Available online at: http://jurnal.untirta.ac.id/index.php/jiss

JOURNAL INDUSTRIAL SERVICESS

Industrial Engineering Advance Research & Application

eISSN 2461-0631

Identification and strategy for the risk mitigation of supply chain with Fuzzy House of Risk: A case study in pallet products

Maria Ulfah*, Achmad Bahauddin, Dyah Lintang Trenggonowati, Ratna Ekawati, Faula Arina, Atia Sonda, Asep Ridwan, Putro Ferro Ferdinant

Department of Industrial Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jend. Sudirman KM 3, Cilegon 42435, Banten, Indonesia

ARTICLE INFO

Article history:
Received 26 January 2023
Received in revised form 12 March 2023
Accepted 18 March 2023
Available online 18 March 2023

Keywords:
Fuzzy
House of Risk
Pallet
Risk miitigation
Supply chain

Editor: Noni Oktiana Setiowati

Publisher's note: The publisher remains neutral concerning jurisdictional claims in published maps and institutional affiliations.

ABSTRACT

X Corp. is a manufacturing company that produces various wood packaging products, including pallets, which are in high demand, particularly for export commodities. However, the company's supply chain activities are often affected by various risks. If these risks are not addressed in a timely manner, they could disrupt the supply chain and lead to negative consequences for the company. Therefore, the company management needs to implement supply chain risk management to identify and mitigate these risks. This study aims to identify the risks that have occurred or are likely to occur in the supply chain of X Corp. and determine which risks should be prioritized for mitigation. The fuzzy house of risk method was used to analyze the data. The results of the study identified 38 risk events and 22 risk agents. Additionally, 17 proactive actions were proposed to the company to address the priority risk agents and mitigate their potential impact.

1. Introduction

The supply chain refers to a network of companies that collaborate to create and deliver products to the end consumer [1]. However, managing supply chain activities is not easy, as there are various risks that could disrupt the company's operations. To minimize these risks, companies need to implement risk management practices that enable them to identify and control potential risks at every stage of the supply chain. Supply Chain Risk Management (SCRM) has gained significant importance in recent years as it helps to reduce the level of uncertainty in the supply chain [2], [3]. SCRM enables companies to identify and assess supply chain disruptions, as well as minimize the negative impact on supply chain performance [4]. To effectively manage the supply chain, companies need to manage three types of flows: raw materials, money, and information [5]. SCRM has a significant influence on the cooperation among partners and the performance of the entire production chain [6]. It encompasses various strategies, including identifying, assessing, mitigating, and monitoring unexpected events or conditions that may have an adverse impact on any part of the supply chain [7]. As such, supply chain risk management has become essential for the success of supply chain operations [8]. Risk management involves making decisions to accept, avoid, transfer, or share a known risk, or implementing actions to reduce the consequences or probability of an adverse event [9]. In summary, effective SCRM practices are critical for companies to manage risks and maintain the stability of their supply chain operations.

X Corp. is a manufacturing company that produces pallets, dunnage, wooden boxes, and haspels. The company has obtained registration from the Agricultural Quarantine Agency under the Indonesian Ministry of Agriculture to carry out treatment and marking certification of wood packaging used for commodity exports in accordance with the requirements of ISPM No. 15. Despite engaging in various supply chain activities, X Corp. still faces potential risks that may have negative impacts. One of these risks is the emergence of live insects or fungi, particularly on pallet products. This risk event can occur when the pallets are stored in unsterile areas, potentially leading to the re-emergence of live insects or mold on the pallets. The pallet products produced by X Corp. are widely used by customers, particularly for export purposes, and must meet strict requirements to

*Corresponding author:
Email: maria@untirta.ac.id

http://dx.doi.org/10.36055/jiss.v9i1.18953

be considered sterile from Plant Destruction Organisms that could potentially disturb the ecosystem of the export destination country.

Another risk that has occurred at X Corp. is the quality of raw materials received from suppliers that are not in good condition. Poor quality of raw materials is indicated by wood that does not meet quality standards, such as breaking easily during the production process, having cracks, or not meeting the specifications ordered by the company.

Apart from that, another risk is the risk of work accidents. These risk events can occur due to employees' lack of concern for Health and Safety Environment. The conditions in the field also show that many workers do not use safety equipment when doing their work, so the risk of work accidents can occur at any time.

In addition, there may be many other risks that have not been identified yet. Therefore, it is important to further investigate the risks in the supply chain flow, especially for pallet products at X Corp. The aim is to identify what risks have occurred or have the potential to arise along the pallet product supply chain flow at X Corp. and to make appropriate risk mitigation actions to prevent or reduce the risk agents from appearing. This will help minimize the impacts caused by the risk agents.

In this study, the risks to be identified are the risk events and risk agents. These risks will be identified based on the mapping of pallet product supply chain activities at X Corp., with the help of the SCOR (Supply Chain Operations Reference) model. The SCOR model is a standard guideline that can assist companies in evaluating performance by identifying and measuring supply chain performance matrices [10]. To identify and assess risks, this study integrates the conventional house of risk method with the fuzzy logic approach, which aims to eliminate subjectivity by converting crisp numbers in the risk assessment questionnaire into fuzzy numbers. In this study, the FIS (Fuzzy Inference System) Mamdani was used because it is highly flexible, tolerates existing data, and is more intuitive and widely accepted. It covers a wide field and is in accordance with the human information input process [11].

Previous research on supply-chain risk management includes studies such as "Challenges in Reducing Seaweed Supply Chain Risks Arising within and outside Remote Islands in Indonesia: An Integrated MCDM Approach" [12], "Food Supply Chain Management: Systems, Implementations, and Future Research" [13], "House of Risk Approach for Assessing Supply Chain Risk Management Strategies" [14], and "Risk Mitigation Strategy for Mangosteen Business Using House of Risk (HOR) Methods" [15]. Other studies include "Risk Mitigation Design in the Production Process of Packaged Fruit Juice Drinks Using a Fuzzy-Based House of Risk (HOR) Approach" [16], "An Advanced Fuzzy Bayesian-Based FMEA Approach for Assessing Maritime Supply Chain Risks" [17], and "Conceptualizing Community in Disaster Risk Management" [18].

This research is expected to benefit PT. X by helping them identify the risks that have occurred or have the potential to arise in the supply chain flow, especially in relation to pallet products. By doing so, the company can anticipate any potential risks and develop effective mitigation strategies to deal with them.

2. Material and method

This research employs a descriptive approach that uses both quantitative and qualitative methods to collect data. The data collection includes conducting interviews with experts in X Corp., field observations, and distributing questionnaires to the company. The first step of the research is to map the supply chain activities at X Corp., using the SCOR model to identify the core processes: plan, source, make, deliver, and return. The second step is to identify potential risk events and agents that could disrupt supply chain activities. The third step involves conducting a risk analysis by assessing the severity, occurrence, and correlation of the risk events and agents. This includes a fuzzification process where the results of the risk assessment questionnaire are converted into linguistic variables to determine the degree of fuzzy membership of each input, followed by determining fuzzy rules to infer output based on input variables. The deffuzification process then maps the value of the fuzzy set into crisp numbers using the centroid method.

The fourth step is conducting a risk evaluation using a Pareto diagram to determine priority risk agents for mitigation. The fifth and final step involves risk mitigation, which includes designing appropriate risk mitigation actions to prevent or reduce the potential risks in the supply chain. This step involves proactive action identification, followed by correlation assessment between risk agents and proactive actions, degree of difficulty assessment to determine the total effectiveness (TEk) and effectiveness to difficulty ratio (ETDk), and ultimately identifying which proactive actions to prioritize based on effectiveness and ease of implementation. The entire fuzzification and deffuzification process in this research was performed using Matlab 2013 software.

3. Results and discussions

3.1. Risk identification

The risk identification process was carried out through observation, interviews, and brainstorming with company management. A crucial step in managing supply chain risks is classifying the sources of risk after identifying them to prioritize risks and allocate scarce resources optimally to minimize those with the highest likelihood of generating losses [19]. The results of the risk identification process revealed 38 risk events and 22 risk agents. Table A1 (see Appendices) shows the results of the risk identification process.

3.2. Risk analysis

At this stage, a risk assessment will be carried out, consisting of assessing the severity, occurrence, and correlation. Then, fuzzification and defuzzification will be conducted to determine the FARP value of each risk agent. The formula for the geometric mean (GM) in Eq. (1) is used to obtain the results of the severity, occurrence, and correlation values.

$$GM = \sqrt[n]{x_1 x_2 \ldots x_n} \tag{1}$$

where n is the number of repondents, x_i is the respond of respondent-i. The results of assessment for severity, occurrence, and correlation are attached in Appendices (Table A2, Table A3, Table A4).

After the risk assessment is carried out, the fuzzy education process is conducted to convert firm numbers into fuzzy numbers. The fuzzification process requires fuzzy input and output fuzzy sets. The fuzzy input sets consist of fuzzy severity, occurrence, and correlation sets, while the fuzzy output sets consist of FARP fuzzy sets. The fuzzy severity set has five linguistic variables: very low (VL), low (L), normal (N), severe (S), and very severe (VS) with a scale from 1 to 10. The set of fuzzy occurrences in this study has three linguistic variables low (L), normal (N) and frequent (F) with a scale from 0 to 1. The fuzzy correlation set in this study has three linguistic variables: low (L), medium (M), and high (H) with a scale from 1 to 9.

Table 1, Table 2, and Table 3 describe the fuzzy severity, occurences, and correlation sets in tabular form. Fig. 1, Fig. 2, and Fig. 3 were created using Matlab 2013 software: a graph for the fuzzy severity set, a graph for the fuzzy occurrence set, and a graph for the fuzzy correlation set.

Table 1.
Fuzzy set of severity

Linguistics	Domain
Very Low	[1 ; 1 ; 2.5 ; 4]
Low	[2.5 ; 4 ; 5.5]
Normal	[4 ; 5.5 ; 7]
Severe	[5.5 ; 7 ; 8.5]
Very Severe	[7 ; 8.5 ; 10 ; 10]

Table 2.
Fuzzy set of occurence

Linguistics	Domain
Low	[0 ; 0 ; 0.25 ; 0.5]
Normal	[0.25 ; 0.5 ; 0.75]
Frequent	[0.5 ; 0.75 ; 1 ; 1]

Table 2.
Fuzzy set of occurence

Linguistics	Domain
Low	[1 ; 1 ; 3 ; 5]
Medium	[3 ; 5 ; 7]
High	[5 ; 7 ; 9 ; 9]

The membership function formulas for the fuzzy severity set are given by Eqs. (2)-(6). The membership function formula for the fuzzy occurence set Eqs. (7)-(9). The membership function formula for the fuzzy correlation set Eqs. (10)-(12).

$$\text{Very low} = \begin{cases} 1 & x \leq 2.5 \\ \dfrac{(4 - x)}{(4 - 2.5)} & 2.5 \leq x \leq 4 \end{cases} \tag{2}$$

$$\text{Low} = \begin{cases} 0 & x \leq 2.5 \text{ atau } x \geq 5.5 \\ \dfrac{(x - 2.5)}{(4 - 2.5)} & 2.5 \leq x \leq 4 \\ \dfrac{(5.5 - x)}{(5.5 - 4)} & 4 \leq x \leq 5.5 \end{cases} \tag{3}$$

$$\text{Normal} = \begin{cases} 0 & x \leq 4 \text{ atau } x \geq 7 \\ \dfrac{(x - 4)}{(5.5 - 4)} & 4 \leq x \leq 5.5 \\ \dfrac{(7 - x)}{(7 - 5.5)} & 5.5 \leq x \leq 7 \end{cases} \tag{4}$$

$$\text{Severe} = \begin{cases} 0 & x \leq 5.5 \text{ atau } x \geq 8.5 \\ \dfrac{(x - 5.5)}{(7 - 5.5)} & 5.5 \leq x \leq 7 \\ \dfrac{(8.5 - x)}{(8.5 - 7)} & 7 \leq x \leq 8.5 \end{cases} \tag{5}$$

$$\text{Very severe} = \begin{cases} \dfrac{(x - 7)}{(8.5 - 7)} & 7 \leq x \leq 8.5 \\ 1 & x \geq 8.5 \end{cases} \tag{6}$$

$$\text{Low} = \begin{cases} 1 & x \leq 0.25 \\ \dfrac{(0.5 - x)}{(0.5 - 0.25)} & 0.25 \leq x \leq 0.5 \end{cases} \tag{7}$$

$$\text{Normal} = \begin{cases} 0 & x \leq 0.25 \text{ atau } x \geq 0.75 \\ \dfrac{(x - 0.25)}{(0.5 - 0.25)} & 0.25 \leq x \leq 0.5 \\ \dfrac{(7.5 - x)}{(7.5 - 0.5)} & 0.5 \leq x \leq 0.75 \end{cases} \tag{8}$$

$$\text{Frequent} = \begin{cases} \dfrac{(x - 0.5)}{(0.75 - 0.5)} & 0.5 \leq x \leq 0.75 \\ 1 & x \geq 0.75 \end{cases} \tag{9}$$

$$\text{Low} = \begin{cases} 1 & x \leq 3 \\ \dfrac{(5 - x)}{(5 - 3)} & 3 \leq x \leq 5 \end{cases} \tag{10}$$

$$\text{Medium} = \begin{cases} 0 & x \leq 3 \text{ atau } x \geq 7 \\ \dfrac{(x - 3)}{(5 - 3)} & 3 \leq x \leq 5 \\ \dfrac{(7 - x)}{(7 - 5)} & 5 \leq x \leq 7 \end{cases} \tag{11}$$

$$\text{High} = \begin{cases} \dfrac{(x - 5)}{(7 - 5)} & 5 \leq x \leq 7 \\ 1 & x \geq 7 \end{cases} \tag{12}$$

After carrying out fuzzification and determining the fuzzy rules, consisting of 45 rules [20], the next step is defuzzification. This process is used to find the FARP (Final Aggregated Risk Priority) value of each risk agent, which enables the identification of the priority risk agent for mitigation. The results of the defuzzification process were obtained using Matlab 2013 software and are presented in Table A5 (see Appendices).

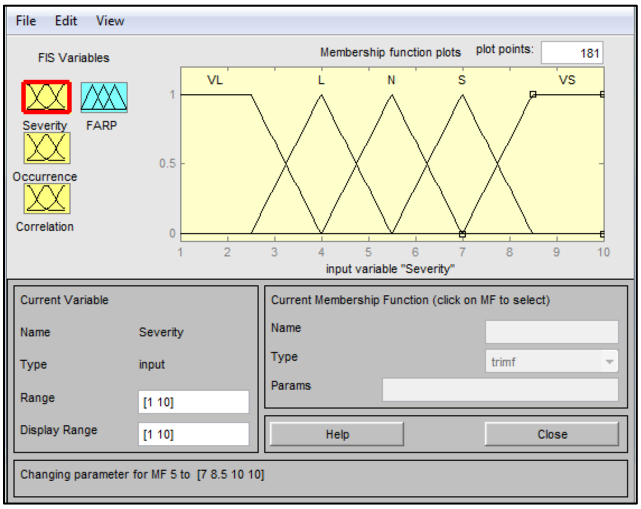

Figure 1. Fuzzy set graph for input severity

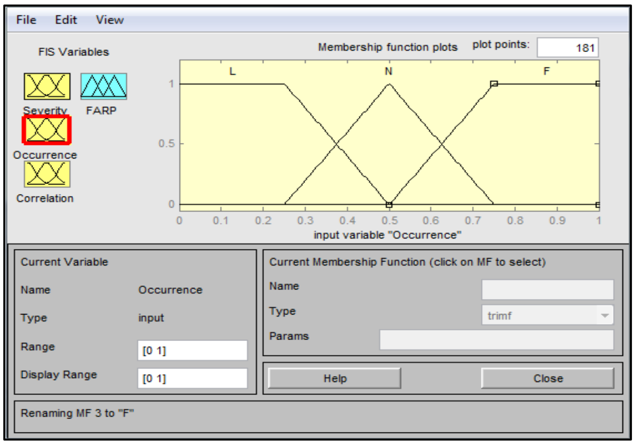

Figure 2. Fuzzy set graph for input occurrence

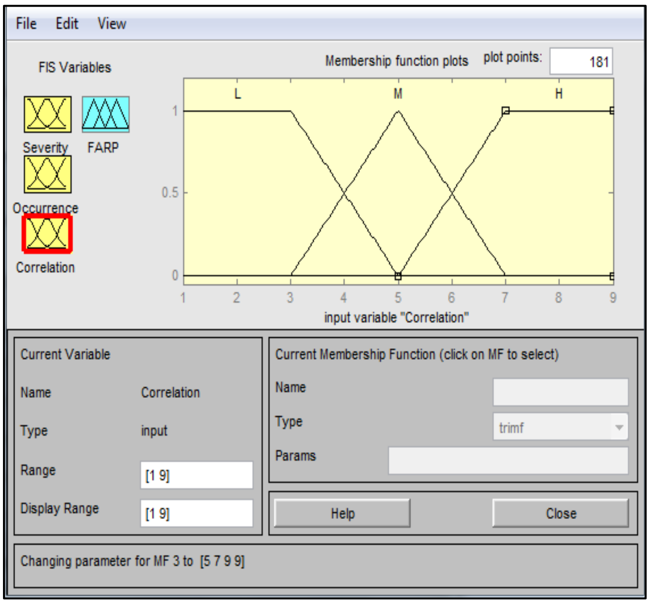

Figure 3. Fuzzy set graph for input correlation

3.3. Risk evaluation

The purpose of the risk evaluation stage is to determine the primary priority for mitigation actions [21]. This involves sorting the FARP values of each risk agent, starting from the largest to the smallest, using a Pareto diagram. Fig. 4 shows the Pareto diagram that displays the priority risk agents for mitigation.

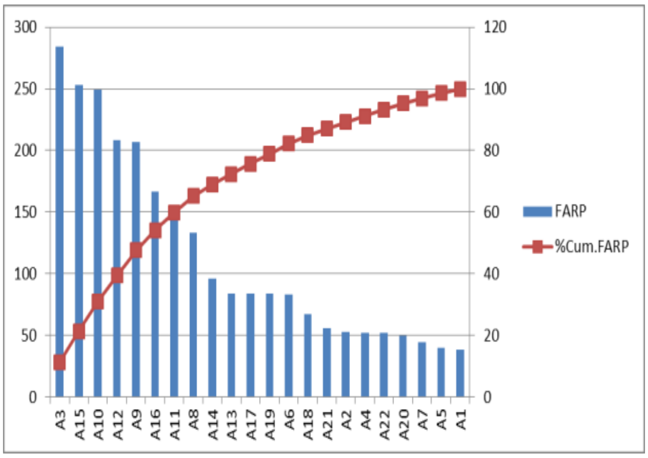

Figure 4. Pareto risk agent diagram

In this study, risk agents are divided into two categories. Category A includes the risk agents with primary priority, while Category B includes the risk agents with secondary priority. The division of risk agents is based on the Pareto principle, also known as the 80/20 principle. Risk agents that belong to Category A are those that have a cumulative value of up to 80%, while the remaining 20% are classified as Category B. The Pareto diagram above shows that 13 risk agents belong to Category A or have primary priority for mitigation, indicating that their cumulative % FARP is 80%. The other 9 risk agents are designated as Category B or risk agents with secondary priority.

3.4. Risk mitigation

The risk mitigation stage involves three steps: risk mitigation actions, evaluation of the results of risk mitigation actions, and determination of risk mitigation action priorities. This stage is carried out using HOR phase 2, as shown in Table A6 (see Appendices). Risk mitigation aims to minimize risk after it arises, which means that it is a form of damage control [22]. Once the priority risk agents for mitigation have been identified, the next step is to take proactive actions to reduce or prevent the potential for risk agents to appear. This process involves conducting interviews and brainstorming sessions with expert judgment from X Corp. Table A7 (see Appendices) shows the results of the risk mitigation actions.

After taking proactive risk mitigation actions, the next step is to evaluate their effectiveness. This process involves assessing the correlation between risk agents and proactive actions, as well as evaluating the degree of difficulty. A questionnaire is used for this assessment, which is completed by management representatives, technical managers, and one operational staff member from X Corp. The rating scale used for assessing the correlation between risk agents and proactive actions is 0, 1, 3, and 9 [23]. On the other hand, the rating scale used for assessing the degree of difficulty is 3, 4, and 5 [24].

After assessing the effectiveness of the risk mitigation actions, the next step is to calculate the Total Effectiveness (TEk) and the Effectiveness to Difficulty Ratio (ETDk). The proposed risk mitigation actions are expected to minimize both the occurrence of risks and potential losses throughout the company's supply chain, from upstream to downstream. By reducing risks in the supply chain, the company aims to improve its overall performance and achieve its targets.

Implementing this risk mitigation action can have a positive impact on the company's supply chain performance. By reducing the emergence of risks and their consequences, the company can achieve its goals, objectives, vision, and mission. Given the current market developments, it's essential to have good supplier participation in managing and distributing products to reach the end customer. Therefore, improving supply chain performance is crucial for a company's success [25].

Risk mitigation involves managing and monitoring risks, creating mitigation measures, reducing risk impact, and decreasing the likelihood of occurrence [26]. Furthermore, implementing this risk mitigation action can enhance the company's productivity. Improved productivity is reflected in enhanced welfare and quality of the company, enabling the company to achieve its targets by efficiently utilizing its resources.

3.5. Managerial implications

This research provides recommendations for companies to mitigate risk agents by implementing effective strategies. By doing so, companies can improve their productivity and product quality.

4. Conclusions

Based on the study's data processing results, 38 risk events and 22 risk agents were identified in all supply chain activities at X Corp., using the SCOR model's five core processes: plan, source, make, deliver, and return. Using the fuzzy house of risk method, 13 risk agents were identified as priority for mitigation: A3, A15, A10, A12, A9, A16, A11, A8, A14, A13, A17, A19, A6. Additionally, the study's data processing revealed 17 priority risk mitigation strategies: PA1, PA2, PA7, PA4, PA8, PA9, PA10, PA3, PA5, PA6, PA14, PA16, PA11, PA15, PA17, PA12, PA13.

Future research should focus on more detailed and thorough risk identification processes. This should include expanding the identification process beyond the five core processes of the SCOR model and considering other categories such as financial and environmental risks. This will provide a better understanding of the risks that exist or may arise in the company's supply chain.

Declaration statement

Maria Ulfah: **Conceptualization, Methodology, Supervision, Project administration, Funding acquisition, Writing - Review & Editing**. Achmad bahauddin: **Software and Resources, Validation, Formal analysis**. Dyah Lintang Trenggowati: **Resources, Visualization, Investigation**. Ratna Ekawati: **Writing - Original Draft**. Faula Arina: **Data curation, Validation**. Atia Sonda: **Writing - Original Draft - Resources, Validation.** Asep Ridwan: **Validation.** Putro Ferro Ferdinant: **Writing.**

Acknowledgement

Thanks and the greatest appreciation to management representatives, technical managers and operational staff of X Corp., which has contributed a lot during the research both as a data source and as a respondent.

Disclosure statement

The authors report there are no competing interests to declare.

Funding statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

[1] I. N. Pujawan and M. Mahendrawathi, *Supply Chain Management Edisi 3*. Yogyakarta: Penerbit ANDI, 2017.

[2] A. Gurtu and J. Johny, “Supply Chain Risk Management: Literature Review,” *Risks*, vol. 9, no. 1, p. 16, Jan. 2021, doi: 10.3390/risks9010016.

[3] A. Wieland and C. M. Wallenburg, “Dealing with supply chain risks: Linking risk management practices and strategies to performance,” *International Journal of Physical Distribution & Logistics Management*, vol. 42, no. 10, pp. 887–905, 2012, doi: 10.1108/09600031211281411.

[4] K. P. Scheibe and J. Blackhurst, “Supply chain disruption propagation: a systemic risk and normal accident theory perspective,” *International Journal of Production Research*, vol. 56, no. 1-2, pp. 43-59, 2018, doi: 10.1080/00207543.2017.1355123.

[5] A. Ridwan, M. I. Santoso, P. F. Ferdinant, and R. Ankarini, “Design of strategic risk mitigation with supply chain risk management and cold chain system approach,” *IOP Conference Series: Materials Science and Engineering*, vol. 673, no. 1, p. 012088, Dec. 2019, doi: 10.1088/1757-899x/673/1/012088.

[6] G. C. Dias, C. T. Hernandez, and U. R. de Oliveira, “Supply chain risk management and risk ranking in the automotive industry,” *Gestão & Produção*, vol. 27, no. 1, 2020, doi: 10.1590/0104-530x3800-20.

[7] G. Baryannis, S. Validi, S. Dani, and G. Antoniou “Supply chain risk management and artificial intelligence: state of the art and future research directions,” *International Journal of Production Research*, vol. 57, no. 7, pp. 2179-2202, 2019, doi: 10.1080/00207543.2018.1530476.

[8] F. Cagnin, M. C. Oliveira, A. T. Simon, A. L. Helleno, and M. P. Vendramini, "Proposal of a method for selecting suppliers considering risk management: An application at the automotive industry," *International Journal of Quality & Reliability Management*, vol. 33, no. 4, pp. 488–498, 2014, doi: 10.1108/IJQRM-11-2014-0172.

[9] T. C. E. Cheng, F. K. Yip, and A. C. L. Yeung, "Supply risk management via guanxi in the Chinese business context: The buyer's perspective," *International Journal of Production Economics*, vol. 139, no. 1, pp. 3–13, Sep. 2012, doi: 10.1016/j.ijpe.2011.03.017.

[10] M. Asrol, M. Marimin, and M. Machfud, "Supply chain performance measurement and improvement for sugarcane agro-industry," *International Journal of Supply Chain Management*, vol. 6, no. 3, pp. 8-21, 2017.

[11] D. Yuliana, "Fuzzy Inference System Metode Mamdani Untuk Mengidentifikasi Jenis Alergi Pernafasan Secara Dini Pada Anak Usia 3-6 Tahun," *Jurnal Lentera ICT*, vol. 5, no. 2, 2019.

[12] W. A. Teniwut, "Challenges in reducing seaweed supply chain risks arising within and outside remote Islands in Indonesia: an integrated MCDM approach," *in Sustainability Modeling in Engineering*, pp. 271-291, 2020, doi: 10.1142/9789813276338_0012.

[13] R. Zhong, X. Xu, and L. Wang, "Food supply chain management: systems, implementations, and future research," *Industrial Management & Data Systems*, vol. 117, no. 9, pp. 2085-2114, 2017, doi: 10.1108/IMDS-09-2016-0391.

[14] T. Immawan and D. K. Putri, "House of risk approach for assessing supply chain risk management strategies: a case study in crumb rubber company Ltd.," *MATEC Web Conf*, vol. 154, pp. 1–4, 2018, doi: 10.1051/matecconf/201815401097.

[15] R. Astuti, R. L. R. Silalahi, and R. A. Rosyadi, "Risk mitigation strategy for mangosteen business using House of Risk (HOR) methods: (A case study in "Wijaya Buah", Blitar District, Indonesia)," *KnE Life Sciences*, vol. 4, no. 2, pp. 17–27, 2017, doi: 10.18502/kls.v4i2.1653.

[16] R. D. Lufika, P. D. Sentia, I. Ilyas, F. Erwan, A. Andriansyah, and A. Muthmainnah, "Risk Mitigation Design in the Production Process of Packaged Fruit Juice Drinks Using a Fuzzy Based House of Risk (HOR) Approach," *Jurnal Sistem Teknik Industri*, vol. 24, no. 2, pp. 245-253, 2022.

[17] C. Wan, X. Yan, D. Zhang, Z. Qu, and Z. Yang, "An advanced fuzzy Bayesian-based FMEA approach for assessing maritime supply chain risks", *Transportation Research Part E: Logistics and Transportation Review*, vol. 125, pp. 222-240, 2019, doi: 10.1016/j.tre.2019.03.011.

[18] A. Räsänen, H. Lein, D. Bird, and G. Setten, "Conceptualizing community in disaster risk management," *International Journal of Disaster Risk Reduction*, vol. 45, p. 101485, May 2020, doi: 10.1016/j.ijdrr.2020.101485.

[19] D. Kern, R. Moser, E. Hartmann, and M. Moder, "Supply risk management: model development and empirical analysis," *International Journal of Physical Distribution & Logistics Management*, vol. 42, no. 1, pp. 60-82, 2012, doi: 10.1108/09600031211202472.

[20] H. L. Ma and W. H. C. Wong, "A-Fuzzy Based House of Risk Assessment Method For Manufacturers In Global Supply Chain," *Industrial Management & Data System*, vol. 118, no. 7, pp. 1463-1476, 2018, doi: 10.1108/IMDS-10-2017-0467.

[21] M. Ulfah, P. F. Ferdinant, D. L. Trenggonowati, and M. Salsabila, "Supply-chain risk mitigation with integration House of Risk and fuzzy logic: A case study in bakery industry," *Journal Industrial Servicess*, vol. 8, no. 2, pp. 151-157, October 2022, doi: 10.36055/jiss.v8i2.17393.

[22] D. L. Trenggonowati, M. Ulfah, F. Arina, and C. Lutifiah, "Analysis and strategy of supply chain risk mitigation using fuzzy failure mode and effect analysis (fuzzy FMEA) and fuzzy analytical hierarchy process (fuzzy AHP)", *IOP Conf. Series: Materials Science and Engineering*, p. 909, 2020, doi: 10.1088/1757-899X/909/1/012085.

[23] N. Pujawan and L. H. Geraldin, "House of risk: a model for proactive supply chain risk management," *Business Process Management Journal*, vol. 15, no. 6, pp. 953-967, 2009, doi: 10.1108/14637150911003801.

[24] M. Cahya and E. Wulandari, "Risiko rantai pasok paprika pada anggota kelompok tani dewa family, Kabupaten Bandung Barat," *Jurnal Pemikiran Masyarakat Ilmiah Berwawasan Agribisnis*, vol. 5, no. 2, pp. 252-275, Juli 2019, doi: 10.25157/ma.v5i2.2230.g2089.

[25] A. Ridwan, K. Kulsum, and E. Sinurat, " Integrasi lean six sigma, balanced scorecard, dan simulasi sistem dinamis dalam peningkatan kinerja supply chain. *Journal Industrial Servicess*, vol. 4, no. 2, 2019, doi: 10.36055/jiss.v4i2.5150.

[26] M. Ulfah, D. L. Trenggonowati, and F. Zahra Yasmin, "Proposed supply chain risk mitigation strategy of chicken slaughterhouse PT X by house of risk method," *MATEC Web of Conferences*, vol. 218, p. 04023, 2018, doi: 10.1051/matecconf/201821804023.

Appendices

Table A1.
Risk identification

Major process	Risk event	Code	Risk agent	Code
Plan	Sudden change in production planning	E1	Mistakes in making a production plan	A1
	Error in notifying production schedule information to employees	E2	A sudden change in production planning	A2
	Gap between recorded and available stock of raw materials	E3	Lack of coordination and checking of remaining stocks	A3
	Planning the number of raw materials to be ordered is not accurate / accurate	E4	Sudden purchase requests	A4
	Error in determining the time of delivery of products to customers	E5	Error checking shipping instruction sent by customer	A5
	The company gets complaints from customers	E6	Products sent are not according to customer requests	A6
Source	Late delivery of raw materials from suppliers	E7	There are obstacles experienced by the supplier	A7
	The warehouse for storing raw materials cannot accommodate all incoming raw materials	E8	Limited warehouse space	A8
	Error in raw material received	E9	Lack of accuracy on the part of the supplier	A9
	The amount of raw material received is not appropriate	E10		
	Raw materials that are damaged or do not comply with quality standards, pass the inspection process	E11	Lack of accuracy when carrying out quality control activities	A10
	Do not evaluate supplier performance	E12	The supplier does not match the company's criteria	A11
	Mistakes in choosing suppliers	E13		
Make	There was damage to production machines and equipment	E14	Lack of maintenance	A12
	There was a work accident	E15	Lack of employee concern for Occupational Health and safety (OHS)	A13
	Delay in production execution	E16	Human resource limitations	A14
	Production results have not been able to meet the number of requests	E17		
	Error in recording production results	E18	Lack of Accuracy during the recording process	A15
	Defective products that will be treated (treatment) pass the inspection	E19	Lack of accuracy when carrying out quality control activities	A10
	Error in making reports on the implementation of the heat treatment process	E20	Lack of Accuracy during the recording process	A15
	The insecticide stock was out of stock	E21	Lack of coordination and checking of remaining stocks	A3
	Lack of firewood stock for the heat treatment processtreatment	E22		
	Environmental pollution	E23	Use of hazardous chemicals	A16
	Fumigators/employees are exposed to methyl bromide gas	E24		
	Products do not comply with quality standards/ damaged	E25	Lack of accuracy when carrying out the production process	A17
	The storage warehouse cannot accommodate finished products.	E26	Limited warehouse space	A8
	The product of the treatment process is exposed to plant pests	E27	The finished product is placed in a non-sterile place	A18
	The certification stamp is damaged	E28	Lack of maintenance	A12
	Out of stock of barcode stickers	E29	Lack of coordination and checking of remaining stocks	A3
	Error in recording of certified products and barcode attachments	E30	Lack of Accuracy during the recording process	A15
Deliver	Products that do not comply with quality standards pass the inspection	E31	Lack of accuracy when carrying out quality control activities	A10
	A decline in quality in finished products	E32	The finished product is exposed to plant pests	A19
	Containers are dirty, leaking or dented	E33	Lack of maintenance	A12
	The product was damaged during the stuffing process	E34	Employees are not careful when stuffing	A20
	Error in recording stuffing and container data	E35	Lack of Accuracy during the recording process	A15
	Late delivery of products to consumers	E36	Containers experience disruption when shipping products to consumers	A21
Return	The product is damaged or does not match the specifications requested by the customer	E37	Lack of accuracy when inspecting the product to be sent	A22
	There are raw materials that are reject/do not match the quality set by the company	E38	Lack of accuracy on the part of the supplier	A9

Table A2.
Severity assessment result

Risk event	R1	R2	R3	GM
E1	7	7	6	6.6
E2	7	8	6	7
E3	7	8	8	7.7
E4	8	7	7	7.3
E5	7	7	6	6.6
E6	8	8	7	7.7
E7	7	7	6	6.6
E8	6	6	7	6.3
E9	7	8	8	7.7
E10	5	8	7	6.5
E11	8	8	7	7.7
E12	5	6	7	5.9
E13	7	9	8	8
E14	9	8	9	8.7
E15	9	8	8	8.3
E16	8	8	6	7.3
E17	7	7	6	6.6
E18	4	6	5	4.9
E19	8	7	8	7.7
E20	7	8	7	7.3
E21	6	7	6	6.3
E22	7	8	8	7.7
E23	9	8	7	8
E24	7	8	9	8
E25	8	7	6	7
E26	7	8	8	7.7
E27	9	8	7	8
E28	5	6	5	5.3
E29	6	6	6	6
E30	8	8	7	7.7
E31	8	8	8	8
E32	8	7	6	7
E33	7	8	7	7.3
E34	8	8	7	7.7
E35	6	7	7	6.6
E36	8	8	7	7.7
E37	7	8	6	7
E38	5	6	7	5.9

Table A3.
Occurrence assessment result

Risk agent	R1	R2	R3	GM
A1	0.2	0.3	0.4	0.3
A2	0.3	0.3	0.2	0.3
A3	0.5	0.6	0.7	0.6
A4	0.3	0.3	0.3	0.3
A5	0.3	0.3	0.3	0.3
A6	0.6	0.7	0.5	0.6
A7	0.3	0.2	0.3	0.3
A8	0.5	0.7	0.6	0.6
A9	0.5	0.7	0.4	0.5
A10	0.9	0.8	0.7	0.8
A11	0.7	0.8	0.6	0.7
A12	0.5	0.6	0.5	0.5
A13	0.9	0.9	0.8	0.9
A14	0.2	0.3	0.3	0.3
A15	0.4	0.6	0.5	0.5
A16	0.7	0.8	0.7	0.7
A17	0.7	0.7	0.6	0.7
A18	0.4	0.3	0.4	0.4
A19	0.8	0.7	0.6	0.7
A20	0.2	0.3	0.2	0.2
A21	0.2	0.3	0.3	0.3
A22	0.3	0.3	0.4	0.3

Table A4.
Correlation assessment result

Risk event	Risk agent	R1	R2	R3	GM
E1	A1	9	3	5	5.1
E2	A2	9	3	7	5.7
E3	A3	5	9	7	6.8
E4	A4	9	9	9	9
E5	A5	3	9	5	5.1
E6	A6	9	9	9	9
E7	A7	9	9	9	9
E8	A8	4	3	5	3.9
E9	A9	9	9	9	9
E10		9	9	9	9
E11	A10	9	9	9	9
E12	A11	9	9	9	9
E13		9	9	9	9
E14	A12	9	9	9	9
E15	A13	9	9	9	9
E16	A14	3	9	5	5.1
E17		9	9	9	9
E18	A15	9	3	5	5.1
E19	A10	9	9	9	9
E20	A15	9	3	7	5.7
E21	A3	9	9	9	9
E22		9	9	8	8.7
E23	A16	9	9	9	9
E24		9	9	9	9
E25	A17	9	9	9	9
E26	A8	9	3	5	5.1
E27	A18	9	9	9	9
E28	A12	9	9	9	9
E29	A3	9	3	6	5.5
E30	A15	9	9	9	9
E31	A10	9	9	9	9
E32	A19	9	9	9	9
E33	A12	9	9	9	9
E34	A20	9	9	9	9
E35	A15	9	9	6	7.9
E36	A21	9	9	9	9
E37	A22	9	9	9	9
E38	A9	9	9	9	9

Table A5.
Defuzzification result

Risk agent	Risk event	FARP	Total FARP	Rank
A1	E1	38	38	22
A2	E2	52.8	52.8	16
A3	E3	79.7	284.5	1
	E21	63.9		
	E22	82.8		
	E29	58.1		
A4	E4	52	52	17
A5	E5	39.5	39.5	21
A6	E6	82.8	82.8	13
A7	E7	44.3	44.3	20
A8	E8	61.1	133	8
	E26	71.9		
A9	E9	82.8	206.5	5
	E10	69.1		
	E38	54.6		
A10	E11	82.8	249	3
	E19	82.8		
	E31	83.4		
A11	E12	62.3	145.7	7
	E13	83.4		
A12	E14	84.7	208.6	4
	E28	40		
	E33	83.9		
A13	E15	84.2	84.2	10
A14	E16	52	96.3	9
	E17	44.3		
A15	E18	29.6	253.2	2
	E20	69.2		
	E30	82.8		
	E35	71.6		
A16	E23	83.4	166.8	6
	E24	83.4		
A17	E25	83.9	83.9	11
A18	E27	67.1	67.1	14
A19	E32	83.9	83.9	12
A20	E34	49.5	49.5	19
A21	E36	55.5	55.5	15
A22	E37	51.8	51.8	18

Table A6.
House of Risk fase 2

Risk Agent	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	PA13	PA14	PA15	PA16	PA17	FARP
A3	9	9																284.5
A15			4.3															253.2
A10				6.2	4.3													249
A12						6.2												208.6
A9							9											206.5
A16								9	9									166.8
A11										9								145.7
A8											9							133
A14												6.2	6.2					96.3
A13														9				84.2
A17															6.2			83.9
A19																9		83.9
A6																	6.2	82.8
TE_k	2560	2560	1095	1553	1077	1301	1858	1501	1501	1311	1197	600	600	757	523	755	516	
D_k	3	3.3	3	3	3.3	4	3.3	3	3	3	5	3.6	4.6	3	3	3	3	
ETD_k	853	775	365	517	326	325	562	500	500	437	239	165	129	252	174	251	172	
Rank	1	2	8	4	9	10	3	5	6	7	13	16	17	11	14	12	15	

Table A7.
Proactive Action Results

Code	Risk Agent	Proactive Action (PA)	Code
A3	Lack of coordination and checking of remaining stocks	Conduct internal meetings with the person in charge	PA1
		Perform regular checks and adjustments between available stock and those recorded in the document	PA2
A15	Lack of accuracy during the recording process	Carry out crosschecks after carrying out the recording process	PA3
A10	Lack of accuracy when performing quality control	Give a warning to the person in charge	PA4
		Re-check incoming raw materials or finished goods	PA5
A12	Lack of maintenance	Perform maintenance on machines and equipment regularly and periodically	PA6
A9	of Lack accuracy from the supplier	Give a warning or warning to the supplier if an error occurs again	PA7
A16	Use of hazardous chemicals	Make sure to use personal protective equipment during the fumigation process	PA8
		Keep a distance of ± 2 meters from the fumigation site	PA9
A11	The supplier does not match the company's criteria	Evaluating supplier performance regularly	PA10
A8	Limited warehouse land	Creating a new warehouse or expanding an existing warehouse	PA11
A14	Human resource limitations	Increase working hours	PA12
		Recruiting new workers	PA13
A13	employees care less about Occupational Health and Safety (OHS)	Give a warning or warning to employees who do not use personal protective equipment	PA14
A17	Lack of accuracy when carrying out the production process	Give a warning or warning to employees who do not use personal protective equipment	PA15
A19	The finished product is exposed to Plant Pest Organisms	Check and clean the finished product warehouse regularly to ensure that the warehouse is free from plant pests	PA16
A6	Products sent are not according to customer requests	Checking and adjusting the finished product with the product criteria ordered by the customer before the product is shipped	PA17