Available online at: http://e-jurnal.lppmunsera.org/index.php/INTECH
Jurnal INTECH Teknik Industri Universitas Serang Raya
ISSN (Print) 2407-781X ISSN (Online) 2655-2655

Risk Mitigation Design in the Supply Chain Process of Arabica Cofee Fort Alla

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ARTICLE INFORMATION

Article history:

Received: September 16, 2025
Revised: December 30, 2025
Accepted: December 31, 2025

Keywords

Delphi Method
House of Risk (HOR)
Risk Mitigation
Supply Chain Risk
Value Chain

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ABSTRACT

The Arabica coffee supply chain in Fort Allé is subject to a number of risks that have the potential to disrupt supply continuity and product quality. The objective of this study is to identify potential risks and develop mitigation strategies that can be integrated into the value chain. The research scope encompasses the identification, prioritization, and design of field-based countermeasures. The Delphi method was employed to identify risk events and agents, and the House of Risk (HOR) approach was utilized for analysis, evaluation, and prioritization of strategies. The data collection process entailed a multifaceted approach, encompassing observational studies, in-depth interviews, the administration of questionnaires, brainstorming sessions, and focus group discussions with cooperative stakeholders. The study identified 14 risk events and 33 risk sources, leading to the formulation of 14 preventive measures. The integration of coffee crops with secondary crops was prioritized (ETDk: 5184), as it enhances both sustainability and profitability. The proposed strategies are embedded within the coffee value chain, offering practical guidance for cooperatives and agroindustry actors to strengthen supply chain resilience and increase added value. The results of this study can serve as a reference for decision-making by cooperatives, agroindustry players, and policymakers in designing coffee supply chain strengthening programs that focus on risk mitigation and increasing added value based on sustainability.

1. INTRODUCTION

The concept of the supply chain existed before the modern understanding of the term emerged (Helo & Hao, 2022). The objectives of the supply chain typically encompass the fulfillment of customer demand, the enhancement of responsiveness, and the establishment and cultivation of relationships with a diverse array of stakeholders (Seyedghorban et al., 2020). A significant challenge confronting numerous organizations is the lack of comprehensive visibility within their supply chains, compounded by the scarcity of available information.

The current state of affairs, in which the available resources within the company are not optimized, is suboptimal. Supply chain management is a critical component for industrial competitiveness, as it enables the provision of affordable, high-quality, and expeditious products (Urnika & Rahmawati, 2020). The primary objective of consumers is to ensure product quality. The manufacturing process, from the procurement of raw materials to the distribution of the final product to consumers, is contingent upon the actions of suppliers and distributors (Sumadi et al., 2019). Every activity in the supply chain is inextricably linked to risk (Kristanto & Kurniawati, 2023). Effective risk management is crucial for ensuring that business operations align with organizational objectives and for enhancing productivity (Rizqiah & Karningsih, 2017). Human factors, systems, and incidents have been identified as the primary causes of risk (Amalina et al., 2024). Common risks include supplier quality failure, delays, logistics damage, vandalism, theft, and terrorism (Rakadhitya et al., 2019). In the agro-industrial sector, risks are more complex because they involve numerous parties and are influenced by factors such as natural resources, environmental issues, seasonality, and health (Imbiri et al., 2021).

The decline in coffee production can be attributed to various factors, including the age and spacing of planting, weather conditions, harvesting services, cooperation with traders, and climate change, which can trigger pests and diseases (Septiani & Kawuryan, 2021; Syakir & Surmaini, 2017). The dearth of coffee management knowledge and technology has also been identified as a contributing factor to the observed decline in production (Sunanto et al., 2019). An analysis of demand data for Benteng Alla Arabica Coffee from 2017 to 2021 reveals an average decrease of 20% from the targeted 25 tons per year. This phenomenon can be attributed to farmers' transition towards cultivating secondary crops and employing conventional maintenance methods, particularly during periods of declining coffee prices. A series of interviews was conducted with the Chairman of Benteng Alla

 http://dx.doi.org/10.30656/intech.v11i2.11358

Cooperative, and the results of these interviews indicated that five primary factors contributed to the decline in production. These factors include extreme weather conditions, pest infestations, inadequate farm management, technical production issues, and price fluctuations. Furthermore, an array of additional risks was identified, including the potential inability to meet demand, the constraints imposed by limited storage facilities, the occurrence of machine breakdowns, a lack of awareness regarding coffee maintenance, inadequate training, and the exorbitant costs associated with transportation.

The value chain is defined as a series of activities that include the design, production, marketing, distribution, and delivery of value to customers (Tadesse & Bekele, 2022). This approach can be used to analyze risks at each stage of the supply chain (Yunus et al., 2023) and identify activities that do not add value, allowing them to be eliminated (Buadit et al., 2023). Several studies have utilized the House of Risk (HOR) method to mitigate risks within the supply chain. For instance, the HOR method has been utilized in the production of ground coffee and the agroindustry of brown sugar (Melly et al., 2019). However, the majority of these enterprises have not yet integrated mitigation strategies into the value chain framework, resulting in underutilized benefits to supply chain sustainability.

Although various risk management and supply chain analysis methods have been widely applied, the use of a single approach has proven unable to address the complexity of the agro-industrial supply chain (Imbiri et al., 2021). The Delphi method is effective in capturing expert knowledge and identifying contextual risks; however, the results obtained tend to be descriptive and lack a mechanism for determining priorities (Seyedghorban et al., 2020). In contrast, the House of Risk (HOR) method offers a systematic framework for mapping the cause-and-effect relationships between risk events and risk agents, as well as prioritizing mitigation actions. However, it is highly dependent on the quality and completeness of the risk data used as input and often does not explain the operational implementation of mitigation (Purnomo et al., 2021). Meanwhile, the value chain approach helps identify activities that add value and those that do not, but it does not inherently provide tools for risk identification or mitigation prioritization (Buadit et al., 2023)

The present study proposes an integrated risk management framework, which is predicated on the aforementioned gap. This framework is achieved by combining the Delphi method for risk identification, the HOR for risk mapping and prioritization, and the value chain to integrate mitigation strategies into operational activities. The objectives of this research are as follows: The initial step involves the mapping of risk events and risk agents. The second step is to formulate effective mitigation strategies. The third step involves aligning mitigation strategies with value-adding activities to enhance supply chain resilience and product competitiveness.

2. RESEARCH METHODS

This research employs a quantitative descriptive approach to design risk mitigation strategies in the Benteng Alla Arabica coffee supply chain. The research process was methodically executed in stages, commencing with the identification of risks, followed by the calculation of potential risks, the determination of mitigation priorities, and culminating in the formulation of strategy recommendations.

Stage 1: Identification of Subjects, Objects, and Research Locations

The research subjects were the chairman, quality control coordinator, production coordinator, internal control system coordinator, marketing coordinator, and internal group coordinator of the Benteng Alla Farmer Cooperative in Benteng Alla Village, Baroko District, Enrekang Regency, South Sulawesi. The focus of the research was the risks in the Benteng Alla Arabica coffee supply chain. The location was selected based on the highest level of problems identified in the supply chain process (Desparita et al., 2023).

Stage 2: Data Collection

The research data consists of:

1) Primary data were collected through various methods, including interviews, observations, Delphi questionnaires, brainstorming sessions, and Focus Group Discussions (FGDs) with experts who have a minimum of five years of experience in their respective fields. This study involved 8 respondents, namely 5 people from the core members and 3 people from the target group. The core members consisted of the chairperson, internal control system, quality control, production, and the target group coordinator, who coordinated 20 farmer groups.
2) Internal reports, scientific literature, and publications related to the Arabica coffee supply chain. This secondary data supports the requirements of primary data.

Stage 3: Identify Potential Risks

This stage is conducted using the Delphi method to ensure that risks that may occur can be identified and thoroughly addressed. The Delphi questionnaire was disseminated to respondents in two stages. In the first stage, the respondents' comprehension was assessed to determine the potential risks and reach a consensus. The characteristics of the Delphi method include anonymity, whereby individuals possess knowledge of the problem and receive controlled feedback iterations (Dadkhah et al., 2022).

Stage 4 – Risk Assessment

After identifying potential risks and risk agents, a risk assessment is conducted by determining the severity and occurrence levels, as well as the level of connection between risk events and risk agents. Then, weighting is carried out based on the HOR Phase 1 method (Table 1) and FGDs. The degree of correlation is classified into four levels: there is a relationship, given a value of 0; low, given a value of 1; medium, given a value of 3; and high, given a value of 9.

Stage 5: Mitigation Strategy Design

This stage involves designing mitigation strategies to be applied to the Arabica coffee supply chain

Table 1. House of risk 1

Risk Agent (Aj)											
Risk Event (Ei)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	Saverity
E1	R11	R12	R13								S1
E2	R21	R22									S2
E3	R31										S3
E4											S4
E5											S5
E6											S6
E7											S7
Ocurance of Agent j	O1	O2	O3	O4	O5	O6	O7	O8	O9	O1O	
ARP j	AR	ARP	ARP	ARP	ARP	ARP	ARP	ARP	ARP	ARP	
Priority rank of agent j	P1	2	3	4	5	6	7	8	9	10	

Table 2. House of risk 2

Risk agents to be corrected	**Preventive Measures (Pak)**					**Aggregate Potential Risk (ARPj)**
	PA1	**PA2**	**PA3**	**PA4**	**PA5**	
E1	E11					
E2						
E3						
E4						
Overall effectiveness of the action	TE1	TE2	TE3	TE4	TE5	
Level of difficulty of performing actions	D3	D4	D5	D3	D4	
Effectiveness ratio to difficulty level	ETD1	ETD2	ETD3	ETD4	ETD5	
Priority ranking	R1	R2	R3	R4	R5	

process. This mitigation design stage uses the HOR Phase 2 method (Table 2) to determine the most effective mitigation strategy. Then, the company integrates risk mitigation into the value chain and adjusts the necessary operations and actions to implement the mitigation strategy.

Stage 6: Discussion and Conclusions

This stage involves formulating conclusions and fulfilling the research objectives. Suggestions are recommendations intended to serve as input relevant to the research conducted and the enhancement of previous research.

3. RESULTS AND DISCUSSION

3.1. Risk Identification

Twelve risk events were identified based on the second round of the Delphi consensus. Then, risk identification was carried out using the House of Risk (HOR) method. The HOR method can be used to analyze potential risk causes, the probability of occurrence, and prevention methods. In this study, the HOR method employed two FMEA criteria: the probability of risk occurrence and the severity of risk impact. These variables were weighted through focus group discussions with experts.

Table 3 above illustrates the outcomes of assigning weights to the severity values of each risk event. The weighting in question is derived from expert opinion using one criterion in the Failure Mode and Effect Analysis (FMEA) method, namely severity, which indicates the level of severity if a failure mode occurs. The potential impact of a risk is defined as the consequences that are likely to ensue if the risk materializes. Following the determination of each risk's category, the next step is to identify the risk agent. Table 4 presents the results of identifying risk agents for each risk event.

Table 3. Risk event

No	**Risk Event**	**Code**	**Severity**
1	Decline in crop yields	E1	9
2	Low coffee bean quality	E2	7
3	Imbalance between demand and production	E3	6
4	Decline in farmer income	E4	9
5	Decline in coffee bean quality	E5	8
6	Increase in production costs	E6	8
7	Errors in coffee bean grade selection.	E7	5
8	Many broken coffee beans	E8	6
9	Changes in coffee bean delivery schedules	E9	5
10	Unexpected shipping costs	E10	5
11	Delays in coffee delivery	E11	8
12	Non-compliance with Market Quality Standards	E12	7

3.2. Risk Analysis

The identification and assessment of risk events and risk agents were carried out through focus group discussions (FGDs) with the company. A team was formed, and questionnaire data were collected to assess the severity of risk events, the occurrence of risk agents, and the correlation between these two factors. This process resulted in the identification of 18 risk events and 22 risk agents. Using the Pareto approach, the dominant risk agents were determined based on the ARP values obtained from the calculations. A Pareto diagram was used to identify the primary sources of risk.

http://dx.doi.org/10.30656/intech.v11i2.11358

Table 4. Risk agent

No	Risk Agent	Risk Sector	Code	Ocurance
1	Extreme weather	P&K	A1	9
2	Pest infestation or plant disease	P	A2	7
3	Farmers convert coffee plantations to non-coffee crops	P	A3	8
4	Inadequate farming practices	P	A4	1
5	Poor crop management	P	A5	1
6	The lack of training programs for farmers	K	A6	6
7	Lack of adequate processing facilities	K	A7	2
8	Difficulties in obtaining market information	P&K	A8	4
9	Lack of access to sustainable markets	P&k	A9	3
10	Inefficient coordination system between farmers and market demand	P&k	A10	3
11	Market price fluctuations	P&k	A11	8
12	Government policies that do not support	P&k	A12	6
13	Lack of diversification of farmers' income sources	P	A13	3
14	Lack of financial protection	K	A14	4
15	Lack of understanding of good processing practices	K	A15	5
16	Lack of training programs and quality monitoring	K	A16	3
17	Excessive use of pesticides	P	A17	7
18	Increases in input prices such as fertilizers, seeds, or fuel	K&P	A18	5
19	Increase in operating costs	K	A19	7
20	Inadequate efficiency in resource management	K	A20	3
21	Lack of understanding of market quality standards	K&P	A21	4
22	Lack of training programs and a good quality control system	K&P	A22	2
23	Inadequate harvesting or processing methods	P	A23	2
24	Lack of appropriate equipment	P	A24	1
25	Lack of processing infrastructure	K	A25	4
26	Logistics or transportation issues	K	A26	8
27	Lack of effective logistics management	K	A27	6
28	Lack of effective logistics management	K	A28	4
29	Unable to predict or manage shipping costs effectively	K	A29	1
30	Transportation or logistics problems	K	A30	4
31	Unable to meet the agreed delivery schedule	K	A31	1
32	Lack of understanding of market quality standards	K&P	A32	2
33	Inadequate quality control systems or lack of monitoring	K	A33	7

Table 5. Pareto chart

Risk Sector	Risk Agent	Code	Apr	Percentage	Presentase Kumulatif
P&k	Extreme weather	A1	2799	15.6%	15.6%
P&k	Market price fluctuations	A11	1800	10.0%	25.6%
P	Farmers convert coffee plantations to non-coffee crops	A3	1728	9.6%	35.2%
P	Pest attacks or plant diseases	A2	1281	7.1%	42.3%
K	Logistics or transportation issues	A26	928	5.2%	47.5%
K	Increased operational costs	A19	861	4.8%	52.3%
K	Lack of training programs for farmers	A6	822	4.6%	56.8%
K	Lack of understanding of good processing practices	A15	675	3.8%	60.6%
K	Lack of effective logistics management	A27	660	3.7%	64.3%
K	Inadequate quality control systems or lack of monitoring	A33	609	3.4%	67.6%
P	Excessive use of pesticides	A17	581	3.2%	70.9%
P&k	Unsupportive government policies	A12	552	3.1%	73.9%
P	Lack of diversification of farmers' income sources	A13	522	2.9%	76.8%
K	Lack of training and quality monitoring programs	A16	498	2.8%	79.6%
K	Lack of adequate processing facilities	A7	474	2.6%	82.2%
P&k	Increases in input prices, such as fertilizer, seeds, or fuel	A18	395	2.2%	84.4%
P&k	An inefficient coordination system between farmers and market demand	A10	345	1.9%	86.4%
P&K	An inefficient coordination system between farmers and market demand	A21	344	1.9%	88.3%
K	Transportation or logistics issues	A30	268	1.5%	89.8%

The Pareto chart was developed by calculating the cumulative percentage of each ARP value of the risk agent (Herdianzah & Immawan, 2020). The results of the risk agent Pareto diagram are shown in Table 5.

Risk sources are prioritized for risk mitigation actions based on the results of the Pareto chart, which assesses the aggregate risk potential (ARP) value of each risk source. When evaluating risk using the Pareto principle, the 20:80 rule is applied, meaning 20% of risk sources are prioritized for handling. Accordingly, the focus is on determining risk mitigation actions for the 14 most dominant risk agents out of 33 total risk agents in the Benteng Alla Arabica coffee supply chain process (Table 6).

Table 6. Dominant risk agent before treatment

Risk Sector	Risk Agent	Code	Occurrance	Severity
P&k	Extreme weather	A1	9	9
P&k	Market price fluctuations	A11	8	9
P	Farmers convert coffee plantations to non-coffee crops	A3	8	8
P	Pest attacks or plant diseases	A2	7	8
K	Logistics or transportation issues	A26	8	8
K	Increased operational costs	A19	7	7
K	Lack of training programs for farmers	A6	6	7
K	Lack of understanding of good processing practices	A15	5	6
K	Lack of effective logistics management	A27	6	6
K	Inadequate quality control systems or lack of monitoring	A33	7	6
P	Excessive use of pesticides	A17	7	6
P&k	Unsupportive government policies	A12	6	7
P	Lack of diversification of farmers' income sources	A13	3	7
K	Lack of training and quality monitoring programs	A16	3	7

Following the establishment of a comprehensive inventory of prioritized risk sources, a risk mapping exercise was initiated to identify the prevailing risk conditions prior to implementing mitigation strategies. The objective of the mapping process was to identify potential risk conditions before implementing mitigation strategies (Fig. 1). The risk mapping results indicate the presence of four risk sources in the designated yellow area: A27, A15, A13, and A16. These sources are classified as being at a moderate risk level. Ten risk sources are situated in the red area, designated as A1, A2, A3, A6, A11, A12, A17, A19, and A33. These risk sources are classified as critical risks due to their significant potential impact on the organization. This mapping suggests the need for risk mitigation to reduce the risk level associated with these risk sources.

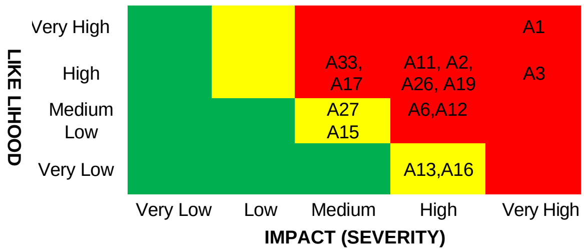

Fig. 1. Risk map before mitigation

3.3. Designing Mitigation Strategy

A series of mitigation strategies has been identified as being of utmost importance for reducing the impact of risk sources. The following sequence of mitigation priorities is derived from calculations utilizing the House of Risk (HOR) table, Phase 2 (Table 7).

The experts first determined the effectiveness level of the treatment's implementation and subsequently undertook a severity and occurrence assessment of the given handling strategy following its implementation. Fig. 2 presents the risk maps after implementing a mitigation strategy.

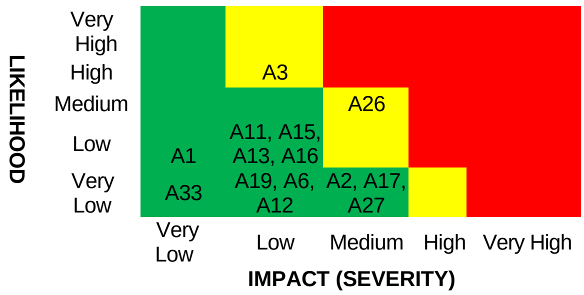

Fig. 2. Risk map after designing mitigation strategy priorities

Following preventive action, the results of risk mapping indicate that 11 risk sources fall within the green area and three are in the yellow area. Some significant changes include the following: A1, A11, A33, A19, A6, A12, A2, and A17 moved from the red area to the green area; A3 and A26 moved from the red area to the yellow area; and A16, A15, A13, and A27 moved from the yellow area to the green area. Overall, preventive action successfully reduced the risk level of 14 risk sources.

These findings are in line with previous studies that applied the HOR method to agro-industrial supply chains. Muzakkir et al. (2021) showed that phase 2 of HOR was effective in formulating priority-based mitigation strategies, with a focus on developing SOPs, collaborating with input suppliers, and increasing human resource capacity. Similarly, Wulandari & Pulansari (2024) reported that mitigation strategies in the coffee supply chain were dominated by preventive measures, such as maintaining production processes and enhancing the skills of business actors, to minimize operational disruptions. However, compared to these studies, the mitigation strategies developed in this study have the advantage of a contextual approach based on the field conditions of cooperatives and farmer groups.

http://dx.doi.org/10.30656/intech.v11i2.11358

Table 7. Risk mitigation strategy priorities

Code	Risk Agent	Code	Preventive Action
A1 (P&K)	Extreme weather	P1	It is essential to identify opportunities for integrating coffee crops with secondary crops, aiming to enhance sustainability and profitability.
A11 (P&K)	Market price fluctuations	P2	Investment in weather protection infrastructure
A3(P)	Farmers convert coffee plantations to non-coffee crops	P3	Establishing long-term partnerships and implementing long-term contracts with buyers to set more stable prices.
A2(P)	Pest attacks or plant diseases	P4	Sustainable agricultural practices to reduce the risk of pest or disease attacks, and implement a monitoring system to detect early symptoms of disease or pest attacks
A26 (K)	Logistics or transportation issues	P5	Conducting regular logistics performance evaluations
A19 (K)	Increased operational costs	P6	Regular monitoring and evaluation of operational costs to identify potential efficiencies
A6 (K)	Lack of training programs for farmers	P7	Develop guidelines and training on safe and sustainable use, and encourage the use of organic or alternative methods that are more environmentally friendly
A15 (K)	An understanding of good processing practices	P8	Build strong relationships with the government and advocate for policies that support the agricultural sector. Actively participate in industry forums or associations to increase representation and influence.
A27 (K)	Lack of effective logistics management	P9	Providing training and resource development in the field of logistics management
A33 (K)	Inadequate quality control systems or lack of monitoring	P10	Integrating training and quality monitoring programs into routine operational processes
A17 (P)	Excessive use of pesticides	P11	Establishment of an agronomy training center to provide regular training and establish cooperation with educational institutions to provide technical training
A12 (P &K)	Unsupportive government policies	P12	Providing education and training directly in the field to improve farmers' understanding
A13 (P)	Lack of diversification of farmers' income sources	P13	Providing incentives or support to develop new products or services and implementing business models that enable farmers to generate income from various sources.
A16 (K)	Lack of training and quality monitoring programs	P14	Implementing sensor and automatic monitoring technology to improve quality control

3.4. Integrating Risk Mitigation Results into Value Chain Activities

Based on the results in Table 7, 14 risk mitigation strategies were prioritized according to the effectiveness-to-difficulty ratio (ETD). After the processing stage in the House of Risk, which aims to plan and formulate risk mitigation systematically, the mitigation results are then mapped and integrated directly into the Benteng Alla Arabica coffee value chain activities, in accordance with Porter's value chain framework, which encompasses both primary and supporting activities.

This integration was carried out to ensure that each mitigation action did not stand alone but was implemented as part of ongoing operational activities, from upstream logistics to after-sales services. Thus, risk mitigation can have a significant impact on enhancing supply chain resilience and generating added value for all stakeholders in the coffee value chain (Table 8).

Following the processing stage at the House of Risk, which is intended to plan and implement further risk mitigation, the risk mitigation results must be integrated into value chain activities. This approach distinguishes this study from previous studies, which generally stop at the stage of identifying and prioritizing risk mitigation. Several studies, such as Putri & Anwar (2025), demonstrate that the House of Risk method and the Aggregate Risk Potential-based approach are effective in identifying dominant sources of risk; however, they have not explicitly mapped mitigation strategies into value chain activities. Other studies that combine House of Risk with the SCOR framework, such as the research by Syaputra et al. (2025) on the coffee supply chain, are able to provide a comprehensive view of the supply chain process flow, but still place mitigation strategies at the process level without directly linking them to daily operational activities or specific functions in the value chain. Unlike these studies, this study maps each mitigation strategy resulting from phase 2 of HOR directly into value chain activities, from inbound logistics and operations to firm infrastructure, enabling cooperatives and supply chain actors to implement risk mitigation more systematically and sustainably. However, the limitation of this study lies in the lack of evaluation of the quantitative impact of risk mitigation integration on supply chain performance. Therefore, further research is recommended to empirically test the effectiveness of risk mitigation implementation across all supply chain actors.

Table 8. Integration of the house of risk 2 result into the value chain

Value chain	Code	Integration
Inbound logistic	P3	It is essential to identify opportunities for integrating coffee crops with secondary crops, aiming to enhance sustainability and profitability.
Operations	P4	The implementation of sustainable agricultural practices is imperative in order to reduce the risk of pest or disease attacks.
Outbound logistics	P10	Furthermore, establishing monitoring systems capable of detecting early signs of disease or pest attacks is essential.
	P5	It is imperative to conduct regular logistics performance evaluations.
Marketing and sales	P9	The provision of training and resource development in the logistics management domain is imperative.
Service	P13	Providing incentives or support for the development of new products or services is essential for advancing any given enterprise.
	P8	Providing education and hands-on training in the field is essential for enhancing farmers' understanding.
Procurement	P1	Investing in weather protection infrastructure.
Technology development	P14	Integrating training and quality monitoring programs into routine operational processes.
	P7	Establishing agronomy training centers to provide regular training and collaborating with educational institutions to provide technical training.
	P10	Implementing sensor and automatic monitoring technologies to improve quality control.
Human resource management	P11	Developing guidelines and training on safe and sustainable use, and encouraging the use of organic or alternative methods that are more environmentally friendly.
Firm infrastructure	P12	Building strong relationships with the government and advocating for policies that support the agricultural sector.
	P2	Actively participating in industry forums or associations to increase representation and influence.
	P13	Developing business models that enable farmers to generate income from multiple sources.

4. CONCLUSION

This study aims to design a risk mitigation strategy in the Benteng Alla Arabica coffee supply chain through a combination of the Delphi, House of Risk (HOR), and Value Chain methods. The results of risk identification using the Delphi method successfully captured risks that are contextual and specific to the cooperative's conditions, particularly those related to climate factors, cultivation practices, human resource limitations, and operational constraints at the farmer group level. These findings align with the discussion in the results section, which confirms that the involvement of experienced local experts plays a significant role in identifying a list of risk events and risk agents relevant to field conditions. Furthermore, the implementation of HOR phases 1 and 2 enables the mapping of cause-and-effect relationships between risk events and risk agents, producing mitigation strategy priorities based on the effectiveness-to-difficulty ratio (ETD). As discussed in the Risk Mitigation Strategy section, the results of Phase 2 of the HOR produced 14 prioritized mitigation strategies. The strategy with the highest ETD value focuses on improving the sustainability of the production system, strengthening cultivation practices, and reducing the risk of disruption due to natural and operational factors. This demonstrates that the HOR approach is not only effective in prioritizing risks but also in generating actionable mitigation recommendations.

Unlike some previous studies that stopped at the mitigation prioritization stage, this study integrated each mitigation strategy into the Benteng Alla Arabica coffee value chain activities, from inbound logistics, operations, outbound logistics, to firm infrastructure. This integration, as discussed in the 'Integration into Value Chain' section, ensures that mitigation strategies are not merely conceptual but are directly embedded in operational activities that create added value. Compared to previous studies that used HOR separately or combined it with other frameworks such as SCOR, the integrated Delphi–HOR–value chain approach proposed in this study provides advantages in systematically linking risk identification, mitigation prioritization, and operational implementation in the context of the coffee agroindustry. However, this study still has limitations. As mentioned in the discussion, this study has not evaluated the quantitative impact of implementing mitigation strategies on supply chain performance, such as increased productivity, product quality, or the accuracy of demand fulfillment. Therefore, further research is recommended to empirically test the effectiveness of implementing this framework using measurable supply chain performance indicators and involving all actors in the coffee supply chain.

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