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A Fuzzy AHP Approach for Supplier Selection in the Brazilian Food Supply Chain Food Safety Suppliers and Halal Criteria: A Case Study Using Fuzzy AHP in Indonesia

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ABSTRACT

This paper evaluates suppliers in the Brazilian and Indonesian food industries, focusing on food safety and halal standards, and uses the fuzzy analytic hierarchy process (FAHP) method to prioritize suppliers based on multiple criteria such as safety and quality. Given that the Brazilian food and beverage industry accounts for 9.6% of the country's GDP, the importance of food safety is particularly emphasized in this context.

In this study, a survey of experts was conducted to identify eight main criteria and 17 sub-criteria, which were categorized into economic, social, and environmental dimensions. The results show that safety is the most important criterion in supplier selection, with supplier number 3 receiving the highest score in this regard.

The authors emphasize the need to separately assess food safety and improve the supplier selection process. This method can help managers understand the challenges of the food supply chain and can be applied to the food industry in other countries

Introduction

1. Problem Definition:

Selecting reliable suppliers in the food industry, especially in Brazil and Indonesia, is accompanied by several challenges related to the complexity of the evaluation criteria, the lack of structured approaches in decision-making, and the importance of food safety and halal products.
1. Complexity of criteria: The supplier selection process involves multiple and conflicting criteria such as price, quality, delivery time, food safety, and halal products. Each of these criteria can have a significant impact on the final decision.
2. Lack of structured decision-making: Many companies use informal methods and raw document validation to evaluate suppliers, which can lead to inefficient choices.
3.Importance of safety and halal: Food safety and compliance with halal products, especially in Muslim communities and also in Brazil, should be considered as key priorities in the supplier selection process to avoid serious risks and reduce consumer trust.
4. Lack of literature: There is a pressing need for existing research, particularly in areas that address mathematical decision-making techniques, such as FAHP and Fuzzy AHP, for supplier selection and emphasizing safety and halal criteria.
The aim of this hybrid study is to develop structured models, such as FAHP and Fuzzy AHP, for evaluating and prioritizing suppliers in the food industry, focusing on safety and halal criteria. These approaches can help improve supplier selection processes and enhance consumer trust.

2.Problem classification:
Considering the content presented in the abstracts of the two articles, the following classifications can be considered for the issues raised in them:

2-1-Article 1:
Main topic: A fuzzy AHP approach for supplier selection in the Brazilian food supply chain
The article examines supplier selection in the Brazilian food industry supply chain and uses the fuzzy analytic hierarchy process (FAHP) approach to facilitate this selection. The main problems of the article are categorized as follows:

2-1-1General problem:
Selecting suitable suppliers to meet the quality, safety, and availability requirements of raw materials in the food industry.
Selecting suitable suppliers to meet the quality, safety, and availability requirements of raw materials in the food industry.

2-1-2Problem dimensions:
- Food safety and quality:
Concerns about food safety in the food industry and pressure from stakeholders (customers, regulatory bodies) to comply with the required standards.
- Diversity of criteria:
The existence of multiple criteria for evaluating suppliers, including price, quality, delivery time, and safety, which may be in conflict.
-Supply chain complexity:
The complexities in the food supply chain due to factors such as perishability, variable quality of raw materials, and stringent regulatory standards.

2.1.3Challenges:
- Lack of structured methods:

Many companies still rely on informal methods to evaluate suppliers, which can lead to incorrect decisions.
- Insufficient attention to food safety:
Food safety is not taken seriously as a core criterion and is usually considered as a subset of quality.
- Low attention to sustainability and green criteria:
While economic and quality criteria dominate, attention to social and environmental aspects is less given to supplier selection.

2.1.4Objective of the article:
- To improve the supplier selection process using FAHP and emphasizing food safety as a key criterion.
- Providing a structured decision-making model to help companies select suppliers based on diverse and conflicting criteria

2.1.5Methodology:
- Using FAHP to evaluate criteria and select suppliers based on expert opinions of stakeholders.
- Assigning weights and scoring suppliers based on fuzzy judgments.
This classification of issues helps to explain the context and challenges of supplier selection in the Brazilian food supply chain and emphasizes the importance of using analytical approaches in this context.

2.2Second Paper:
Main Issue: Food Safety Suppliers and Halal Criteria: A Case Study Using Fuzzy AHP in Indonesia

-2.2.1Main Issue: Supplier Selection
The main issue addressed in the paper is the selection and evaluation of suppliers in the food industry, which is complicated by the following challenges:
The existence of a very large number of suppliers.
The diversity of criteria (qualitative and quantitative).
The complexities of the supply chain

-2.2.2Sub-Issues
-Food Safety Risks: Food safety-related risks can lead to financial losses and disruption to operations. The selection process should consider suppliers that offer safe products.
- Compliance with Halal Principles: With the increasing number of Muslim consumers, ensuring that products are halal is of particular importance. Suppliers must comply with Halal requirements, including raw materials, production methods, and transportation protocols.
-Complex Decision Making: The interaction between different stakeholders and selection criteria complicates the decision-making process.

-2.2.3Evaluation Criteria
The study identified eight criteria and 17 sub-criteria across three different dimensions:
- Economic criteria: quality, cost, and service efficiency.
- Social criteria: occupational health and safety.
- Environmental criteria: environmental impacts and certifications.
The important factors identified for evaluating suppliers include:
- Product compliance with specifications.
- Halal certification system.
- Product price calculation.
- Food safety management certificates. 2.2.4-Methodology
This study uses the fuzzy analytic hierarchy process (FAHP) method to process uncertainty and

complexity in supplier selection. FAHP allows decision makers to transform qualitative assessments into quantitative values and make more informed decisions.

2.2.5- Case Study Context

The case focus of this study is on a food company producing biscuits in Indonesia. This study examines four suppliers of salt for biscuit production and emphasizes the practical application and validation of the proposed evaluation framework.

Conclusion

In summary, the paper classifies the supplier selection problem into several effective problems, emphasizes the importance of food safety and halal compliance, establishes a clear set of evaluation criteria, and uses an appropriate methodological approach to achieve meaningful results that can be useful for decision makers in the food industry.

1- Mathematical Modeling:

3-1 First Paper

The paper examines mathematical methods for supplier selection in the Brazilian food industry supply chain, using the fuzzy analytic hierarchy process (FAHP) approach for this purpose. The mathematical modeling in this research involves three main steps. First, the decision-making hierarchy structure is defined. This structure includes key criteria such as safety, quality, and price, and also includes sub-criteria that help to more accurately evaluate the performance of suppliers.

In the second step, the criteria are compared and weighted. Decision makers determine the importance of each criterion and sub-criteria using pairwise comparisons and fuzzy numerical tools. These comparisons are designed to assess the relevance and consistency of the data and ensure that the judgments are accurate and reliable. Comparative language and triangular numbers are used to gather information to obtain an accurate assessment of suppliers. In the third step, the calculated weights for the criteria are applied to calculate the total scores of suppliers based on the various criteria. Using software such as Microsoft Excel, suppliers are evaluated based on the final scores. The results show that safety is selected as the most important criterion and the third supplier (S3) is selected as the best option. This mathematical modeling method allows decision makers to systematically and fairly evaluate suppliers and be more precise in their choices.

3-2 Article 2:

Basic Principles of Modeling

The mathematical modeling in this paper is centered around the fuzzy analytic hierarchy process (Fuzzy AHP). The AHP method is generally used for multi-criteria decision-making and decomposes complex problems into a hierarchy of criteria, sub-criteria, and options. A fuzzy approach is also added to this model to manage the uncertainties and ambiguities in subjective assessments. In this method, the subjective assessments of experts are expressed using linguistic expressions that are translated into fuzzy numbers (specifically triangular fuzzy numbers). Then, fuzzy weights are calculated for each criterion and sub-criteria using specific methods such as geometric mean and defuzzification. Finally, these weights are combined to obtain the overall preference vector for each option (supplier) against all criteria and sub-criteria. This model allows for the consideration of uncertainties and ambiguous judgments of decision makers, which is very important for evaluating quality factors such as supplier commitment to food safety and halal principles.

Mathematical Calculation Details

Mathematically, the Fuzzy AHP model in this paper uses triangular fuzzy numbers to represent linguistic evaluations. Each triangular fuzzy number is characterized by three values: a lower bound (l), a middle value (m), and an upper bound (u), and is written as (l, m, u). These fuzzy numbers are subjected to operations such as fuzzy addition, multiplication, and division based

on the rules of fuzzy set theory. Pairwise comparisons are recorded in fuzzy comparison matrices, whose elements indicate the degree of superiority of one criterion over another. The compatibility of these matrices is also usually evaluated using fuzzy compatibility indices. The fuzzy weight of each criterion is calculated using the geometric mean and then defuzzified to obtain definite numbers. For this, the center-of-mass method is used, which provides specific weights to be used in the final ranking. This step is very important, as it converts the fuzzy inputs into measurable values so that the model can be used for ranking.

Final Combination and Ranking

Finally, the model combines these deterministic weights to create a final weighted score for each supplier. This process involves multiplying the normalized weights of each criterion and sub-criteria by the corresponding evaluation scores (result of pairwise comparisons of options using fuzzy numbers) for each supplier. These products are then summed across all criteria to obtain a total weighted score for each supplier. The supplier with the highest total score is considered the best option based on the selected set of criteria. The goal of this ranking and selection process using Fuzzy AHP is to provide a more robust and reliable method for supplier selection by considering both quantitative and qualitative factors. As such, the model emphasizes the importance of incorporating halal compliance and food safety standards into supply chain management decisions. 1- Problem Solving Method:

4-1 First Paper:

The paper examines supplier selection in the Brazilian food supply chain and uses the fuzzy analytic hierarchy process (FAHP) approach. In the first step, criteria and subcriteria are defined. Decision makers determine the decision hierarchy structure based on the importance of food safety, quality, delivery time, and cost. This step involves identifying and assigning relative weights to each criterion through pairwise comparisons and expert opinion. Comparative language and fuzzy numbers are used to collect data and scale the criteria.

In the second step, fuzzy judgments are applied to evaluate suppliers. Decision makers evaluate the performance of suppliers against predetermined criteria using the FAHP method. For each supplier, fuzzy scores are recorded, which are obtained according to the pairwise comparisons. Also, the consistency of judgments is checked using the Central Consistency Index (CCI) to ensure that the decisions made are valid and accurate. This step helps to reduce uncertainty in judgments and ensure the quality of the assessment.

In the final step, the calculated weights are applied to the final ranking of suppliers. By aggregating the fuzzy scores of each supplier and calculating their final score, suppliers are ranked in order of best performance. The analysis results show that the third supplier (S3) is the best choice due to its high results in safety and quality criteria. This method not only emphasizes the importance of safety criteria, but also provides a framework for decision-making in the selection of suppliers in the food supply chain that can be used as a model for other organizations.

4-2 Article Two:

Stages of Supplier Evaluation

The article systematically explains the problem-solving method through three key stages of supplier evaluation in the food industry. In the first stage, the criteria and sub-criteria related to supplier evaluation are identified and determined. These criteria are collected through a review of existing literature and the opinions of industry experts and specialists, and take into account economic, social and environmental dimensions. The second stage is dedicated to the weighting of the criteria and sub-criteria, which is carried out using the Fuzzy AHP method. In this stage, first the decision-sensitive components are identified and then the weights related to each sub-criteria are determined based on pairwise comparisons using fuzzy numbers.

Implementation and Testing of Fuzzy AHP Method

The implementation of the Fuzzy AHP method involves converting linguistic variables into triangular fuzzy numbers, through which qualitative values are converted into precise numbers. The paper shows how different groups express their opinions on the determined criteria by pairwise comparisons, and these comparisons are converted into numerical matrices. Through the use of fuzzy calculations, the strengths and weaknesses of suppliers are analyzed, thereby leading to the identification of the best supplier. The specialization of this method in research focuses on the use of meaningful calculations along with the experiences and opinions of experts, which makes the evaluation process stronger.

Case Study and Results

A case study conducted in a biscuit manufacturing plant in Indonesia on four suppliers of salt for the production process shows the success of the Fuzzy AHP method. The studies show that among the various criteria, “product compliance with specifications” and “fulfillment of halal standards” are identified as the most important criteria. The analysis results show that the number two supplier received the highest overall score and is considered the best option for cooperation. These results clearly show that the use of Fuzzy AHP can help improve transparency and credibility in the decision-making process and provide a powerful tool for evaluating suppliers when faced with complex and diverse criteria.

Literature Review

1-5First Article:

This article comprehensively reviews the existing literature on supplier selection in the food supply chain and its related challenges. The authors point out specific problems faced by the food supply chain, including product perishability, raw material quality, and the need for quality requirements, and emphasize the need to develop effective supplier selection strategies. However, the existing literature does not sufficiently address food safety as an independent criterion and rather examines it as a subset of quality. This deficiency indicates the need to pay more attention to food safety as a key factor in the supplier selection process and emphasizes the inadequacy of current approaches. In addition, the article points out the lack of specific studies on the food supply chain in Brazil and considers the need for further research in this area essential. The authors also emphasize the limitations of the supplier selection process, such as the use of informal methods and the lack of commitment to scientific and mathematical approaches. These problems can lead to incorrect decisions and reduced trust in suppliers. Thus, the article makes an attempt to improve supplier selection methods and respond to the deficiencies in the literature by proposing the use of the Fuzzy Analytic Hierarchy Process (FAHP) model and emphasizing food safety, with the hope that this tool can help improve the quality of decision-making in the food industry. 5-2 Paper Two:

Lack of Research and Insufficient Focus

The present paper does a good job of pointing out the gaps in the research literature on supplier selection, especially focusing on food safety and halal criteria. The authors rightly state that most previous research has focused more on economic and environmental aspects and has less focused on simultaneously and comprehensively examining food safety and halal criteria. This deficiency has become a serious challenge, especially in industries dealing with Muslim consumers. The paper also points out the existence of conflicts between different criteria that make it difficult for organizations to select the right supplier. This makes the need to use multi-criteria decision-making methods (MCDM) such as Fuzzy AHP inevitable to address these complexities. The paper effectively points out that existing research has not comprehensively examined specific food safety and halal criteria in the supplier selection process.

Methodological Limitations and Proposed Approach

The literature review in this paper also points out the methodological limitations of previous research, which often did not pay enough attention to the specific characteristics of suppliers and the mismatch of criteria in the best decision-making methods. Existing papers have focused more on general quantitative and qualitative criteria and have not specifically considered modern food

safety management systems and the need to comply with halal criteria. This deficiency has led to risks to consumer health and the reputation of food brands. By adopting the Fuzzy AHP approach, the authors have attempted to fill these gaps and provide a more accurate and comprehensive tool for supplier evaluation. In summary, the paper, with an effective critique of the previous literature, well justifies the necessity of its proposed approach for improving supply chain decisions in the food industry and Muslim communities, and plays a key role in improving supply chain strategies.

Dimensions	Article 1: Fuzzy AHP in Brazil	Article 2: Fuzzy AHP in Indonesia	Research gaps and opportunities
Research Objective	Food Supply Chain Supplier Selection	Food Safety Suppliers and Halal Criteria	Need to synthesize and more comprehensively examine the neutral harms in the food supply chain
Methodology	Using Fuzzy AHP	Using Fuzzy AHP	Need to compare and combine different methodologies
Criteria	Performance, Cost, Quality, and Delivery Time	Safety, Halal, and Quality	Develop new criteria and dimensions for assessment
Areas of Study	Brazil	Indonesia	Research on cultural and social influences on supplier selection
Results	Identifying Superior Suppliers	Identifying Halal and Safe Suppliers	Comparison between results and real-world applications in different markets
Challenges	**Data assimilation, fuzzy modeling**	**Compliance with Sharia standards**	Investigate challenges in implementation in different countries

Conclusion:

These papers emphasize the effective application of fuzzy analytic hierarchy process (FAHP) in supplier selection in the food industry. The results show that FAHP helps decision makers to systematically consider multiple criteria such as food safety and compliance with halal standards in supplier evaluation.

The research shows that the third supplier (S3) is recognized as the best option in terms of food safety, while in another case study, the second supplier was identified as the best option to cooperate. These results emphasize that food safety should be considered as a key criterion in the decision-making process.

In addition, this research recommends that food industry managers comply with food safety and halal standards by conducting regular audits and reviewing supplier certifications. It is suggested that future research should examine social and ethical factors in supplier evaluation and use the integration of other methods, such as DEMATEL and fuzzy ANP, to improve evaluation frameworks. Overall, these papers demonstrate the importance of using scientific and systematic methods in supplier selection in order to improve the quality and safety of food products.