formalizes the probability level $M_1 \geq M_2$ can be written for two TFN numbers $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$.. Equation (8) is a model for performing the defuzzification evaluation. Furthermore, assuming that $'(A_i) = min\, V(S_i \geq S_k)$ to $k = 1,2, \ldots, n : k \neq i$, by solving Equation (9), we obtain the values of the weight vector. By solving Equation (10), we obtain the formula for weight normalization.

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

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

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

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

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

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

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

$$V(M \geq M_1, M_2, \ldots, M_k = V(M \geq M_1), V(M \geq M_2), \ldots V(M \geq M_k) = (min\, V(M \geq M_1), i=1,2,\ldots,k \quad (8)$$

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

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

This weighting is carried out on the criteria and sub-criteria of supplier evaluation. Furthermore, the weights of the criteria and sub-criteria of supplier evaluation are used to weight and rank suppliers with fuzzy AHP.

3.2 Case study

A case study was conducted on a food industry company that produces biscuits in Indonesia. This research will focus on the evaluation of 4 suppliers of salt suppliers in the production of biscuits. Three experts conducted a focus group discussion to determine the criteria and sub-criteria of supplier evaluation. The criteria and sub-criteria of food industry supplier evaluation are shown in Table 3. Experts also conduct pairwise comparisons based on linguistic variables to assess the criteria, sub-criteria, and performance of 4 suppliers. The results of pairwise comparisons are used for weighting criteria and sub-criteria and ranking suppliers.

4. Results and Discussion

4.1 Weight of criteria, sub-criteria and best supplier

The weights of the criteria and sub-criteria for evaluating food industry suppliers are shown in Table 4. The results show that the sub-criterion of product conformity to specifications (Q2) is the highest weight with a value of 0.252. Halal certification system (HP) is a sub-criteria that occupies the second position with a value of 0.231. The sub-criteria Product price (C1) and Food safety management system certificates (FS2) occupy the 3rd and 4th positions, respectively, with a value of 0.112 and 0.111. The findings of this study indicate that product conformity to specifications (Q2) and the Halal certification system (HP) are the most important sub-criteria in supplier evaluation in Indonesia.

Table 3. criteria and sub-criteria for evaluating food industry suppliers

Dimension	Criteria	Sub-Criteria
Economic	Quality (Q)	- Quality management system (Q1)
		- Product conformity to specifications (Q2)
	Cost (C)	- Product price (C1)
		- Shipping cost (C2)
	Service efficiency (S)	- Warranty and insurance (S1)
		- Responsiveness (S2)
		- Flexible in quantity change (S3)
	Delivery (D)	- Ability to deliver products on time (D1)
		- Flexibility (D2)
Social	Occupational Health and Safety (OHS)	- Occupational health and safety practices (OHS1)
		- OHS management and certificate (OHS2)
	Food safety (FS)	- Traceability system (FS1)
		- Food safety management certificates (FS2)
	Halal Perspective (HP)	- Halal certification system (HP)
Environment	Environmental Issues (EI)	- Environmental certificate (EI1)
		- Eco-friendly packaging (EI2)
		- Waste treatment management and pollution prevention (EI3)

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Table 4. Weights of food industry supplier evaluation criteria and sub-criteria

Criteria	Wight	Sub Criteria	Wight	Global Weight
Quality (Q)	0.2630	Q1	0.043	0.011
		Q2	0.957	0.252
Cost (C)	0.1172	C1	0.957	0.112
		C2	0.043	0.005
Service efficiency (S)	0.0892	S1	0.093	0.008
		S2	0.454	0.040
		S3	0.454	0.040
Delivery (D)	0.1080	D1	0.957	0.103
		D2	0.043	0.005
Occupational Health and Safety (OHS)	0.0530	OHS1	0.500	0.027
		OHS2	0.500	0.027
Food safety (FS)	0.1160	FS1	0.043	0.005
		FS2	0.957	0.111
Halal Perspective (HP)	0.2312	HP	1.000	0.231
Environmental Issues (EI)	0.0224	EI1	0.333	0.007
		EI2	0.333	0.007
		EI3	0.333	0.007

The results of Supplier weighting based on Fuzzy AHP are presented in Fig. 1. This weighting is based on the weight of the sub-criteria from the supplier evaluation. The results show that Supplier 2 has the highest weight with a score of 0.4158, and supplier 4 follows in second place with a score of 0.3733. Meanwhile, suppliers 1 and 3 occupy positions three and four, respectively, with weights of 0.211 and 0. These results indicate that supplier priority is given to Supplier 2.

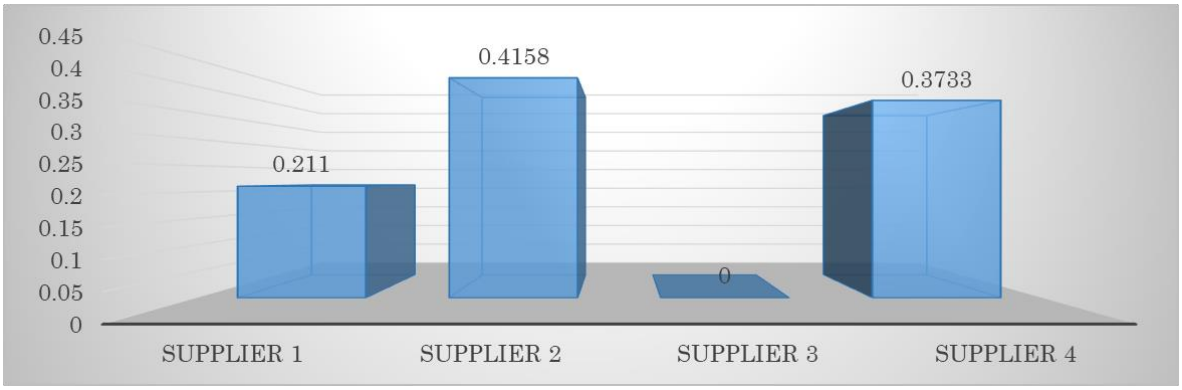

Fig. 1 Supplier Weight based on Fuzzy AHP

4.2 Managerial Insights

This study used some economic, social, and environmental criteria for supplier evaluation, particularly on food safety and halal certification. The findings show that Product conformity to specifications (Q2) and the Halal certification system (HP) has the most significant weight. Not surprisingly, these results are in close agreement with previous research investigated by Başaran and Çakir [27]. This study's primary criteria, Halal certification system (HP) and Food safety management certificates (FS2) are ranked two and four out of 17 sub-criteria, respectively.

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This finding is important in Indonesia, which has the world's largest Muslim population, because it shows that people are concerned about the risks of companies' halal compliance. Quality and food safety practices are intertwined in evaluating food safety. Customers' concerns regarding product halalness and food safety can be minimized by having their products Halal and food safety certified. It encourages consumers to shop more frequently. Therefore, monitoring mechanisms, audits, and laboratory analyses of certified products can be done regularly to improve halal and food safety assurance systems. Meanwhile, many food industries contribute a sizable portion to the economy in Indonesia. It is common knowledge that companies' food safety, among others, can be negatively impacted by their suppliers. This paper is one of the first attempts to use fuzzy AHP methodology to evaluate suppliers. It proposes using food safety and halal compliance as the main selection criteria.

In addition, decision-makers and managers in the food industry benefit from the fuzzy AHP approach. This approach fully incorporates management support and experts to eliminate bias in supplier evaluation. This procedure can easily weigh7 the criteria and sub-criteria and weight the suppliers. The results show that the proposed methodology is an effective decision-support tool for selecting suppliers in fuzzy settings where multiple conflict criteria.

5. Conclusion

In this paper, we propose a fuzzy AHP procedure to evaluate suppliers in the food industry involving Food Safety and Halal Criteria. 8 criteria and 17 sub-criteria are used for supplier evaluation in the food industry. The results show that product conformity to specifications (Q2) and the Halal certification system (HP) are the criteria that rank first and second. Meanwhile, the criteria of the product price (C1) and food safety management system certificates (FS2) are in the third and fourth positions. Fuzzy AHP can also evaluate suppliers in the food industry based on weight. Some of the limitations of this research include that each criterion and sub-criteria is considered to have no dependence. Future research must consider the dependence on criteria and sub-criteria in evaluating suppliers. Integrating the Dematel fuzzy procedure and Fuzzy ANP needs to be investigated in evaluating suppliers in the food industry.

Declarations

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