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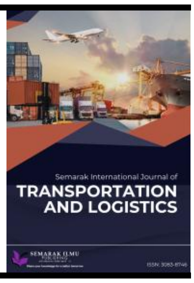

Assessment and Risk Mitigation of Halal Food Supply Chain using Interpretative Structural Modeling (ISM) and House of Risk (HoR)

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ABSTRACT

The objective of this study is to identify and evaluate risk events and their causes in the halal food supply chain. Using field observations, interviews, and questionnaires with company owners and staff, the study applies the SCOR model to categorize risks into planning, sourcing, making, and delivering stages. Interpretative Structural Modeling (ISM) and House of Risk (HoR) approaches are also applied in this study. Findings reveal several key risk events: expired halal certification (Plan), lack of halal labels on raw materials (Source), inadequate hygiene and contamination during production (Make), and missing halal labels on packaging and contamination during delivery (Deliver). Severity assessments highlight critical risks with high impact, such as expired certification and lack of halal labels, which significantly affect supply chain integrity. The Structural Self-Interaction Matrix (SSIM) and Reachability Matrix (RM) further clarify the interrelationships and hierarchies among risk events, showing that risks like certification expiration and non-halal raw materials are pivotal, necessitating targeted preventive measures. This structured approach, including the use of ISM and House of Risk methodology, provides a comprehensive framework for managing and mitigating risks in halal food supply chains.

1. Introduction

Assessment and risk mitigation are pivotal components in ensuring the integrity and safety of the Halal food supply chain. The adherence to Halal standards is not only a matter of religious compliance but also a critical aspect of consumer trust and market integrity. Businesses can proactively address issues such as cross-contamination, mislabeling, or fraudulent practices by systematically analyzing potential hazards and vulnerabilities across various stages of production, distribution, and consumption. Handayani *et al.,* [13] believed that ensuring the integrity of Halal products is crucial for meeting the religious and cultural dietary requirements of Muslim consumers worldwide. Any compromise in the Halal status of food items can lead to significant trust issues and legal

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repercussions. According to Ali and Suleiman [4], rigorous assessment and risk mitigation strategies safeguard against potential contamination, fraud, or non-compliance with Halal standards throughout the supply chain, guaranteeing the purity and authenticity of Halal products. Additionally, effective risk management practices promote transparency, traceability, and accountability among stakeholders, fostering confidence in the integrity of the Halal food industry [1]. The comprehensive risk assessment allows stakeholders to implement targeted strategies to minimize risks and uphold Halal authenticity, thus safeguarding consumer confidence and maintaining market competitiveness.

The House of Risk (HoR) framework provides a structured approach to identify, assess, and manage risks within the Halal food supply chain. H.C. Wahyuni *et al.,* [55] affirmed that by systematically analyzing potential hazards and vulnerabilities across various stages of production, distribution, and consumption, businesses can proactively address issues such as cross-contamination, mislabeling, or fraudulent practices. The comprehensive risk assessment allows stakeholders to implement targeted strategies to minimize risks and uphold Halal authenticity, thus safeguarding consumer confidence and maintaining market competitiveness. Interpretative Structural Modeling (ISM) further enhances the efficacy of risk mitigation strategies within the Halal food supply chain. Kherde, More, and Sawant [25] indicated that ISM enables a deeper understanding of the interdependencies and relationships between different risk factors, facilitating the prioritization of interventions and resource allocation. Through ISM, stakeholders can identify key drivers of risk, such as inadequate certification processes or weak traceability systems, and develop hierarchical structures to address these challenges effectively. By integrating ISM with the HoR framework, businesses can establish robust risk management protocols that align with Halal principles and regulatory requirements [43,45[. This holistic approach can strengthen the resilience of the Halal food supply chain and foster transparency, accountability, and sustainability across the entire ecosystem, thereby enhancing consumer trust and driving long-term growth in Halal markets worldwide.

Prior studies on the assessment and risk mitigation of the Halal food supply chain utilizing House of Risk (HoR) and Interpretative Structural Modeling (ISM) have underscored the significance of a comprehensive framework in ensuring the integrity and compliance of Halal products. Masudin *et al.,* [37] have highlighted the multifaceted nature of risks inherent in the Halal food supply chain, ranging from logistical challenges to ethical considerations, emphasizing the need for a structured approach for risk evaluation and mitigation. The integration of HoR provides a systematic means to identify, categorize, and prioritize risks within the supply chain [31], while ISM facilitates the establishment of interrelationships among these risks, enabling a deeper understanding of their complexities and potential cascading effects [14]. Tieman [51] and Khan *et al.,* [22] have demonstrated the efficacy of several combined methodologies in enhancing Halal supply chain resilience, fostering transparency, and bolstering consumer confidence in Halal products.

Despite the progress made in prior studies utilizing House of Risk (HoR) and Interpretative Structural Modelling (ISM) in assessing and mitigating risks within the supply chain, there remains a notable research gap concerning the integration of these methods into empirical applications, especially in Halal food supply chain. While existing literature has demonstrated the efficacy of HoR and ISM in identifying, prioritizing, and understanding the interrelationships among risks, there is a scarcity of empirical studies applying these methodologies in real-world Halal supply chain contexts. Empirical research focusing on the implementation of integrated risk assessment frameworks such as HoR and ISM could provide valuable insights into the practical challenges and opportunities for enhancing the integrity and compliance of Halal products. Bridging this gap will enable future research to develop more robust risk management strategies tailored to the unique complexities of the Halal food supply chain, ultimately enhancing consumer confidence and industry sustainability.

2. Methodology

2.1 Principles and Challenges of Halal Food Supply Chains

The halal food supply chain's principles are indispensable for guaranteeing that products adhere to Islamic dietary regulations and satisfy consumer expectations. Shariah Compliance is the initial principle, stated by Mustapha *et al.,* [41]. The halal food supply chains are required to comply with Islamic dietary regulations, which encompass the prohibition of polytheism, immorality, and contamination with non-halal substances. In order to guarantee the integrity of halal products, it is necessary for all stakeholders, including producers and retailers, to adhere to these principles. The second area pertains to ethical concerns that are fundamental to the halal food supply chains, with an emphasis on Shariah law compliance and authenticity. Not only is it a religious obligation to maintain halal integrity, but it is also a strategic imperative for brand management and marketing [41]. Simultaneously, Hasnan and Kohda [17] asserted that halal certification is essential for establishing consumer trust and entering Islamic markets. As evidenced by Japan's existence of numerous certification bodies without a unified standard, the certification process can be intricate and variable by region [53]. Nevertheless, the implementation of the principles of halal food supply chains presents a number of challenges, as numerous previous researchers have noted. According to Jasman and Ariffin [19], halal food supply chains are susceptible to a variety of hazards, such as contamination and fraud. In order to mitigate these risks and guarantee adherence to halal standards, it is imperative to implement effective risk management strategies.

2.2 Risk Management in Halal Supply Chains

Risk management in Halal supply chains is a critical aspect of ensuring the integrity and compliance of Halal products throughout the supply chain. Several studies have delved into this topic, highlighting the unique challenges and strategies involved in managing risks effectively. One key theme that emerges from the literature is the importance of transparency and traceability in Halal supply chains. Ab Rashid and Bojei [1] believed that maintaining clear documentation and visibility into each step of the supply chain is crucial for verifying Halal compliance and addressing any potential risks related to contamination or fraud. Transparency and traceability can help in verifying Halal compliance and play a vital role in building trust among consumers, especially those who prioritize Halal products [36]. Khan *et al.,* [21] believed that effective risk management in Halal supply chains involves collaboration and communication among all stakeholders, including suppliers, manufacturers, certifying bodies, and regulatory agencies. Implementing robust risk assessment protocols and contingency plans can further enhance the resilience of Halal supply chains against various risks, such as supply chain disruptions, quality issues, and ethical concerns [23].

2.3 Application of HoR in Assessing Risks in the Halal Food Supply Chains

Previous research has explored the application of the House of Risk (HoR) framework in assessing risks within Halal food supply chains. The HoR framework provides a structured approach to identifying, evaluating, and managing risks across various stages of the supply chain. In the context of Halal food, where compliance with religious requirements and ethical standards is paramount, the HoR framework offers a systematic method to address potential risks that could compromise the integrity including in Halal products [47]. Researchers have highlighted the significance of considering not only traditional supply chain risks such as logistics and quality control but also Halal-specific risks such as contamination, fraud, and non-compliance with Halal standards. The HoR framework provides a structured approach to managing risks that could jeopardize the integrity of Halal products, emphasizing the importance of addressing both traditional supply chain risks and Halal-specific risks such as contamination, fraud, and non-compliance with Halal standards [54]. This comprehensive perspective is crucial in ensuring the overall integrity and trustworthiness of Halal supply chains.

2.4 ISM Analysis of Risk Factors in Halal Food Supply Chains

Prior studies have extensively utilized Interpretive Structural Modeling (ISM) to analyze the interrelationships among risk factors in Halal food supply chains. This approach involves identifying and mapping the complex network of risk factors that can impact Halal compliance, including issues related to contamination, fraud, and non-compliance with Halal standards. For instance, a study by research by Sharma, Abbas, and Siddiqui [50] applied ISM to analyze the interrelationships among risk factors in the Halal food supply chain, highlighting the critical nodes that significantly influence Halal compliance and integrity. Another study by Rejeb *et al.,* [48] highlights the role of technology such as blockchain and IoT devices in enhancing traceability and transparency, which are critical for maintaining Halal integrity and reducing risks. ISM analysis in Halal food supply chains has also shed light on the hierarchical structure of risk factors, distinguishing between critical, moderate, and minor risks based on their influence and dependencies. This hierarchical understanding enables stakeholders to prioritize risk mitigation strategies effectively, allocating resources and attention to the most significant risk factors first. An ISM analysis conducted by Masudin *et al.,* [37] identified cross-contamination as a critical risk factor in Halal food supply chains, highlighting the need for stringent measures in production and distribution processes.

2.5 Integration of HoR and ISM in Halal Food Supply Chain Risk Management

The integration of the House of Risk (HoR) framework and Interpretive Structural Modeling (ISM) in Halal Food Supply Chain Risk Management has been a subject of significant interest and research. Prior studies have highlighted the complementary nature of these methodologies in addressing complex risk factors specific to Halal food supply chains. The HoR framework provides a structured approach to identifying, categorizing, and prioritizing risks, including Halal-specific risks such as contamination, fraud, and non-compliance with Halal standards [15]. On the other hand, ISM offers a robust analytical tool for understanding the interrelationships among these risk factors, allowing for a more holistic risk management strategy [39]. In the context of HoR and ISM integration, research has demonstrated the effectiveness of integrating HoR and ISM in enhancing risk mitigation efforts in Halal food supply chains. For instance, research by Kang *et al.,* [20] showcased how the combined use of risk management and ISM provided a comprehensive understanding of risk factors and their interdependencies, enabling proactive risk management strategies.

3. Methodology

This study examines the Halal mozzarella supply chain from supplier selection to marketing, using interviews and surveys to identify risks, dependencies, and challenges in production, distribution, and retail. The House of Risk (HoR) methodology is applied for risk identification, assessment, and prioritization [27]. Potential risks such as supply chain disruptions, quality control issues, and regulatory compliance are documented. Risks are then assessed based on impact and likelihood, using qualitative and quantitative methods to assign risk scores. Additionally, ISM is used to analyze risk interdependencies and develop a mitigation strategy [11]. This method creates a hierarchical structure of risk factors, revealing causal relationships to identify critical risks and formulate mitigation strategies.

HoR consists of two phases: HoR Phase 1 and HoR Phase 2. In Phase 1, risks are identified using the SCOR model, covering planning, sourcing, production, delivery, and returns. Risk severity is evaluated through interviews and surveys, with probabilities assigned to determine likelihood. Risk correlations are rated as low, medium, or high, and the Aggregate Risk Potential (ARP) is calculated by multiplying probability and severity.

ARP = $O_i \sum_i S_j R_{ij}$

This ARP is used to determine the priority of risk factors for which implementation of mitigation strategies is recommended [35]. Then, in the HOR phase 2, priority is given to risk factors with the highest ARP values to determine which ones should receive mitigation strategies or handling first. The identification of mitigation strategies/handling is done through discussions/interviews with business owners and workers. Identification of correlation exists in HOR phase 2, which involves assigning values to the relationship between risk causes and mitigation strategies. This correlation is symbolized by numbers indicating low, medium, and high correlations. Next, analyze the level of effectiveness (TEk) in the recommendation and implementation process of each mitigation strategy provided. Also, identifying the difficulty level of strategies to be implemented by the Company, then analyzing to determine which strategy should be prioritized based on the Effectiveness to Difficulty Ratio (ETDk) value sequence. The following is the calculation formula for the effectiveness level (TEk) and ETDk (Effectiveness to Difficulty Ratio) [58].

$$\text{TEk} = \sum ARPjEjk \tag{1}$$

$$\text{ETDk} = \frac{TEk}{Dk} \tag{2}$$

where Dk = *Degree of Difficulty*

The application of ISM in the third stage adds a layer of depth to the risk analysis process. ISM is a powerful tool that allows for the creation of a structural model depicting the relationships and interdependencies between various risk factors within the Halal food supply chain [24]. By using ISM, researchers can identify the key drivers of risk, as well as the underlying causal relationships between different factors. This level of analysis enables a more systematic understanding of how risk factors interact and influence each other, providing valuable insights for developing effective risk management strategies [57].

3.1 Research Design

The research design for assessing and mitigating risks in the Halal food supply chain involves several stages, including the utilization of the House of Risk (HoR) method and ISM. The initial stage focuses on understanding the various risk factors within the halal supply chain, utilizing the HoR method to identify and classify risk events and agents [34]. This involves a detailed analysis of potential risks, their severity levels, and probabilities, providing a comprehensive view of the risk landscape. Subsequently, the ISM framework is employed to establish the interrelationships among these risk factors, mapping out the complex network of dependencies and influences.

The integration of House of Risk (HoR) and ISM follows four key stages to assess and mitigate risks in the Halal food supply chain (Figure 1). The first stage involves a literature review to gather insights on challenges, risk factors, and mitigation strategies [49]. Additionally, interviews and questionnaires with stakeholders help identify critical risks and assess current mitigation efforts [5]. In Phase 1 of HoR, risks are identified and categorized based on data from suppliers, distributors, and regulatory bodies. This includes risks like ingredient contamination, supply shortages, and regulatory non-compliance. Prioritization is based on severity and likelihood, ensuring high-impact risks receive more attention [28]. Stage 3 of ISM involves mapping risk relationships using ISM analysis software. Steps include identifying barrier variables, constructing a Structural Self-Interaction Matrix (SSIM), and developing a reachability matrix to analyze transitivity [9]. The ISM model refines risk connections, while HoR prioritizes mitigation strategies, which are then evaluated in HoR Phase 2. Table 1 represent the Experts's Team.

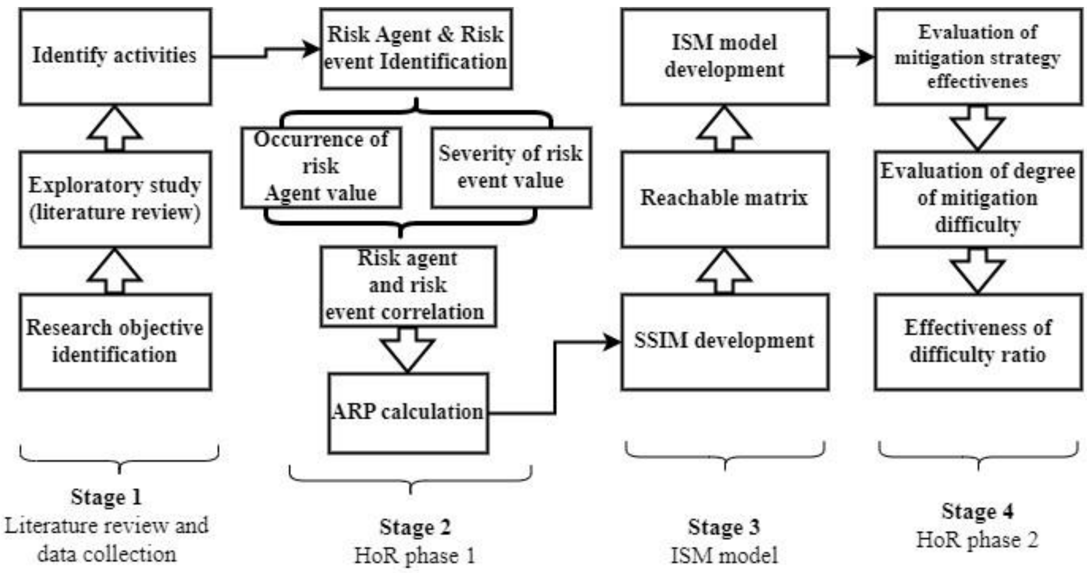

Fig. 1. Research design

Table 1
Experts's Team

Expert	Status	Position	Education	Experience	Expertise
P	Practitioner	Production Planner	Bachelor	9 years	Product based SMEs
Q	Practitioner	Marketing Head	Bachelor	8 years	Product based SMEs
R	Practitioner	Production Head	Bachelor	7 years	Product based SMEs
S	Practitioner	Marketing	Bachelor	6 years	Product based SMEs
X	Practitioner	Owner	Masters	15 years	Sustainable supply chain management

In Phase 2 of the House of Risk (HoR) methodology, the assessment of risk severity levels plays a crucial role in guiding decision-making regarding risk mitigation strategies. This assessment involves categorizing risks based on their potential severity and impact on various aspects of the Halal food supply chain. Risks are typically classified such as low, medium, and high severity levels, allowing stakeholders to prioritize their focus and allocate resources effectively [52]. For instance, high-severity risks that could significantly disrupt critical supply chain processes or compromise food safety may require immediate and robust mitigation actions, while lower-severity risks may be addressed through less resource-intensive measures. Moreover, the development of risk mitigation strategies is a key outcome of Phase 2. This stage involves identifying and designing specific actions and interventions to reduce the likelihood and impact of identified risks. Mitigation strategies can vary widely depending on the nature of the risk, ranging from operational adjustments and process improvements to strategic partnerships and investment in technology or infrastructure [42].

4. Results and Discussion

Risk events and agents were identified using field observations, interviews, and surveys with company stakeholders. Based on the SCOR model (Plan, Source, Make, Deliver), this process clarifies risks in supply chain activities. Table 2 summarizes the findings.

Table 2
Risk event

Process	Activity	Risk of Incident	Code
Plan	Halal product certification guarantee	Expiration of halal certification	A1
Source	Receipt of main and auxiliary raw materials	Auxiliary raw materials lacking halal labels (such as rennet enzyme, citric acid, salt, and powdered milk)	A2
Make	Production process	Product is not properly maintained in terms of hygiene and halal during production	A3
	Quality control	Cheese product contamination with non-halal tools or materials	A4
	Packaging	No halal label or expiration date on the packaging	A5
Deliver	Delivery process	Contamination of cheese products with non-halal products	A6

Table 2 lists risks in the halal food supply chain. These include halal certification expiration (A1), unlabeled raw materials (A2), hygiene issues (A3), contamination during quality control (A4), missing halal labels (A5), and cross-contamination during transport (A6). The impact of each process event is determined based on activities that can influence the halal supply chain and cause disruptions. The notation used for risk events is "A" to simplify data processing and software analysis. To assess the level of impact or disruption caused by these risks, an evaluation using a numerical notation of 1-10, also known as severity, is required. Table 3 presents the severity assessment for a risk event.

The severity table highlights critical risks in Halal food production, scoring each from 1 to 10. In the "Plan" phase, expired Halal certification (A1, score 8) poses a major issue. The "Source" phase faces unverified raw materials (A2, score 7). The "Make" phase includes poor hygiene (A3, score 7) and contamination risks (A4, score 7). These scores stress the need for better risk management.

Table 3
Severity values in risk events

Process	Activity	Risk Event	Code	Severity (1-10)	Description
Plan	Halal product certification assurance	Expiration of the halal certification	A1	8	There is a halal certification that expired in 2021, but the company has not yet taken steps to renew it, thus reducing the certainty of the product's halal status.
Source	Receiving of main and auxiliary raw materials	Presence of auxiliary raw materials without a halal label (such as rennet enzyme, citric acid, salt, and sugar)	A2	7	Citric acid auxiliary raw material from China was found without a halal label on its packaging.
Make	Production process	Lack of cleanliness during the production process in terms of hygiene and product halalness	A3	7	Often, employees forget to use Personal Protective Equipment (PPE) during the production process
	Quality control	Contamination of cheese products with non-halal tools or materials	A4	7	There are still questions regarding the halal certification of auxiliary raw materials

4.1 Structural Self Interaction Matrix (SSIM)

In this stage of the Interpretive Structural Modeling (ISM) process, the development of the Structural Self Interaction Matrix (SSIM) is crucial for understanding the complex relationships between various risk event variables. The SSIM is constructed using ISM professional 2.0 software, which facilitates the systematic analysis of these relationships. The matrix is developed by considering four distinct types of relationships between variables, denoted by specific symbols. These symbols include:

- **V**: Indicates that risk variable i influences risk variable j.
- **A**: Suggests that risk variable j influences risk variable i.
- **X**: Denotes a bidirectional influence, where risk variable i influences risk variable j and vice versa.
- **O**: Represents no relationship between the variables i and j.

These notations are integral to capturing the contextual relationships within the risk assessment process, allowing for a structured analysis of how different risk events interact with each other. By mapping these interactions, the SSIM provides a foundational framework for further analysis and decision-making. This approach aligns with previous studies, which emphasize the importance of systematically analyzing relationships in complex systems to enhance the accuracy of risk assessment and management [8]. Consequently, the SSIM developed in this stage serves as a critical input for subsequent phases of the ISM process, as illustrated in Table 4.

The SSIM analyzes interrelationships among six key activities in managing halal food supply chain risks: Plan, Source, Make (Production, Quality Control, Packaging), and Deliver. It identifies activity influences using symbols—V (leads to), A (led by), X (mutual influence), and O (no influence). The Plan activity strongly impacts all others except itself, while Source influences Make and is led by Plan, highlighting raw material quality’s role. Make drives Quality Control and Packaging but depends on upstream activities. Quality Control influences Packaging, which mainly impacts Delivery. Delivery, as the final stage, depends on all prior activities. This SSIM analysis underscores how planning and sourcing ensure halal certification integrity throughout production and delivery.

Table 4
Structural Self-Interaction Matrix

	(,1)	(,2)	(,3)	(,4)	(,5)	(,6)
(1,)	NA	**V**	**A**	**A**	**X**	**A**
(2,)	NA	NA	**V**	**X**	**V**	**O**
(3,)	NA	NA	NA	**V**	**A**	**O**
(4,)	NA	NA	NA	NA	**V**	**O**
(5,)	NA	NA	NA	NA	NA	**O**
(6,)	NA	NA	NA	NA	NA	NA

The results of the SSIM are then transformed into the Reachability Matrix, which helps in understanding and visualizing the relationships between elements in a complex system using binary numbers (1 and 0). The Reachable Matrix value explains that a binary "1" indicates a connection between risk event elements, while a binary "0" indicates no connection between risk event elements i and j. According to Kim, Kim, and Kang [26], the Reachability Matrix is detailed using notations 1 and 0.

- If the relationship (i,j) in the SSIM is V, then the relationship (i, j) in the RM is 1 and (j, i) is 0.
- If the relationship (i, j) in the SSIM is A, then the relationship (i, j) in the RM is 0 and (j, i) is 1.
- If the relationship (i, j) in the SSIM is X, then the relationship (i, j) in the RM is 1, and (j, i) is also 1.
- If the relationship (i, j) in the SSIM is O, then the relationship (i, j) in the RM is 0, and (j, i) is also 0.

This process allows for determining the hierarchy and relative influence of each element and system. Table 5 is the final result of the Reachability Matrix.

Table 5
Reachable matrix

	A1	A2	A3	A4	A5	A6
A1	1	1	1	1	1	0
A2	0	1	1	1	1	0
A3	1	0	1	1	1	0
A4	1	1	0	1	1	0
A5	1	0	1	0	1	0
A6	1	0	0	0	0	1

The Reachability Matrix (RM) in Table 5, derived from the Structural Self-Interaction Matrix (SSIM), visualizes risk event interactions in a binary format. Each entry (1 or 0) indicates direct influence between risk events. For example, Halal certification (A1) directly connects with raw materials (A2), production (A3), and quality control (A4), affecting overall risk. However, A1 has no direct influence on packaging (A5) or delivery (A6). This analysis highlights how certification impacts key processes while remaining independent of others, providing insights into risk interdependencies within the system.

The Reachability Matrix aids risk analysis by identifying interconnected risks and cascading effects. It helps assess how mitigating one risk impacts others, guiding effective risk management.

For example, resolving Halal certification (A1) may not directly affect packaging but remains vital. This matrix clarifies direct and broader risk relationships, enhancing strategic decision-making. The final result in the Reachability Matrix is the Canonical Matrix, which displays the results of driver power, dependence, rank, and hierarchy. Table 6 shows the results from the Canonical Matrix.

Table 6
Canonical matrix

Risk event	Driving power	Rank	Dependence	Hierarchy
A1	5	1	5	1
A2	4	2	3	3
A3	4	2	4	2
A4	4	2	4	2
A5	3	3	5	1
A6	2	4	1	4

Table 6 presents a canonical matrix analyzing various risk events in terms of their driver power, rank, dependence, and hierarchy. The matrix indicates that risk events A1 and A5 are the highest in terms of driver power and rank, both being assigned a power rating of 5 and ranking 1 in terms of their influence and importance. Risk events A2, A3, and A4 share similar power ratings of 4 and rank 2, indicating moderate influence and importance. In terms of dependence, A1 and A5 both exhibit high dependence, ranking 1, reflecting their critical role in the system's vulnerability. Conversely, risk events A2 and A6 have lower dependence scores, ranking 3 and 4, respectively, suggesting less impact on the overall system. The hierarchy further supports that A1 and A5 are top priorities due to their high driver power and dependence, necessitating focused attention and intervention.

4.2 ISM Hierarchical Structure

Based on the reachability matrix, a graph was created where the X-axis represents the measurement of driver power (level of influence) and the Y-axis represents the measurement of dependence (level of dependence) (Figure 2). The Figure is divided into four parts: Part 1 represents autonomous variables, Part 2 represents dependent variables, Part 3 represents linkage variables, and Part 4 represents independent (driver) variables.

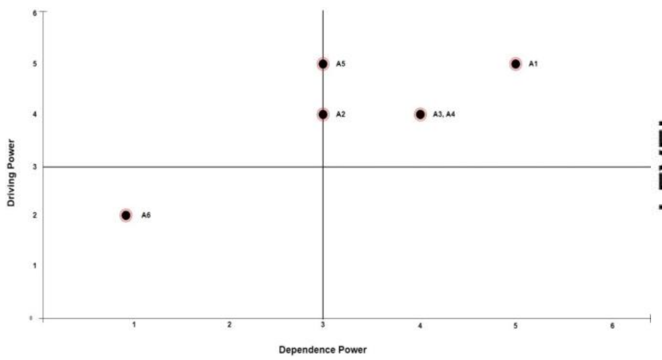

Fig. 2. Driving Power-Dependence variables

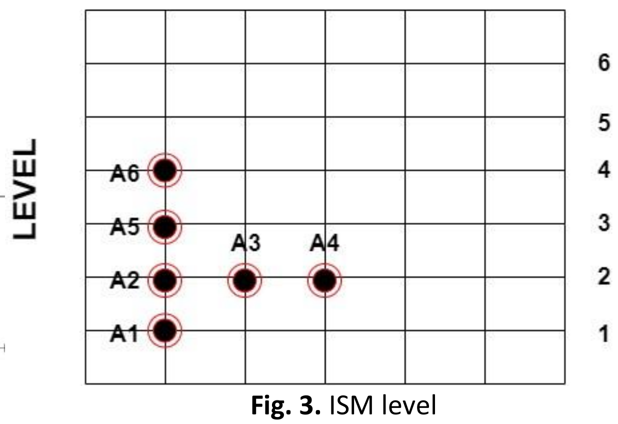

Fig. 3. ISM level

Based on the results of both the ISM diagram (Figure 4) and the level graph (Figure 3), it was found that A1 (expiry of halal certification), A2 (presence of non-halal labeled auxiliary materials such as rennet enzymes, citric acid, salt, and milk powder), A3 (poor hygiene and halal maintenance of the product during production), and A4 (contamination of cheese products with non-halal equipment or materials) have significant driver power and thus can influence other risk events. In the level graph results, these risk event variables are positioned at level 1 for risk event A1 and level 2 for risk events A2, A3, and A4. Therefore, further actions are needed to determine the causes of these risks and their prevention using the House of Risk method.

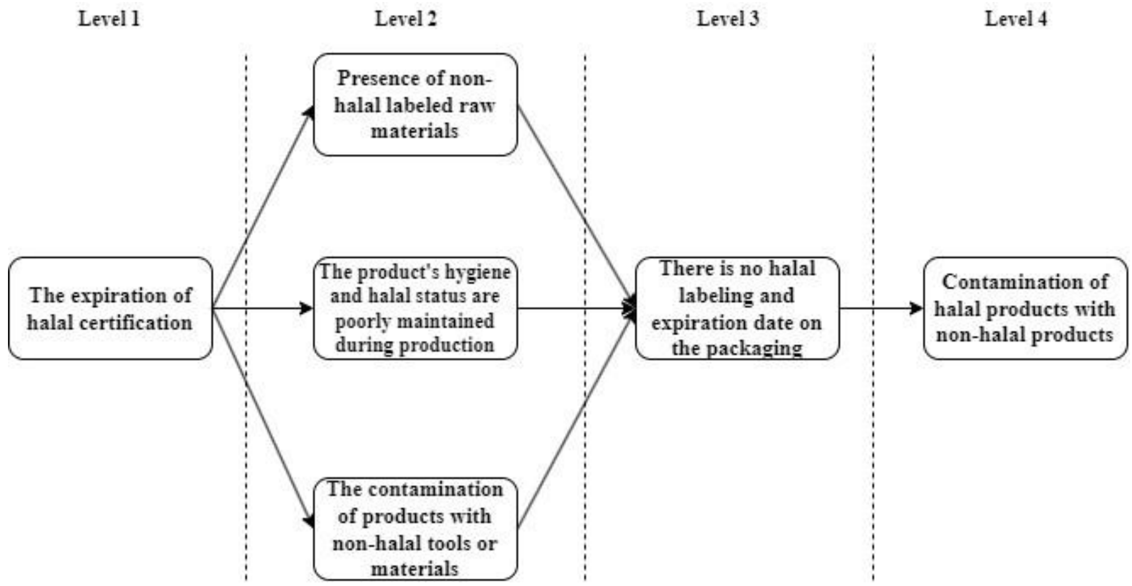

Fig. 4. ISM Hierarchical Structure

Based on the results of both the ISM diagram and the level graph, it was found that A1 (expiry of halal certification), A2 (presence of non-halal labeled auxiliary materials such as rennet enzymes, citric acid, salt, and milk powder), A3 (poor hygiene and halal maintenance of the product during production), and A4 (contamination of cheese products with non-halal equipment or materials) exhibit significant driver power and thus have the potential to influence other risk events. The level graph positions these risk variables at level 1 for risk event A1 and level 2 for risk events A2, A3, and A4, indicating their critical roles in the risk hierarchy. This finding aligns with prior studies that emphasize that the expiry of certification and the presence of non-halal materials are primary concerns in maintaining halal integrity [16].

4.3 House of Risk Phase 1

At this stage of the analysis, the House of Risk phase 1 (HOR I) methodology plays a critical role in identifying and understanding the correlation between selected risk events and their underlying causes. Thoroughly investigating these risk events allows the process to systematically examine the factors that contribute to potential risks within the system. A key aspect of this stage involves assessing the likelihood of occurrence for each identified risk cause. This is accomplished using a standardized scale ranging from 1 to 10, where each value represents the probability of a particular risk cause leading to a risk event. A score of 10 indicates a severe impact on severity and signifies a frequent occurrence.

Table 7 presents the occurrence values for various risk agents associated with halal food certification and production. Each risk agent is assigned a code and an occurrence score ranging from 1 to 10, reflecting its likelihood of impact. The high occurrence score of 7 for both "Lack of action from the company regarding the official renewal of halal food certification" (E1) and "Insufficient checking of halal labels on both primary and secondary raw materials" (E3) underscores a significant concern about the potential erosion of consumer trust and product contamination. These findings align with prior research, which emphasizes the importance of rigorous certification processes and thorough verification of raw materials to uphold halal standards [29]. The moderate risk scores of 6 for "Lack of regular maintenance of production machinery" (E2) and "Lack of coordination and communication between the supplier and the owner" (E4) also resonate with previous studies, which have highlighted that production disruptions and communication failures can compromise both operational efficiency and halal compliance [18]. The lower score of 4 for "Insufficient cleanliness of the production tools used" (E5) reflects a relatively lower perceived risk but still emphasizes the necessity of maintaining high standards of cleanliness, consistent with findings that suggest even minor lapses in hygiene can lead to significant issues in halal food production [3]. These results collectively reinforce the critical need for robust management practices across all areas of halal food production to ensure compliance and maintain consumer confidence.

Table 7
Occurrence value of the risk agent

Risk agent	Code	Occurrence (1-10)	Remark
Lack of action from the company regarding the official renewal of halal food certification	E1	7	The lack of halal certification renewal can reduce customer trust in the halal status of the cheese product.
Lack of regular maintenance of production machinery	E2	6	Machines under repair can hinder the production process.
Insufficient checking of halal labels on both primary and secondary raw materials	E3	7	Unlabeled auxiliary materials risk non-halal contamination.
Lack of coordination and communication between the supplier and the owner	E4	6	Lack of monitoring and unlabeled raw materials affect halal product certainty.
Insufficient cleanliness of the production tools used	E5	4	In the company, some tools still require additional cleaning.

The next step of HOR I is to determine the correlations represented by the numbers 0, 1, 3, and 9 (see Table 8). The relationship between risk events and causes is denoted as Rij (0, 1, 3, 9), where 0 indicates no correlation, 1 indicates low correlation, 3 indicates moderate correlation, and 9 indicates high correlation. This phase aims to produce the ARP (Aggregate Risk Potential) value, which is used as input in House of Risk phase 2. HOR phase 1 correlation valueFrom the ARP values, the rankings (Pj) are sorted from highest to lowest. This indicates that the risk causes should be prioritized for preventive actions based on their impact and likelihood of occurrence. The ARP results show that E3 is ranked first, E1 second, followed by E5, E4, and E2, respectively. The results from the ARP values indicate that the risk associated with insufficient checking of halal labels on raw materials (E3) poses the highest threat, followed by the failure to act on halal certification extensions (E1) and deficiencies in production equipment cleanliness (E5). This prioritization aligns with the findings of prior research, which highlights the critical importance of rigorous certification processes and effective monitoring systems in ensuring compliance with halal standards [12]. For instance, Chen and Lien [7] emphasize that lapses in certification and labeling can lead to significant compliance risks, a concern reflected in the high ARP score for E3 in this study. Similarly, the research underscores the necessity of regular maintenance and hygiene practices, aligning with the study's emphasis on the need for action regarding E5 and E4. The observed ranking also corresponds with observations by Lestari *et al.,* [30], who found that inadequate monitoring and maintenance significantly contribute to operational failures in halal food production. Thus, prioritizing these risk factors for preventive measures is consistent with established literature advocating for enhanced oversight and stringent maintenance protocols to mitigate halal certification risks [44].

Table 8
Analysis of occurrence value of the risk agent

Risk Agent		Failure of the company to take official action regarding the extension of halal food certification contracts	Production machine maintenance is not carried out regularly	Insufficient checking of halal labels on both main and auxiliary raw materials	Lack of coordination and communication between the supplier and the owner	Deficiencies in the cleanliness of the production equipment used	Sj (1-10)
		E1	E2	E3	E4	E5	
The expiration of halal certification	A1	9		1			8
Presence of supporting raw materials without halal labels (such as rennet, citric acid, salt, and powdered milk)	A2	9		9	9		7
Inadequate hygiene and halal maintenance during the production process	A3		9	3		9	7
Contamination of cheese products with non-halal equipment or ingredients	A4	3		9	1	9	7
Oj		7	6	3	5	4	
ARPj		1008	432	36	290	36	
Pj		1	3	6	4	6	

In Stage II of the House of Risk (HOR II), the ARP (Aggregate Risk Potential) values from the final stage of HOR I will be used as a basis to propose appropriate risk mitigation actions for each risk agent. The steps in HOR phase 2 involve determining risk prevention actions based on the results of the three highest ARP values, namely E3, E1, and E5. There are 6 identified risk mitigation actions as shown in Table 9.

Table 9
Risk mitigation actions

Risk Mitigation	**Code**
Extension of halal certification before expiration	P1
Routine audits and inspections of both main and auxiliary raw materials for quality and halal compliance	P2
Training and education for employees on halal principles and the importance of adherence	P3
Utilization of tracking technology to monitor the supply chain for halal standards (e.g., ERP and SCM systems)	P4
Written SOPs related to product halal aspects	P5

The goal of HOR Phase 2 is to determine the Effectiveness to Difficulty Ratio (ETDk) of prevention strategies based on the company's available resources. To find this value, Degree of Difficulty (Dk) is required, which is derived from interviews and assigned numerical notations: 3 (mitigation action is easy to implement), 4 (mitigation action is somewhat difficult to implement), and 5 (mitigation action is difficult to implement). Additionally, Total Effectiveness (TEk) is evaluated using a scoring formula. The next step involves establishing the correlation/relationship between risk causes and mitigation strategies using values of 0, 1, 3, and 9 to indicate each correlation. ETDk can be calculated by dividing the TEk value by the Dk value.

Table 10
Analysis of risk mitigation effectiveness

Risk agent		Preventive action					ARP
		Extend halal certification before it expires	Regular audits ensure raw material quality and halal compliance.	Employee training on halal principles and compliance	Using tracking technology to monitor halal supply chains (e.g., ERP and SCM systems)	Having written SOPs related to product halal aspects	
		P1	P2	P3	P4	P5	
Company's inaction on extending halal certification contract	E1	9	3	3			798
Lack of verification related to halal labels on both main and supporting raw materials	E3		9		9	1	1085
Deficiency in the cleanliness aspect of the production equipment used	E5			1			504
TEk		7182	12,159	2898	9765	1085	
Dk		3	3	4	5	3	
ETDk		2394	4053	724.5	1953	361.67	

The TEk result identifies strategy difficulty using values of 3 (easy), 4 (moderate), and 5 (difficult), based on interviews with the company owner. ETDk values rank mitigation strategies from easiest to hardest: P2 (audits/inspections), P1 (halal certification renewal), P4 (tracking technology), P3 (employee training), and P5 (SOP establishment).

Table 10’s risk mitigation strategies are compared with prior studies to assess effectiveness. Regular audits (P2) rank highest, followed by halal certification renewal (P1), tracking technology (P4), employee training (P3), and SOPs (P5). This aligns with past research highlighting routine checks and real-time monitoring in halal supply chains. For example, Gordon *et al.,* [10] found that continuous monitoring and auditing significantly reduce compliance issues by promptly identifying and addressing deviations from halal standards. Their study reported that regular inspections and audits are crucial for maintaining high compliance levels and reducing the risk of certification lapses, corroborating the high effectiveness and relative ease of implementing regular audits observed in our study. Conversely, our study highlights the complexity and lower effectiveness of certain strategies like employee training and SOP development compared to other measures. This finding resonates with earlier work by Adham *et al.,* [2], who noted that while training and documentation are essential for long-term compliance, their immediate impact on risk reduction is less pronounced compared to proactive measures such as certification renewal and technology integration.

4.4 Managerial Implications

The results of this study highlight several critical risk events in the halal food supply chain, revealing significant managerial implications for each stage of the process. The highest severity risks identified, such as the expiration of halal certification and the lack of halal labels on auxiliary raw materials, underscore the need for rigorous management and oversight. Managers must prioritize the timely renewal of halal certifications and enforce stringent verification procedures for raw materials to ensure compliance and prevent potential contamination [44]. Addressing these issues can help maintain the integrity of the halal certification and safeguard consumer trust, ultimately enhancing the brand's reputation and market positioning. Additionally, implementing regular audits and training programs can further strengthen the supply chain's resilience by ensuring that all stakeholders are well-informed and aligned with halal standards [32]. Moreover, integrating technology, such as blockchain for traceability, can provide real-time monitoring and transparency, reducing the likelihood of non-compliance and enhancing halal supply chain efficiency.

In the production phase, the findings emphasize the importance of maintaining high hygiene standards and preventing contamination. The frequent omission of Personal Protective Equipment (PPE) and the use of non-halal tools or materials during production are critical concerns that require immediate action. Management should implement comprehensive training programs on hygiene and halal maintenance for production staff and enforce strict quality control protocols to minimize contamination risks. To reinforce this approach, Malavi, Abong’, and Muzhingi [33] have shown that regular training and stringent quality control measures significantly reduce contamination risks in food production, thereby enhancing both product safety and consumer trust. Regular audits and adherence to best practices in hygiene can significantly reduce the likelihood of non-compliance and product contamination. Handayani *et al.,* [13] have shown that clear and accurate Halal labeling can meet consumer expectations and enhance brand trust and loyalty among Muslim consumers. By integrating these measures into their risk management strategies, companies can better address potential vulnerabilities and enhance their overall supply chain resilience.

The House of Risk Phase 1 analysis underscores the importance of addressing critical risk agents through targeted mitigation strategies. For instance, the high occurrence scores associated with the lack of action in renewing halal certification and insufficient checking of halal labels highlight urgent areas for intervention. Companies should prioritize the renewal of halal certifications to maintain consumer trust and ensure compliance with halal standards. Mohamed, Abdul Rahim, and Ma'aram [38] studies have highlighted that ongoing certification renewal and stringent supplier management practices are critical for maintaining the integrity of halal products throughout the supply chain. Furthermore, investing in preventive maintenance for production machinery and improving overall cleanliness standards will reduce the likelihood of production-related issues. Wakiru *et al.,* [56] believed that regular maintenance and cleanliness practices can extend equipment lifespan and enhance operational efficiency, ultimately leading to fewer disruptions in production processes.

4.5 Theoretical Contributions

In this study, the application of ISM and HOR methodology has significantly contributed to understanding and managing risk events in the halal food supply chain. By utilizing field observations, interviews, and questionnaires with stakeholders across various departments, including production and marketing, the study identified critical risk events related to halal certification, raw materials, production hygiene, quality control, and packaging. The integration of these methods facilitated a detailed analysis of the interrelationships among risk events, leading to the development of the SSIM. This matrix, alongside the Reachability Matrix, enabled the identification of key risk events with high driver power and dependence, such as the expiration of halal certification and the presence of non-halal labeled materials. The results underscore the importance of robust risk management strategies to address these critical issues, ensuring the integrity of halal products throughout the supply chain. This approach aligns with findings by Mustapha *et al.,* [40], who emphasize that comprehensive risk management practices are crucial for maintaining consumer trust and preventing contamination or non-compliance within halal food systems.

Furthermore, the hierarchical structure derived from the ISM analysis reveals the significant impact of specific risk events on the overall risk landscape. Risk events such as the expiration of halal certification and contamination during production exhibit substantial driver power, influencing subsequent risk events within the supply chain. This finding aligns with existing research emphasizing the necessity of addressing foundational risks to prevent cascading effects [6]. The application of the House of Risk methodology, specifically Phase 1, further highlights the importance of identifying and prioritizing risk causes, such as insufficient halal label checks and lack of certification renewal, to mitigate potential disruptions effectively. This approach aligns with previous findings [46], where proactive identification and prioritization of risk causes in supply chains have been shown to significantly reduce the likelihood of disruptions. This comprehensive approach provides valuable insights for developing targeted risk management strategies, ultimately enhancing the resilience and compliance of halal food supply chains.

5. Conclusion

In this study, the identification of risk events and their causes within the halal food supply chain was achieved through comprehensive data collection methods, including field observations, interviews, and questionnaires from various stakeholders. Using the SCOR model, which breaks down the supply chain into Plan, Source, Make, and Deliver stages, key risks were identified. These risks ranged from expired halal certifications to contamination issues during production and delivery. The severity of each risk was assessed, with high scores indicating significant potential impacts on the halal integrity of the products. This structured approach to risk identification and assessment is essential for understanding the vulnerabilities within the halal food supply chain and highlights critical areas requiring attention to maintain compliance and product quality.

The Interpretive Structural Modeling (ISM) methodology further refined the analysis by mapping the interrelationships between identified risk events. The Structural Self-Interaction Matrix (SSIM) and Reachability Matrix provided insights into how these risks influence each other, revealing critical dependencies and the hierarchical structure of risk events. The Canonical Matrix highlighted the driver power and dependence of each risk, with certain events such as the expiration of halal certification and contamination during production showing high driver power. These findings underscore the importance of addressing primary risks that have substantial impacts on other parts of the supply chain. The next step involves applying the House of Risk methodology to identify underlying causes and develop targeted preventive measures, ensuring a robust strategy to mitigate identified risks and enhance the overall integrity of the halal food supply chain. To further advance this research, future studies could explore the integration of advanced technologies such as blockchain for real-time tracking of halal certification and raw material authenticity to enhance transparency throughout the supply chain. Additionally, investigating the impact of employee training programs on adherence to halal standards and risk mitigation could provide valuable insights into improving compliance and reducing risk events in the halal food industry.

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References

[1] Ab Rashid, Norasekin, and Jamil Bojei. "The relationship between halal traceability system adoption and environmental factors on halal food supply chain integrity in Malaysia." *Journal of Islamic Marketing* 11, no. 1 (2020): 117-142. https://doi.org/10.1108/JIMA-01-2018-0016

[2] Adham, Khairul Akmaliah, Nur Sa'adah Muhamad, Adlin Masood, and Alina Abdul Rahim. "Diagnosing a Halal Certification System for Cosmetics: The Viable System Model Approach." *Systemic Practice and Action Research* 37 no. 2 (2024): 139-159. https://doi.org/10.1007/s11213-023-09647-x

[3] Al-shami, Hamzah Ali, and Shariman Abdullah. 2023. "Halal food industry certification and operation challenges and manufacturing execution system opportunities. A review study from Malaysia." *Materials Today: Proceedings* 80: 3607-3614. https://doi.org/10.1016/j.matpr.2021.07.331

[4] Ali, Mohd Helmi, and Norhidayah Suleiman. "Eleven shades of food integrity: A halal supply chain perspective." *Trends in Food Science & Technology* 71 (2018) : 216-224. https://doi.org/https://doi.org/10.1016/j.tifs.2017.11.016

[5] Azmi, Fadhlur Rahim, Abu Abdullah, Haslinda Musa, and Wan Hasrulnizzam Wan Mahmood. "Perception of food manufacturers towards adoption of halal food supply chain in Malaysia." *Journal of Islamic Marketing* 11, no. 3 (2020): 571-589. https://doi.org/10.1108/JIMA-12-2018-0236

[6] Cernev, Tom, and Richard Fenner. "The importance of achieving foundational Sustainable Development Goals in reducing global risk." *Futures* 115 (2020): 102492. https://doi.org/10.1016/j.futures.2019.102492

[7] Chen, Shin-Yu, and Keng-Wen Lien. "Analysis of the implementation of the certification of second-tier quality control in Taiwan food businesses and common non-conformities." *Journal of Consumer Protection and Food Safety* (2024). https://doi.org/10.1007/s00003-024-01518-4

[8] Delikhoon, Mahdieh, Esmaeil Zarei, Osiris V. Banda, Mohammad Faridan, and Ehsanollah Habibi. "Systems Thinking Accident Analysis Models: A Systematic Review for Sustainable Safety Management." *Sustainability* 14, no. 10 (2022). https://doi.org/10.3390/su14105869.

[9] Dhir, Sanjay, and Swati Dhir. "Modeling of strategic thinking enablers: a modified total interpretive structural modeling (TISM) and MICMAC approach." *International Journal of System Assurance Engineering and Management* 11, no. 1 (2020): 175-188. https://doi.org/10.1007/s13198-019-00937-z

[10] Gordon, André, Carolina Mueses, Helen Kennedy, and Rickey Ong-a-Kwie. 2020. "Chapter 4 - Supplier quality assurance systems: important market considerations." In *Food Safety and Quality Systems in Developing Countries*, edited by André Gordon, 125-184. Academic Press.

[11] Guan, Li, Alireza Abbasi, and Michael J. Ryan. "Analyzing green building project risk interdependencies using Interpretive Structural Modeling." *Journal of Cleaner Production* 256 (2020): 120372. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.120372

[12] Haleem, Abid, Mohd Imran Khan, and Shahbaz Khan. "Halal certification, the inadequacy of its adoption, modelling and strategising the efforts." *Journal of Islamic Marketing* 11, no. 2 (2020): 384-404. https://doi.org/10.1108/JIMA-05-2017-0062
[13] Handayani, Dwi Iryaning, Ilyas Masudin, Abdul Haris, and Dian Palupi Restuputri. "Ensuring the halal integrity of the food supply chain through halal suppliers: a bibliometric review." *Journal of Islamic Marketing* 13, no. 7 (2022): 1457-1478. https://doi.org/10.1108/JIMA-10-2020-0329
[14] Handayani, Dwi Iryaning, Ilyas Masudin, Aries Susanty, and Ika Deefi Anna. "Modeling of halal supplier flexibility criteria in the food supply chain using hybrid ISM-MICMAC: A dynamic perspective." *Cogent Engineering* 10, no. 1 (2023): 2219106. https://doi.org/10.1080/23311916.2023.2219106
[15] Hanifah, Muti, Ari Yanuar Ridwan, and Mohammad Deni Akbar. 2024. "Designing risk mitigation system of halal food supply chain management based on SNI 99001:2016 using house of risk method." *AIP Conference Proceedings* 2951 (1). https://doi.org/10.1063/5.0192730
[16] Hanifasari, Dina, Ilyas Masudin, Fien Zulfikarijah, Aniek Rumijati, and Dian Palupi Restuputri. "Millennial generation awareness of halal supply chain knowledge toward purchase intention for halal meat products: empirical evidence in Indonesia." *Journal of Islamic Marketing* 15, no. 1 (2024): 1847-1885. https://doi.org/10.1108/JIMA-01-2023-0012
[17] Hasnan, Norlena, and Youji Kohda. 2023. "Halal Supply Chain: Challenges of Halal Certification in Japan." *Proceedings of the 3rd International Conference on Management and Communication (ICMC 2023), 1-2 March, 2023, Kuala Terengganu, Malaysia* 132: 764-778. https://doi.org/10.15405/epsbs.2023.11.02.60.
[18] Husin, Maizaitulaidawati Md, Suzilawati Kamarudin, and Adriana Mohd Rizal. "Food and beverage industry competitiveness and halal logistics: Perspective from small and medium enterprises in Malaysia." *Asian Journal of Islamic Management (AJIM)* 3, no.1 (2021): 1-10. https://doi.org/10.20885/ajim.vol3.iss1.art1
[19] Jasman, Nor Azizah, and Nor Hapiza Mohd Ariffin. "Risk Factors Analysis in Halal Supply Chain Management System." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 46 no. 2 (2025): 213-226. https://doi.org/10.37934/araset.46.2.213226.
[20] Kang, Jian, Han Wang, Hao Jin, Zhixing Wang, and Jixin Zhang. "Risk analysis and management of hydrogen station fire and explosion accidents using DEMATEL-ISM and complex network models." *International Journal of Hydrogen Energy* (2024). https://doi.org/10.1016/j.ijhydene.2024.02.141
[21] Khan, Mohd Imran, Abid Haleem, and Shahbaz Khan. "Defining Halal Supply Chain Management." *Supply Chain Forum: An International Journal* 19, no. 2 (2018): 122-131. https://doi.org/10.1080/16258312.2018.1476776
[22] Khan, Shahbaz, Abid Haleem, and Mohd Imran Khan. "Risk management in Halal supply chain: an integrated fuzzy Delphi and DEMATEL approach." *Journal of Modelling in Management* 16, no. 1 (2021): 172-214. https://doi.org/10.1108/JM2-09-2019-0228
[23] Khan, Shahbaz, Mohd Imran Khan, Abid Haleem, and Abdur Rahman Jami. "Prioritising the risks in Halal food supply chain: an MCDM approach." *Journal of Islamic Marketing* 13, no. 2 (2022): 45-65. https://doi.org/10.1108/JIMA-10-2018-0206
[24] Khan, Waseem, Asif Akhtar, Saghir Ahmad Ansari, and Aruna Dhamija. "Enablers of halal food purchase among Muslim consumers in an emerging economy: an interpretive structural modeling approach." *British Food Journal* 122, no. 7 (2020): 2273-2287. https://doi.org/10.1108/BFJ-08-2018-0528
[25] Kherde, Rajesh V., Kiran C. More, and Priyadarshi H. Sawant. "An evaluation of project risk in Indian infrastructural projects using interpretative structural modeling." *Asian Journal of Civil Engineering* (2024). https://doi.org/10.1007/s42107-024-00991-4
[26] Kim, S. S., Y. K. Kim, and Y. M. Kang. 2021. "AORM: Fast Incremental Arbitrary-Order Reachability Matrix Computation for Massive Graphs." *IEEE Access* 9: 69539-69558. https://doi.org/10.1109/ACCESS.2021.3077888.
[27] Kristanto, Dwi, and Dwi Agustina Kurniawati. "Development of halal supply chain risk management framework for frozen food industries." *Journal of Islamic Marketing* 14, no. 12 (2023): 3033-3052. https://doi.org/10.1108/JIMA-04-2022-0112
[28] Kwak, Dong-Wook, Vasco Sanchez Rodrigues, Robert Mason, Stephen Pettit, and Anthony Beresford. "Risk interaction identification in international supply chain logistics." *International Journal of Operations & Production Management* 38, no. 2 (2018): 372-389. https://doi.org/10.1108/IJOPM-03-2016-0121
[29] Lee, Umi Hamidaton Mohd Soffian, Zizi Azlinda Mohd Yusof, Anita Ismail, and Ainnur Husna Mohd Daud. "Addressing Key Importance of Halal Certificate in Meat-Based Industry: Menangani Pentingnya Sijil Halal dalam Industri Berasaskan Daging." *Sains Insani* 8, no. 2 (2023): 319-326.
[30] Lestari, Fitra, Rahmad Kurniawan, Johar Arifin, Muhammad Yasir, Mawardi Muhammad Saleh, and Akbarizan. "An integrated framework for the measurement of halal good manufacturing practices on the case of SMEs in the food sector." *Journal of Islamic Marketing* 14, no. 1 (2023): 82-105. https://doi.org/10.1108/JIMA-04-2021-0105

[31] Lestari, Fitra, Ahmad Mas'ari, Silfia Meilani, Irsan Nuari Riandika, and Abu Bakar Abdul Hamid. "Risk Mitigation Via Integrating House of Risk and Probability Impact Matrix in Halal Food Supply Chain." *Jurnal Teknik Industri* 22, no. 2 (2021): 138-154. https://doi.org/10.22219/JTIUMM.Vol22.No2.138-154
[32] Lima, Mimi. "Strengthening Healthcare Supply Chains: A Comprehensive Strategy for Resilience in the Face of Natural Disasters." *Health Economics and Management Review* 5, no. 2 (2024): 47-67. https://doi.org/10.61093/hem.2024.2-04
[33] Malavi, Derick Nyabera, George Ooko Abong', and Tawanda Muzhingi. "Effect of food safety training on behavior change of food handlers: A case of orange-fleshed sweetpotato purée processing in Kenya." *Food Control* 119 (2021): 107500. https://doi.org/10.1016/j.foodcont.2020.107500
[34] Maman, Ujang, Akhmad Mahbubi, and Ferry Jie. "risk mitigation in the Australian–Indonesian red meat supply chain." *Journal of Islamic Marketing* 9, no. 1 (2018): 60-79. https://doi.org/10.1108/JIMA-12-2015-0095
[35] Mangla, Sachin Kumar, Sunil Luthra, Nishikant Mishra, Akshit Singh, Nripendra P. Rana, Manoj Dora, and Yogesh Dwivedi. "Barriers to effective circular supply chain management in a developing country context." *Production Planning & Control* 29, no. 6 (2018): 551-569. https://doi.org/10.1080/09537287.2018.1449265
[36] Masudin, Ilyas, Bima B. Rahmatullah, Muhammad A. Agung, Inka A. Dewanti, and Dian P. Restuputri. "Traceability System in Halal Procurement: A Bibliometric Review." *Logistics* 6, no. 4 (2022). https://doi.org/10.3390/logistics6040067
[37] Masudin, Ilyas, Putri Elma Zuliana, Dana Marsetiya Utama, and Dian Palupi Restuputri. "Assessment and risk mitigation on halal meat supply chain using fuzzy best-worst method (BWM) and risk mitigation number (RMN)." *Journal of Islamic Marketing* 15, no. 3 (2024): 842-865. https://doi.org/10.1108/JIMA-08-2022-0240
[38] Mohamed, Yusaini Hisham, Abdul Rahman Abdul Rahim, and Azanizawati Ma'aram. "The effect of halal supply chain management on halal integrity assurance for the food industry in Malaysia." *Journal of Islamic Marketing* 12, no. 9 (2020): 1734-1750. https://doi.org/10.1108/JIMA-12-2018-0240
[39] Movahedipour, Mahmood, Jianqiu Zeng, Mengke Yang, and Xiankang Wu. "An ISM approach for the barrier analysis in implementing sustainable supply chain management." *Management Decision* 55, no. 8 (2017): 1824-1850. https://doi.org/10.1108/MD-12-2016-0898
[40] Mustapha, Mohamad Reeduan, Farhana Ahamad, Noor Yuslida Hazahari, and Nurhusna Samsudin. "Ethical issues in the halal food supply chain: a systematic bibliometric review." *Journal of Islamic Marketing* ahead-of-print (ahead-of-print) (2024a). https://doi.org/10.1108/JIMA-07-2023-0210
[41] Mustapha, Mohamad Reeduan, Farhana Ahamad, Noor Yuslida Hazahari, and Nurhusna Samsudin. "Ethical issues in the halal food supply chain: a systematic bibliometric review." *Journal of Islamic Marketing* ahead-of-p (ahead-of-print) (2024b). https://doi.org/10.1108/JIMA-07-2023-0210
[42] Namdar, Jafar, Xueping Li, Rupy Sawhney, and Ninad Pradhan. "Supply chain resilience for single and multiple sourcing in the presence of disruption risks." *International Journal of Production Research* 56, no. 6 (2018): 2339-2360. https://doi.org/10.1080/00207543.2017.1370149
[43] Nasyiah, T., I. Masudin, F. Zulfikarijah, D. Kannan, A. Rumijati, and R. Wijaya. "Explaining Sustainable Performance With SEM–FsQCA: The Role of Traceability Systems, Knowledge Management, Halal SCM Practices, and Spiritual Leadership in Small–Medium Enterprises (SMEs)." *IEEE Transactions on Engineering Management* 71 (2024): 5691-5705. https://doi.org/10.1109/TEM.2024.3365660
[44] Nawangsari, Ertien R, Rima Ratintya Yusuf, and Dicky Anggoro. 2023. *Halal Certification Policy: Boosting Performance and Policy Recommendation for Empowering SME's in East Java*. MEGA PRESS NUSANTARA.
[45] Osman, Osman Ahmed, and Abdel Moneim Elhadi Sulieman. 2023. *Halal and Kosher Food: Integration of Quality and Safety for Global Market Trends*. Springer Nature.
[46] Piprani, Arsalan Zahid, Noor Ismawati Jaafar, and Suhana Mohezar Ali. "Prioritizing resilient capability factors of dealing with supply chain disruptions: an analytical hierarchy process (AHP) application in the textile industry." *Benchmarking: An International Journal* 27, no. 9 (2020): 2537-2563. https://doi.org/10.1108/BIJ-03-2019-0111
[47] Rani, Hafnidar A., Jurisman Amin, Ridha Syuhada, Muhammad Hafidz Mubarak, and Muhammad Shafly Aqsha. "Enhancing Supply Chain Management Risk Mitigation: A House of Risk Methodology Applied to Brick Manufacturing in Aceh Besar Regency." *Qeios* (2024). https://doi.org/10.32388/FSJF2F
[48] Rejeb, Abderahman, Karim Rejeb, Suhaiza Zailani, Horst Treiblmaier, and Karen J. Hand. "Integrating the Internet of Things in the halal food supply chain: A systematic literature review and research agenda." *Internet of Things* 13 (2021): 100361. https://doi.org/10.1016/j.iot.2021.100361
[49] Ren, Shan, Yingfeng Zhang, Yang Liu, Tomohiko Sakao, Donald Huisingh, and Cecilia M. V. B. Almeida. "A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: A framework, challenges and future research directions." *Journal of Cleaner Production* 210 (2019): 1343-1365. https://doi.org/10.1016/j.jclepro.2018.11.025

[50] Sharma, Anshuman, Haidar Abbas, and Muhammad Qutubuddin Siddiqui. "Modelling the inhibitors of cold supply chain using fuzzy interpretive structural modeling and fuzzy MICMAC analysis." *Plos One* 16, no. 4 (2021): e0249046.

[51] Tieman, Marco. "Halal risk management: combining robustness and resilience." *Journal of Islamic Marketing* 8, no. 3 (2017): 461-475. https://doi.org/10.1108/JIMA-06-2015-0041

[52] Van der Fels-Klerx, H. J., E. D. Van Asselt, M. Raley, M. Poulsen, H. Korsgaard, L. Bredsdorff, M. Nauta, M. D'Agostino, D. Coles, H. J. P. Marvin, and L. J. Frewer. "Critical review of methods for risk ranking of food-related hazards, based on risks for human health." *Critical Reviews in Food Science and Nutrition* 58, no. 2 (2018): 178-193. https://doi.org/10.1080/10408398.2016.1141165

[53] Voak, Adam, Brian Fairman, and Hana Catur Wahyuni. "Halal Supply Chain Competencies." *Journal of Resilient Economies* 3, no. 2 (2023). https://doi.org/10.25120/jre.3.2.2023.4021.

[54] Wahyuni, D., A. H. Nasution, I. Budiman, and N. Arfidhila. "Halal Risk Analysis at Indonesia Slaughterhouses Using the Supply Chain Operations Reference (SCOR) and House of Risk (HOR) Methods." *Journal of Physics: Conference Series* 1542, no. 1 (2020): 012001. https://doi.org/10.1088/1742-6596/1542/1/012001

[55] Wahyuni, Hana Catur, Mochamad Alfan Rosid, Rima Azara, and Adam Voak. "Blockchain technology design based on food safety and halal risk analysis in the beef supply chain with FMEA-FTA." *Journal of Engineering Research* (2024). https://doi.org/https://doi.org/10.1016/j.jer.2024.02.002

[56] Wakiru, James M., Liliane Pintelon, Peter Muchiri, and Peter Chemweno. "Integrated maintenance policies for performance improvement of a multi-unit repairable, one product manufacturing system." *Production Planning & Control* 32, no. 5 (2021): 347-367. https://doi.org/10.1080/09537287.2020.1736684

[57] Xu, Xiaoxiao, and Patrick X. W. Zou. "Analysis of factors and their hierarchical relationships influencing building energy performance using interpretive structural modelling (ISM) approach." *Journal of Cleaner Production* 272 (2020): 122650. https://doi.org/10.1016/j.jclepro.2020.122650

[58] Yahya, Shanty, Heri Supomo, and Setyo Nugroho. "Risk Analysis of Ship Collision in Indonesian Water Using House of Risk." *J. Eng. Sci. Technol.* 16, no. 6 (2021): 5044-5059.