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IDENTIFICATION AND EVALUATION OF DISTRIBUTION RISK IN FOOD SUPPLY CHAIN USING AHP METHOD

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Abstract

The study aims to present a structured approach for identifying and assessing distribution risk within the food supply chain by employing the Analytic Hierarchy Process (AHP) method. Through a comprehensive literature review, various risk factors impacting the distribution network of food supply chains are identified, facilitating the development of a hierarchical framework. This framework integrates multiple criteria and sub-criteria to enable a systematic evaluation of distribution risks, considering aspects such as transportation delays, inventory management, quality control, and supplier reliability. The AHP method is then applied to assign relative weights to these criteria, allowing for a quantitative analysis of risk levels and prioritization of mitigation strategies. The findings reveal that the AHP model offers a valuable decision-making tool for stakeholders in the food industry to proactively manage and mitigate distribution risks, thereby enhancing operational efficiency and ensuring food safety and security. Keywords: identification, evaluation, distribution risk, food supply chain, Analytic Hierarchy Process (AHP), criteria, mitigation strategies, operational efficiency, food safety.

I. INTRODUCTION

The identification and evaluation of distribution risk in the food supply chain using the Analytic Hierarchy Process (AHP) method is a critical aspect of ensuring the safety and reliability of food products as they move from producers to consumers. In recent years, there has been a growing emphasis on the need to proactively assess and manage the various risks that can impact the distribution of food, given the potential for contamination, spoilage, and other hazards along the supply chain. The AHP method provides a structured and systematic approach to prioritize and quantify these risks by breaking down complex decision-making processes into hierarchical criteria, sub-criteria, and alternatives, allowing stakeholders to compare and weigh different factors based on their relative importance. By applying the AHP method specifically to the context of food distribution, organizations can effectively identify vulnerabilities, measure the likelihood and impact of potential risks, and develop targeted strategies to mitigate and manage these risks. Through a combination of expert knowledge, data analysis, and stakeholder input, the AHP method enables decision-makers to make informed choices that enhance the resilience and efficiency of the food supply chain, ultimately safeguarding public health and consumer confidence. This approach not only helps in identifying specific points of vulnerability within the distribution network but also in aligning risk management efforts with broader organizational goals and regulatory requirements. Furthermore, the AHP method allows for a dynamic and iterative process that can adapt to changing circumstances, emerging threats, and evolving market conditions, ensuring that distribution risk in the food supply chain is continuously monitored and addressed. Overall, the utilization of the AHP method for the identification and evaluation of distribution risk in the food supply chain represents a proactive and strategic approach to enhancing the security, quality, and sustainability of the global food system.

II. LITERATURE REVIEW

1. The study focuses on risk identification and evaluation within the context of supply chain management. By utilizing a F-AHP evaluation, the researchers aim to enhance decision-making processes to mitigate risks and improve overall supply chain performance. This methodology underscores the importance of proactive risk management strategies in complex supply chain environments.

2. A notable contribution in the literature survey pertains to the application of BP neural networks for evaluating risks in agricultural product supply chains. This approach offers a data-driven method for assessing and addressing potential risks, emphasizing the need for accurate and timely risk evaluation to ensure the smooth functioning of agricultural supply chains

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3. Another significant study discusses the integration of AHP and fuzzy comprehensive evaluation techniques to assess supply chain risks comprehensively. By combining these methodologies, the researchers aim to provide a more robust risk assessment framework that considers both qualitative and quantitative factors, thereby enhancing decision-making in supply chain management

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4. Big data-driven process management for supply chain risks is highlighted as a crucial aspect in improving risk management practices. The study emphasizes the importance of leveraging advanced data analytics techniques to sense, predict, evaluate, and mitigate risks effectively, showcasing the potential for technology-driven solutions in enhancing supply chain resilience.

5. The effectiveness of supply chain risk information processing capability is underscored from an information processing perspective. This study sheds light on the significance of efficient information processing mechanisms in managing supply chain risks, emphasizing the need for streamlined processes to facilitate timely risk assessment and decision-making.

6. Authentication and traceability of food products through the supply chain using NQR spectroscopy presents an innovative approach to enhancing traceability and quality control in food supply chains. This study underscores the role of technological advancements in ensuring transparency and accountability throughout the supply chain, particularly in the food industry.

7. Designing key performance indicators for distribution sustainable supply chain management is addressed as a crucial aspect for evaluating and optimizing supply chain performance. This study emphasizes the need for metrics that align with sustainable supply chain goals, providing insights for enhancing operational efficiency and meeting environmental objectives.

8. Building a sustainable food supply chain management system based on Hyperledger Fabric blockchain highlights the potential of blockchain technology in enhancing transparency and security in food supply chains. This study emphasizes the role of distributed ledger technology in ensuring traceability and trustworthiness within the supply chain ecosystem.

9. An agri-food supply chain traceability system for China based on RFID and blockchain technology provides insights into technological solutions for improving traceability and monitoring capabilities in agri-food supply chains. By leveraging RFID and blockchain technologies, this study aims to enhance supply chain visibility and accountability, contributing to improved food safety and quality assurance.

10. A quantitative risk assessment methodology and evaluation framework for food supply chains offers a structured approach to assess and manage risks effectively. The study emphasizes the importance of quantifying risks to enable informed decision-making, highlighting the need for robust risk assessment methodologies to enhance supply chain resilience and performance.

III. EXISTING SYSTEM

The existing system for identification and evaluation of distribution risk in the food supply chain using the Analytic Hierarchy Process (AHP) method presents several disadvantages. Firstly, one of the major drawbacks is the complexity and time-consuming nature of the AHP method itself. The process of structuring the hierarchy, pairwise comparisons, and calculating the weights of the criteria and alternatives can be cumbersome and labor-intensive, requiring a significant amount of data and expert input. This complexity can lead to potential errors or inconsistencies in the decision-making process, affecting the accuracy of risk evaluation. Additionally, the subjectivity inherent in AHP, especially during the pairwise comparisons, can introduce bias and lack of transparency into the assessment of distribution risks. The reliance on expert judgment may lead to disagreements or differing interpretations among stakeholders, further impacting the reliability of the results. Moreover, the existing system may lack adaptability and flexibility to changes in the food supply chain dynamics or emerging risks, as the criteria and weights are often determined based on historical data or assumptions that may no longer be relevant. This rigidity limits the system's ability to respond effectively to evolving risk factors, potentially leaving vulnerabilities unaddressed. Lastly, the existing system may require specialized knowledge or training in AHP methodology, making it inaccessible to users who are not familiar with the technique, thus hindering widespread adoption and understanding of the risk evaluation process in the food supply chain.

IV. PROPOSED SYSTEM

The proposed work aims to address the critical issue of identification and evaluation of distribution risk within the food supply chain, utilizing the Analytical Hierarchy Process (AHP) method. The research will focus on developing a comprehensive framework to identify and assess various types of distribution risks that can potentially impact the efficiency and safety of food distribution. By employing AHP, a multi-criteria decision-making tool, the study will enable the systematic evaluation of different risk factors based on their impact and likelihood. This approach will provide a structured method for quantifying and prioritizing risks, allowing stakeholders within the food supply chain to allocate resources effectively and proactively manage potential threats. The research will involve data collection from various stakeholders, including suppliers, distributors, and retailers, to gather insights into the specific risk factors affecting the distribution process. Through the application of AHP, the study aims to offer a quantitative and objective assessment of distribution risks, helping decision-makers to make informed choices and implement strategic interventions to enhance the resilience of the food supply chain. Ultimately, the proposed work seeks to contribute to the development of robust risk management strategies that can safeguard the integrity and reliability of food distribution systems, ensuring the delivery of safe and high-quality products to consumers.

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V. METHODOLOGY ARCHITECTURE DIAGRAM

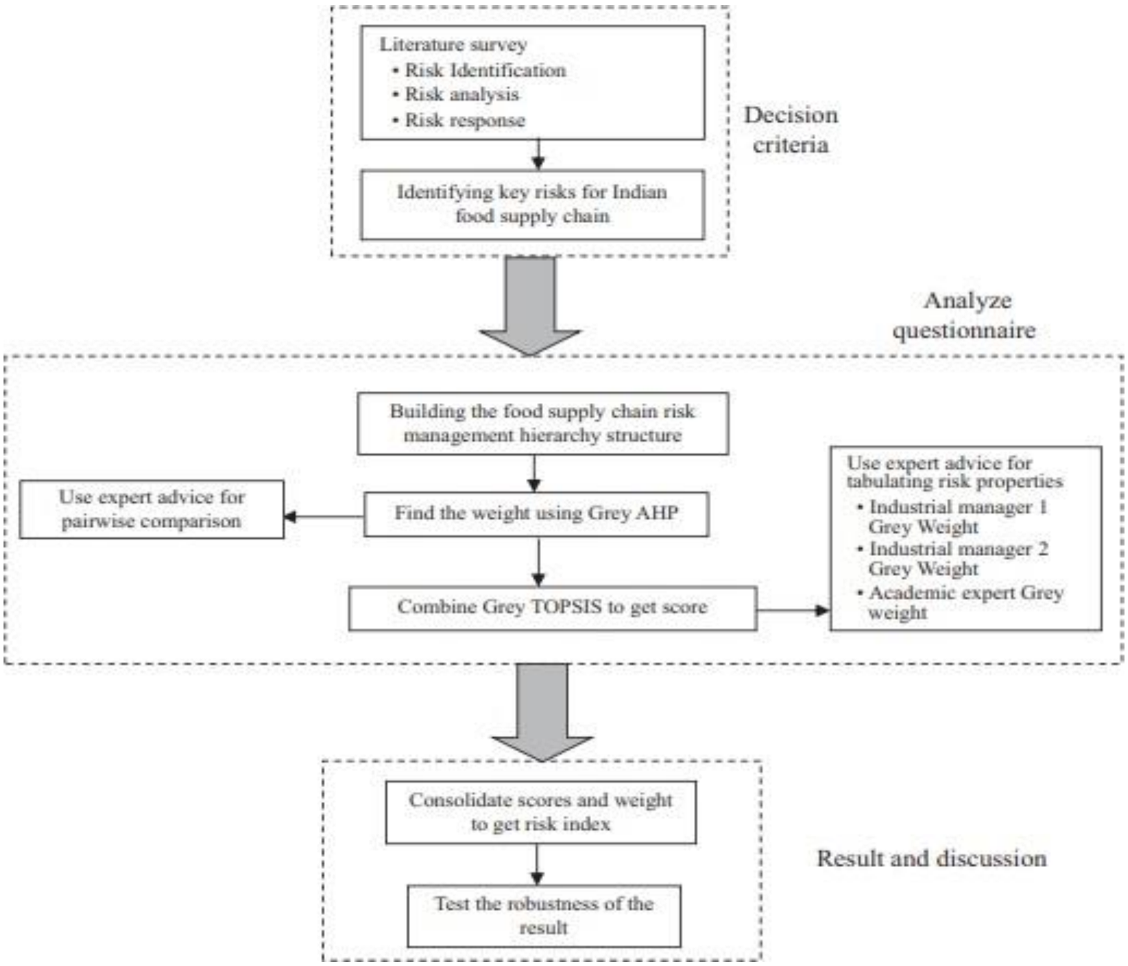

Fig. 1. A proposed framework for identifying risk in food supply chain

VI. METHODOLOGY

Module 1: Data Collection and Risk Identification

This module focuses on collecting relevant data to identify potential risks in the food supply chain. It involves gathering information on various factors such as supplier performance, transportation routes, storage conditions, and regulatory compliance. By utilizing the Analytical Hierarchy Process (AHP) method, this module facilitates the systematic evaluation of these factors to identify vulnerabilities and deviations that could pose risks to the distribution process.

The data collected will be crucial in establishing a comprehensive understanding of the distribution network and enable stakeholders to pinpoint specific areas requiring attention to mitigate potential risks effectively.

Table : Risk Rating from the Respondent 1

	Supply Chain Disruptions	**Regulatory Compliance**	**Technological Failures**	**Market Demand Fluctuations**
Supply Chain Disruptions	1	5	6	4
Regulatory Compliance	1/5	1	4	3
Technological Failures	1/6	1/4	1	5
Market Demand Fluctuations	1/4	1/3	1/5	1

Respondant 2

	Supply Chain Disruptions	**Regulatory Compliance**	**Technological Failures**	**Market Demand Fluctuations**
Supply Chain Disruptions	1	6	7	5
Regulatory Compliance	1/6	1	3	2
Technological Failures	1/7	1/3	1	6
Market Demand Fluctuations	1/5	1/2	1/6	1

Respondent 3

	Supply Chain Disruptions	**Regulatory Compliance**	**Technological Failures**	**Market Demand Fluctuations**
Supply Chain Disruptions	1	7	6	7
Regulatory Compliance	1/7	1	2	3
Technological Failures	1/6	1/2	1	4
Market Demand Fluctuations	1/7	1/3	1/4	1

Respondent 4

	Supply Chain Disruptions	**Regulatory Compliance**	**Technological Failures**	**Market Demand Fluctuations**
Supply Chain Disruptions	1	6	5	6
Regulatory Compliance	1/6	1	3	2
Technological Failures	1/5	1/3	1	4
Market Demand Fluctuations	1/6	1/2	1/4	1

Module 2: Risk Assessment and Prioritization

Once risks are identified, the next step is to assess these risks to prioritize management efforts. The Analytic Hierarchy Process (AHP) method will be applied due to its systematic approach to dealing with complex decision making and its ability to handle both quantitative and qualitative data. Here's how the AHP method will be used for risk assessment in this study:

1. Development of the AHP Model:

- Hierarchy Structure: Constructing a hierarchy that starts with the goal at the top (minimize risk in the food supply chain), followed by the criteria layer (main categories of identified risks), and finally the sub-criteria layer (specific risks under each category).

2. Pairwise Comparisons:

- Criteria Comparisons: Each risk category is compared pairwise to assess their relative importance against one another. This involves using a scale of relative importance standardized by AHP, where stakeholders are asked to provide their judgments.
- Risk Comparisons: Within each category, specific risks are similarly compared pairwise to determine their priority within the category.

3. Priority Weights Calculation:

- Calculating Weights: Using the eigenvalue method to calculate the priority weights for each criterion and sub-criterion based on the pairwise comparison matrices.
- Consistency Check: Ensuring the consistency of the comparisons through the consistency ratio (CR). A CR less than 0.1 is generally acceptable, indicating consistent judgments.

4. Aggregation of Priorities:
- Synthesizing Results: Combining the weights of the sub-criteria to form an overall priority for each risk, thus aiding in the identification of the most critical risks that require immediate attention.

5. Validation:
- Expert Review: The initial results will be presented to the experts for feedback to validate the findings.
- Sensitivity Analysis: Performing sensitivity analysis to see how changes in the input data affect the outcome priorities, ensuring robustness in the results.

Module 3: AHP Methodology

AHP is utilized to derive the weights of various risk factors identified in the food supply chain. These weights are crucial as they determine the relative importance of each risk factor, influencing the overall risk assessment and prioritization process.

The steps involved in the AHP methodology are:

1. Hierarchy Construction: Define the hierarchy involving the goal (risk evaluation), criteria (risk factors), and sub-criteria (specific risks) related to the food supply chain.

2. Pairwise Comparisons: Conduct pairwise comparisons among the criteria and sub-criteria to determine their relative importance. This is done using a scale of judgments provided by experts in the field.

3. Weight Calculation: Compute the weights from the pairwise comparison matrices. These weights reflect how each criterion and sub-criterion contributes to the overall risk level.

4. Consistency Check: Evaluate the consistency of the judgments to ensure the reliability of the decision-making process. A consistency ratio (CR) is calculated, and adjustments are made if the CR exceeds acceptable levels (generally 0.1 or 10%).

5. Synthesis of Priorities: Aggregate the weights across different levels of the hierarchy to derive overall priority scores for each risk factor. This helps in identifying which risks are most critical and should be addressed as a priority in the supply chain.

4.1.1 Mathematical Notation

In the AHP methodology used for this study, the following notations are defined to facilitate the calculation and analysis of risk within the food supply chain:

- D: The decision goal, in this case, to evaluate distribution risk in the food supply chain.
- C: Set of criteria used to assess the risk. $C = \{c1, c2, \ldots, cn\}$
- A: Set of alternatives or risk scenarios being assessed. $\mathrm{A} = \{\mathrm{a1}, \mathrm{a2}, \ldots, \mathrm{am}\}$
- w: Weight vector derived from the pairwise comparisons of the criteria. $w=[w1,w2,\ldots,wn]$ where (w_i) is the weight of the ith criterion.
- S: Set of stakeholders or decision-makers involved in the evaluations. $S = \{s1, s2, \ldots, sk\}$.
- R: Risk assessment matrix, where each element r_{ij} represents the evaluation of the ith alternative under the j th criterion.
- P: Priority vector for alternatives, calculated as $P = Rw$ where is R the risk assessment matrix and w is the weight vector.

Pairwise Comparison Matrix:

- B: A square matrix of size $n \times$,where n is the number of criteria. Each element bij represents the importance of criterion i relative to criterion j, based on expert judgments. Consistency Ratio:

- CR: Consistency ratio, used to measure the consistency of the judgments made in the pairwise comparison matrix. It is calculated based on the consistency index (CI) and the random index (RI) specific to the matrix size: $$CR = \frac{CI}{RI}.$$

Normalization and Synthesis:

- N: Normalized matrix derived from the pairwise comparison matrix B . Each nij is calculated as $$n_{ij} = \frac{b_{ij}}{\sum_{k=1}^{n} b_{kj}}.$$
- Y: Final priority scores for alternatives, calculated by multiplying the normalized matrix N by the weight vector W to derive overall scores reflecting the importance or priority of each alternative in managing risks within the supply chain.

VII. RESULT AND DISCUSSION

The system for the identification and evaluation of distribution risk in the food supply chain using the Analytical Hierarchy Process (AHP) method is designed to provide a structured and systematic approach to assessing and managing risks in food distribution. AHP is a decision- making tool that helps in prioritizing and evaluating multiple criteria by breaking down complex problems into smaller, more manageable components. In the context of the food supply chain, this system assists in identifying potential risks at different stages of distribution, such as transportation, storage, and handling, and evaluates these risks based on their impact and likelihood of occurrence. By using AHP, stakeholders can assign weights to various risk factors and criteria, enabling a more informed decision-making process regarding risk mitigation strategies. This system not only helps in identifying vulnerabilities in the food supply chain but also aids in developing proactive measures to enhance the resilience and efficiency of the distribution network, ultimately ensuring the safety and quality of food products reaching consumers.

The weighted results obtained from the Analytic Hierarchy Process (AHP) offer a nuanced perspective on the prioritization of distribution risks in the food supply chain. Each risk factor's weighted importance reveals not only the perceived impact but also where stakeholders should focus their mitigation efforts. Here is an in-depth analysis of each:

Supply Chain Disruptions (56.35%): This risk is identified as the most critical, which underscores the vulnerabilities within the supply chain's logistical and operational aspects. Disruptions can stem from various sources, including natural disasters, labor strikes, logistic failures, or even pandemics such as COVID-19, which can halt or severely delay the flow of goods. The high percentage indicates that improving supply chain resilience—through diversified suppliers, enhanced logistic strategies, or more robust contingency planning—is essential for maintaining steady and reliable distribution channels.

Regulatory Compliance (22.98%): Compliance with government regulations is a substantial concern, reflecting the complexities and costs associated with adhering to regional, national, and international laws. This risk is particularly pronounced in the global food supply chain where different countries may have vastly different regulatory environments. The importance of this factor suggests that companies must invest in better compliance management systems, regular training for staff on regulatory changes, and active engagement with regulatory developments to adapt swiftly to new laws and standards.

Technological Failures (10.35%): While technology enhances efficiency in the supply chain, its failures pose significant risks. This includes breakdowns in automation systems, failures in refrigeration and tracking systems that ensure food safety, or cyberattacks that compromise distribution data. The relative weight of this risk suggests a growing reliance on technological solutions in supply chain management and the need to invest in reliable, secure, and up-to-date technologies. It also points to the necessity of having robust IT support and effective response strategies for technological disruptions.

Market Demand Fluctuations (5.33%): This risk, while less weighted than others, still plays a crucial role in supply chain management. Variability in consumer demand can lead to issues like overstocking or stockouts, affecting profitability and operational efficiency. The lower relative importance might reflect a perception that demand fluctuations are more manageable compared to other risks, possibly through flexible and responsive supply chain practices like just-in-time inventory systems or enhanced demand forecasting techniques.

VIII. CONCLUSION

In conclusion, the system for identification and evaluation of distribution risk in the food supply chain using the AHP method offers a structured and systematic approach to assessing potential risks. By utilizing the Analytical Hierarchy Process (AHP), this system provides a quantitative framework for decision-making that takes into account multiple factors and criteria. This enables food supply chain stakeholders to prioritize and mitigate risks effectively, ultimately enhancing the overall resilience and efficiency of the distribution process. With its ability to streamline risk assessment and management, the system serves as a valuable tool for ensuring food safety and security throughout the supply chain.

IX. FUTURE WORK

Future work on the system for identification and evaluation of distribution risks in the food supply chain using the Analytical Hierarchy Process (AHP) method could focus on enhancing the model's applicability and accuracy. Researchers could explore the integration of real-time data and advanced analytics techniques for more dynamic risk assessment. Additionally, expanding the scope of the study to incorporate a broader range of risk factors and stakeholders in the food supply chain could provide a more comprehensive understanding of the distribution risks. Furthermore, conducting case studies or practical experiments to validate the effectiveness of the AHP model in real-world scenarios would be beneficial. Collaborating with industry partners to implement the system and gather feedback for continuous improvement would also be a valuable direction for future research. Overall, these efforts could contribute to the development of a robust and practical tool for effectively managing distribution risks in the food supply chain.

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