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Prioritizing supply chain risks in small-scale egg distribution: a house of risk approach

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ABSTRACT

Purpose: to identify supply chain risk events and risk agents in a small-scale egg distribution business, prioritize the most critical risk agents using the house of risk (HOR) approach, and determine the most effective mitigation strategies based on the aggregate risk potential (ARP) and effectiveness-to-difficulty (ETD) ratio.
Method: a quantitative descriptive case study was conducted at a small-scale egg distribution business in Berau regency, Indonesia. Data were collected through in-depth interviews, field observations, and two phases of structured questionnaires. Supply chain risks were analyzed using the two-phase house of risk (HOR) method, including the calculation of aggregate risk potential (ARP) to prioritize risk agents and the effectiveness-to-difficulty (ETD) ratio to rank mitigation actions.
Findings: ten risk events and twelve risk agents were identified, with seven risk agents classified as priority based on ARP and pareto 80/20 analysis. Among nine proposed mitigation actions, implementing a simple demand forecasting method ranked highest in ETDk, followed by adding backup partner farmers and providing buffer stock.
Implications: small-scale egg distribution businesses should adopt low-cost, high-impact mitigation actions gradually, guided by both quantitative priority and practical resource constraints.
Originality: this study extends the application of the House of Risk approach to a small-scale egg distribution business, providing new insights into supply chain risk prioritization under limited resource conditions.

Introduction

The distribution of table eggs is an essential component of the agri-food supply chain because they are a staple food commodity with consistently high market demand (Barrett et al., 2022). Unlike durable food products, eggs are highly perishable and susceptible to physical damage and quality deterioration throughout storage and transportation (Gao et al., 2025; Supaphol, 2026). Consequently, maintaining product quality and ensuring distribution continuity require effective supply chain management capable of addressing operational uncertainties (Katsaliaki et al., 2022). Previous studies have emphasized that supply chain performance in agri-food systems is strongly influenced by the ability to identify, assess, and mitigate risks across interconnected supply chain activities (Is, 2019; Nurjannah et al., 2024; Ummi et al., 2023). Moreover, improving supply chain resilience has become increasingly important for small and medium-sized agri-food enterprises, whose limited resources often constrain their capacity to respond effectively to operational disruptions (Wicaksono & Illés, 2022).

One example of such a business is Telur Murjani, a small-scale egg wholesaler and collector located in Tanjung Redeb, Berau regency, East Kalimantan. Operating as an intermediary between three to five layer poultry farms and local retail stores, the business plays a crucial role in maintaining egg availability in the regional market. However, preliminary interviews with the operational manager revealed several recurring supply chain disruptions. These include egg breakage caused by poor road conditions during transportation, quality deterioration due to elevated warehouse temperatures during hot weather, and imbalances between supply and fluctuating customer demand that frequently result in either excess inventory or stock shortages. Furthermore, inventory replenishment decisions are currently based on visual estimation of remaining stock rather than systematic demand forecasting, increasing the likelihood of inaccurate purchasing decisions and inefficient inventory management. Such conditions indicate that operational risks are managed reactively rather than through a structured risk management framework, potentially reducing supply chain reliability and business performance (Nurdina et al., 2022).

Risk management has become an important research topic in supply chain studies, with numerous methods proposed to identify and prioritize operational risks. Among these, the house of risk (HOR) approach has gained considerable attention because it integrates risk identification, risk prioritization, and mitigation planning within a single analytical framework (Hadi et al., 2020; Ridwan et al., 2020). HOR has been successfully applied in various contexts, including manufacturing industries (Marchello et al., 2023; Vandhana, 2025; Wali et al., 2022), food and agricultural SMEs (Elviani et al., 2025; Khusnaini et al., 2023; Rahman & Destiarni, 2024), fisheries (Rizqi, 2022), furniture industries (Ulfah, 2021), and logistics operations (Pettawali et al., 2025). Recent studies have also extended HOR by integrating it with complementary methods such as bow tie analysis (Primadhiya et al., 2026) and resilience-oriented frameworks (Tubis & Wojciechowska, 2026). Although several studies have investigated egg supply chains (Is, 2019; Nurjannah et al., 2024; Ramadani et al., 2025), most focus on general supply chain analysis, failure mode and effects analysis (FMEA), or large-scale production systems.

Research applying the house of risk specifically to small-scale egg distribution agencies remains very limited. Even the recent study by Kinasih & Immawan (2025), which employed HOR for layer egg supply chains, was conducted in a different organizational and regional context. Therefore, limited evidence is available regarding how HOR can support risk prioritization in resource-constrained egg distribution businesses operating in remote regions such as Berau regency, East Kalimantan. This contextual limitation represents the primary research gap addressed in this study. Accordingly, the novelty of this research lies in applying the House of Risk approach to a small-scale egg distribution agency characterized by limited managerial resources, simple inventory practices, and geographically challenging distribution conditions.

Based on this research gap, this study aims to (1) identify supply chain risk events and risk agents within the egg distribution network of Telur Murjani, (2) calculate aggregate risk potential (ARP) values to determine the most critical risk agents requiring priority attention, and (3) develop and prioritize mitigation actions according to their effectiveness and implementation difficulty using the house of risk framework. By systematically identifying the dominant sources of operational risk, this study provides a practical basis for selecting mitigation strategies that are feasible for small-scale enterprises with limited financial and organizational resources.

This research is significant from both theoretical and practical perspectives. Theoretically, it extends the application of the house of risk method to a relatively underexplored context, namely small-scale egg distribution businesses in Indonesia, thereby enriching the body of knowledge on supply chain risk management for agri-food SMEs. Practically, the findings are expected to provide evidence-based recommendations for improving inventory planning, transportation management, product quality preservation, and overall supply chain resilience at Telur Murjani. Furthermore, the proposed mitigation priorities may serve as a reference for similar egg distributors and other small agri-food enterprises facing comparable operational constraints. Ultimately, the study contributes to enhancing supply chain reliability, reducing operational losses, and supporting more sustainable distribution practices in regional food supply systems.

Literature review

Supply chain risk management

Supply chain risk management (SCRM) refers to the systematic process of identifying, assessing, evaluating, and controlling risks that may disrupt the flow of materials, information, and financial resources throughout the supply chain (Oliveira et al., 2024). The concept is grounded in supply chain management (SCM) theory, which views supply chains as interconnected systems in which the performance of each member affects the overall efficiency and competitiveness of the network (Negi, 2024). As supply chains become increasingly complex and uncertain, risk management has evolved into an integral component of supply chain strategy, emphasizing not only the prevention of disruptions but also the enhancement of resilience and operational continuity (Katsaliaki et al., 2022). The principles of ISO 31000 further reinforce this perspective by defining risk management as a structured process of risk identification, analysis, evaluation, treatment, monitoring, and continuous improvement.

Within agri-food supply chains, risk management is particularly important because agricultural products are characterized by perishability, fluctuating demand, quality deterioration, and dependency on environmental and logistical conditions. Kholisoh et al. (2025), through a literature review based on ISO 31000, reported that food-related micro, small, and medium enterprises (MSMEs) commonly experience risks associated with supply uncertainty, demand fluctuations, limited storage capacity, and operational resource constraints. Likewise, Wicaksono & Illés (2022) argued that improving resilience is essential for agri-food SMEs because limited organizational resources reduce their ability to absorb operational disturbances. From a broader sustainability perspective, Ummi et al. (2023) emphasized that supply chain risk management remains an evolving research area in sustainable agri-food systems, particularly regarding proactive approaches for identifying and mitigating operational risks before they affect supply chain performance.

Studies focusing specifically on egg supply chains demonstrate similar operational challenges. Is (2019) analyzed the supply chain structure of commercial layer eggs and highlighted the importance of effective coordination among producers, distributors, and retailers to ensure efficient product distribution. Similarly, Nurjannah et al. (2024) employed the food supply chain network (FSCN) framework and concluded that coordination among supply chain actors significantly influences market responsiveness and product availability. Kinasih & Immawan (2025) further integrated ISO 31000 and the house of risk (HOR) framework to analyze risks within the commercial egg supply chain, identifying delayed deliveries and product damage as dominant operational concerns. Complementing these findings, Ramadani et al. (2025) applied failure mode and effects analysis (FMEA) to a parent-stock egg production system. They found that inadequate packaging and improper handling during transportation represented the major contributors to product quality deterioration.

House of risk (HOR)

The house of risk (HOR) is a proactive supply chain risk management framework originally developed by integrating the principles of failure mode and effects analysis (FMEA) and the house of quality (HOQ) (Susanto et al., 2025). Rather than focusing solely on evaluating risk consequences, HOR prioritizes the underlying causes of risk, enabling organizations to implement preventive actions before disruptions occur (Yogaswara & Korry, 2025). According to Hadi et al. (2020), the method consists of two sequential phases. The first phase (HOR1) identifies risk events and their associated risk agents, followed by the calculation of the aggregate risk potential (ARP) to determine the priority risk agents requiring mitigation. The second phase (HOR2) develops preventive actions and prioritizes them based on the ratio between mitigation effectiveness and implementation difficulty, thereby facilitating efficient allocation of organizational resources. Wali et al. (2022) similarly emphasized that HOR supports decision-makers in selecting mitigation strategies that provide the greatest reduction in overall supply chain risk.

The applicability of HOR has been demonstrated across various industrial sectors. Ulfah (2021) implemented HOR in the furniture industry to identify production risks associated with wood processing, while Ridwan et al. (2020) applied the method to pallet and dunnage supply chains. Rizqi (2022) extended HOR to aquaculture by analyzing risks within milkfish seed supply chains. In the food sector, Elviani et al. (2025) and Rahman & Destiarni (2024) successfully applied HOR to food-processing MSMEs, illustrating its capability to prioritize mitigation strategies under limited operational resources. Larger-scale industrial applications include instant agar manufacturing (Marchello et al., 2023), safety equipment warehousing (Vandhana, 2025), general supply chain operations (Akbar & Apsari, 2024), and manufacturing logistics (Pettawali et al., 2025). Several recent studies have further enhanced the analytical capability of HOR by integrating it with complementary methods, including the supply chain operations reference (SCOR) model (Asrory, 2023), SCOR combined with FMEA (Ananda et al., 2025), and bow tie analysis (Primadhiya et al., 2026). Furthermore, Tubis & Wojciechowska (2026) reviewed the evolution of house-based frameworks. They proposed resilience-oriented extensions, demonstrating the continuing development of HOR as a strategic supply chain risk management tool.

Existing studies consistently indicate that the number and type of identified risk events depend on the characteristics and complexity of the investigated supply chain. Hadi et al. (2020) identified only a limited number of risk events within a relatively simple production system. In contrast, Wali et al. (2022) identified 25 risk events and 49 risk agents within a large-scale manufacturing environment. Similarly, Arini et al. (2025) found substantially fewer risk events when HOR was applied to a stationery company with simpler operational processes. These findings suggest that HOR should not be implemented using a standardized template but rather be adapted to the operational characteristics, organizational scale, and resource limitations of each business. This flexibility makes HOR particularly suitable for analyzing risk within small-scale egg distribution enterprises such as Telur Murjani.

Demand forecasting as a supply chain risk mitigation strategy

Demand forecasting constitutes one of the essential operational practices for reducing uncertainty within supply chains. In inventory-intensive businesses, inaccurate demand estimation frequently leads to either excess inventory or stock shortages, both of which increase operational costs and reduce customer service performance (Arora et al., 2025). From a supply chain management perspective, forecasting functions as a preventive decision-support mechanism that aligns procurement, inventory, and distribution planning with expected market demand. Nurdina et al. (2022) demonstrated that applying the Weighted Moving Average forecasting method improved production planning for a food MSME by producing inventory decisions that better reflected historical demand patterns, thereby reducing the risk of overstocking and understocking. Although forecasting techniques are not formally included within the House of Risk framework, they can be incorporated as preventive mitigation actions when inaccurate demand planning is identified as a dominant risk agent. Consequently, demand forecasting represents a practical and economically feasible mitigation strategy for small-scale egg distributors that continue to rely on manual inventory estimation.

Method

This study employed a quantitative descriptive case study to investigate supply chain risks in a small-scale egg distribution business. A case study approach was considered appropriate because it enables an in-depth examination of risk management practices within a real operational setting while preserving the contextual characteristics of the supply chain. The research was conducted at Telur Murjani, a wholesale egg distributor and collector located on DR. Murjani II street, Tanjung Redeb, Berau regency, East Kalimantan, Indonesia. The business has been operating for approximately 1.5 years and serves as an intermediary between three to five partner poultry farms and local retail stores. Daily operational activities, including procurement, warehousing, inventory management, and product distribution, are handled by two employees.

Data were collected using multiple sources to enhance the reliability of the findings. First, in-depth interviews were conducted with the operational manager to obtain comprehensive information regarding the supply chain structure, operational activities, previous disruption experiences, and potential sources of risk. The interview results were subsequently used to identify preliminary risk events and risk agents throughout the distribution process. Second, direct field observations were carried out to validate the operational workflow and verify the conditions of transportation, storage facilities, inventory handling, and distribution activities. Finally, two rounds of structured questionnaires were administered as the primary data collection instrument for the house of risk analysis.

The first questionnaire (HOR Phase 1) was designed to evaluate three essential components of the house of risk framework. Respondents assessed the severity (S) of each identified risk event, the occurrence (O) of each risk agent, and the correlation (R) between risk events and their corresponding risk agents. These assessments formed the basis for calculating the aggregate risk potential (ARP) of each risk agent. After the priority risk agents had been identified, a second questionnaire (HOR Phase 2) was distributed to evaluate the proposed preventive actions. This questionnaire measured the effectiveness (Ejk) of each mitigation action in reducing the occurrence of the priority risk agents as well as the degree of implementation difficulty (Dk) associated with each action. In total, nine proposed mitigation actions were evaluated against seven priority risk agents identified during the first phase of the analysis.

The overall research procedure is presented in Figure 1. The study began with a preliminary investigation and literature review to understand the characteristics of the egg distribution supply chain and establish the theoretical foundation. This was followed by risk identification through interviews and field observations, questionnaire design and validation, data collection, house of risk analysis (HOR Phase 1 and HOR Phase 2), formulation of mitigation priorities, and finally interpretation of the results and preparation of research conclusions.

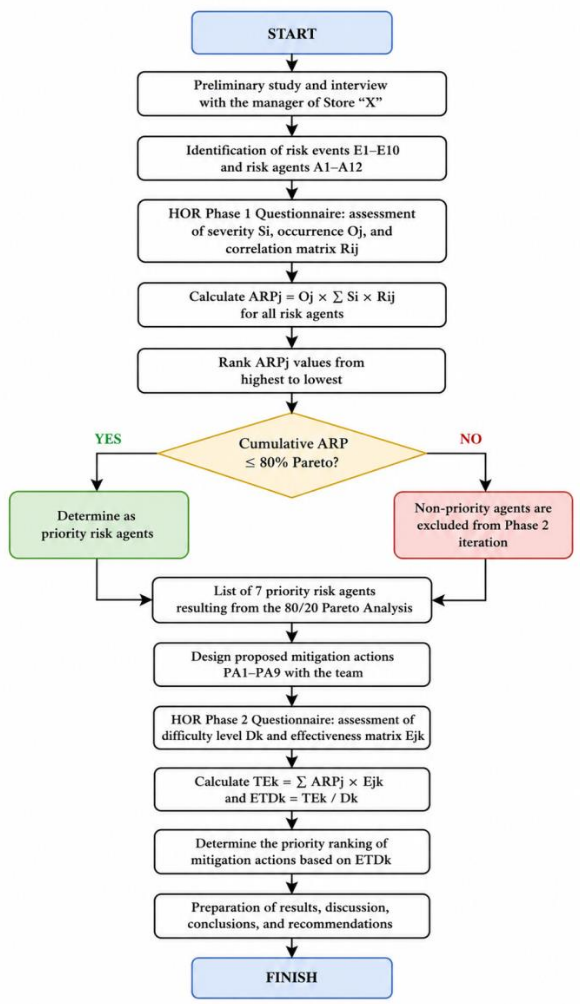

Figure 1 research flowchart of the house of risk method

Data analysis followed the two-phase house of risk (HOR) framework proposed by Hadi et al. (2020) and widely adopted in supply chain risk management studies (Wali et al., 2022). In HOR Phase 1, risk events (E) and risk agents (A) were first identified based on interview and observation results. Each risk event was assigned a severity score (Si), while each risk agent was evaluated according to its occurrence level (Oj). The relationship between risk events and risk agents was then assessed using a correlation matrix (Rij) with the standard HOR correlation scale. Subsequently, the Aggregate Risk Potential (ARP) for each risk agent was calculated using equation (1):

$$ARPj = Oj \times sum(i)\ (Si \times Rij)$$

Where ARPj denotes the aggregate risk potential of risk agent j, Oj represents the occurrence rating of the risk agent, Si is the severity score of risk event i, and Rij indicates the correlation between risk event i and risk agent j. The resulting ARP values were ranked in descending order, and the Pareto 80/20 principle was applied to identify the priority risk agents that contributed most significantly to overall supply chain risk. In HOR Phase 2, the selected priority risk agents were linked to a set of proposed preventive actions through an effectiveness matrix. The total effectiveness (TEk) of each mitigation action was calculated using equation (2):

$$TEk = sum(j)\ (ARPj \times Ejk)$$

Where Ejk denotes the effectiveness of mitigation action k in reducing risk agent j. The effectiveness score was then adjusted by considering the implementation difficulty of each action. The effectiveness-to-difficulty ratio (ETD) was calculated using equation (3):

$$ETDk = TEk / Dk$$

Where Dk represents the implementation difficulty of mitigation action k. Mitigation strategies with higher ETD values were considered to provide greater risk reduction relative to the required implementation effort and were therefore prioritized for recommendation to Telur Murjani. The application of the two-phase house of risk framework enables systematic identification of critical supply chain risks while simultaneously providing a rational basis for prioritizing mitigation strategies. This approach is particularly suitable for small-scale enterprises because it supports decision-making under limited financial, human, and operational resources by focusing improvement efforts on the most influential sources of risk.

Results and discussion

Identification of risk events and risk agents

The first phase of the analysis focused on identifying potential disruptions throughout Telur Murjani's egg distribution supply chain. Based on in-depth interviews, field observations, and the Phase 1 questionnaire, a total of 10 risk events (E1–E10) and 12 risk agents (A1–A12) were identified. In the House of Risk (HOR) framework, risk events represent undesirable incidents that may disrupt supply chain activities, whereas risk agents are the underlying causes that trigger these events. The identified risks cover the main operational processes, including procurement, transportation, warehousing, inventory management, order fulfillment, and customer service.

The severity assessment presented in Table 1 indicates that the most critical consequence perceived by respondents was the loss of loyal customers due to delayed supply (E5), which received the highest severity score (9). This finding reflects the importance of service reliability in maintaining customer relationships within small-scale distribution businesses. Other highly severe events include egg breakage during transportation (E1) and egg stock shortages (E6), with severity scores of 8 and 7, respectively. Meanwhile, inventory accumulation (E4), egg spoilage during storage (E2), and order quantity errors (E8) were perceived as relatively less severe because their impacts can still be corrected through subsequent operational adjustments.

Table 1 risk events and severity values

Code	Risk event	Si
E1	Eggs cracked or broken during transportation from farms to the warehouse	8
E2	Eggs spoiled during warehouse storage	5
E3	Declining egg quality (watery eggs) due to prolonged storage	6
E4	Excess inventory caused by slow sales	5
E5	Loss of loyal customers due to delayed supply	9
E6	Egg stock shortages (stockout)	7
E7	Delayed deliveries from warehouse to retailers	7
E8	Incorrect quantity or egg size delivered	4
E9	Customer complaints or product returns due to quality issues	6
E10	Incorrect purchasing quantity from partner farms	6

Source: primary data, processed (2026).

The occurrence assessment of the identified risk agents is summarized in Table 2. Three risk agents received the highest occurrence ratings (8), namely the absence of a structured demand forecasting system (A11), poor road infrastructure (A1), and uncertain market demand (A5). These findings indicate that planning uncertainty and transportation conditions represent the dominant sources of operational risk. In contrast, communication-related issues (A10) and manual loading procedures (A8) were considered less frequent, although they remain potential contributors to supply chain disruptions.

Table 2 risk agents and occurrence values

Code	Risk agent	Oj
A1	Poor and damaged road infrastructure	8
A2	Unsafe truck driving behavior	5
A3	High warehouse temperature during extreme weather	7
A4	Supply schedules inconsistent with market demand	5
A5	Uncertain market demand fluctuations	8
A6	Dependence on a limited number of partner farms	7
A7	Delayed deliveries from partner farms	5
A8	Manual loading and unloading without standard procedures	4
A9	No checklist during order preparation	4
A10	Lack of order confirmation with customers	3
A11	Absence of a structured demand forecasting system	8
A12	Limited local delivery vehicles	5

Source: primary data, processed (2026).

To facilitate visualization of the relationships between identified risk events and their corresponding risk agents, the complete house of risk phase 1 correlation matrix is presented in Figure 2. The matrix illustrates the strength of the relationship between each risk event and its associated risk agent using the standard HOR correlation values. Furthermore, the calculated aggregate risk potential (ARP) values shown at the bottom of the matrix provide an initial indication of which risk agents require priority mitigation.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	Si
E1	9	9						3					8
E2			9										5
E3			3								9		6
E4				3	9				9		9		5
E5						3	9					3	9
E6			3			9	9						7
E7	3	1					3					9	7
E8									9	3			4
E9	3	3	3					1	3				6
E10				9	3						9		6
Oj	8	5	7	5	8	7	5	4	4	3	8	5	
ARPj	888	485	567	450	504	630	825	120	216	36	1224	450	

0 = Does not exist
1 = Very low
3 = Low
9 = High
Agent Validation Priorities
ARP Non-priorities
ARP Priorities

Figure 2 house of risk phase 1 matrix (risk events × risk agents)
Source: primary data, processed (2026).

Aggregate risk potential (ARP) analysis

After completing the severity, occurrence, and correlation assessments, the aggregate risk potential (ARP) value of each risk agent was calculated using the HOR Phase 1 model. ARP represents the overall contribution of each risk agent to the total supply chain risk by combining the likelihood of occurrence with the severity of the risk events it influences. Consequently, risk agents with higher ARP values represent more critical sources of disruption and therefore require higher mitigation priority.

The ranking results are presented in Table 3. Among the twelve identified risk agents, A11 (absence of a structured demand forecasting system) obtained the highest ARP value (1,224), accounting for approximately 19.1% of the cumulative risk potential. This result highlights that inadequate planning rather than physical operational failures constitutes the primary source of risk within the observed supply chain. The second-highest ARP was attributed to poor road infrastructure (A1), followed by delayed deliveries from partner farms (A7) and dependence on a limited number of suppliers (A6). Together, these findings demonstrate that both internal managerial practices and external logistical conditions simultaneously influence supply chain performance. Applying the pareto principle revealed that the first seven risk agents contributed approximately 80.1% of the total cumulative ARP. Therefore, A11, A1, A7, A6, A3, A5, and A2 were selected as priority risk agents for the second phase of the house of risk analysis.

Table 3 ARP ranking and pareto 80/20 analysis

Rank	Code	ARP value	Cumulative %	Status
1	A11	1224	19.1	Priority
2	A1	888	33.0	Priority
3	A7	825	45.9	Priority
4	A6	630	55.8	Priority
5	A3	567	64.6	Priority
6	A5	504	72.5	Priority
7	A2	485	80.1	Priority
8	A12	450	87.1	Non-priority
9	A4	450	94.2	Non-priority
10	A9	216	97.6	Non-priority
11	A8	120	99.4	Non-priority
12	A10	36	100	Non-priority

Source: primary data, processed (2026).

Prioritization of mitigation actions (HOR phase 2)

Following the identification of priority risk agents, the House of Risk Phase 2 analysis was conducted to determine the most effective preventive actions. Nine mitigation alternatives (PA1–PA9) were developed collaboratively with the business owner based on operational feasibility and previous studies. Each proposed action was evaluated according to its effectiveness in reducing priority risk agents and the difficulty associated with its implementation. The relationship between mitigation actions and priority risk agents is illustrated in Figure 3.

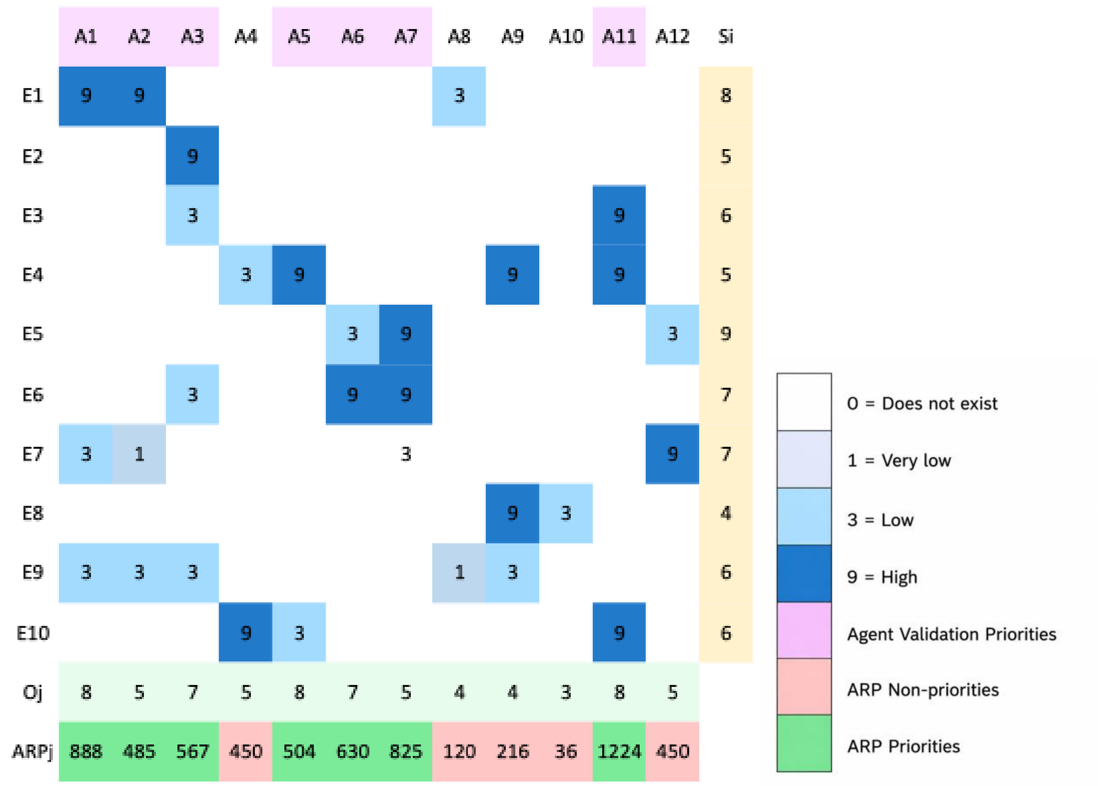

Figure 3 house of risk phase 2 matrix (priority risk agents × mitigation actions)

Source: primary data, processed (2026).

The calculated total effectiveness (TE) and effectiveness-to-difficulty (ETD) ratios are summarized in Table 4.

Table 4 mitigation action priority ranking based on the ETD ratio

Code	Mitigation action	TEk	Dk	ETDk	Rank
PA1	Simple demand forecasting (moving average)	15552	3	5184	1
PA8	Add backup partner farms	13095	4	3273.75	2
PA7	Establish buffer stock	9567	4	2391.75	3
PA5	Additional protective packaging	9447	4	2361.75	4
PA3	Alternative transportation routes	7992	4	1998	5
PA2	Digital inventory and sales recording	5184	3	1728	6
PA9	Additional warehouse ventilation/exhaust fans	5103	3	1701	7
PA4	Driver safety briefing	4365	3	1455	8
PA6	Fixed delivery schedule with partner farms	2475	3	825	9

Source: primary data, processed (2026).

The ETD analysis indicates that PA1 (implementing a simple demand forecasting system) represents the highest-priority mitigation strategy. This action directly addresses the two most influential risk agents, namely the absence of demand forecasting (A11) and demand uncertainty (A5), while requiring relatively low implementation effort. This finding is consistent with Nurdina et al. (2022), who demonstrated that the Weighted Moving Average forecasting method improved inventory planning and reduced both overstocking and stockout risks in food SMEs. The second-ranked mitigation strategy, PA8, recommends expanding the number of partner farms to reduce dependence on a limited supplier base. Diversifying suppliers decreases vulnerability to supply interruptions and improves supply chain flexibility. Meanwhile, PA7 (buffer stock) and PA5 (protective packaging) mainly address operational risks associated with transportation disruptions and product damage. Although these actions require greater investment than PA1, their relatively high effectiveness justifies their prioritization.

Interestingly, the quantitative ranking obtained through the HOR analysis differed from the practical preferences expressed by the business owner during the interviews. From the managerial perspective, PA9 (improving warehouse ventilation) and PA2 (digital inventory recording) were perceived as the most feasible short-term initiatives because they require relatively modest financial investment and can be implemented immediately. However, the HOR framework prioritizes actions according to their overall contribution to reducing aggregate supply chain risk rather than implementation convenience alone. This discrepancy illustrates the value of quantitative decision-support methods in complementing managerial intuition. Accordingly, a phased implementation strategy appears more appropriate: low-cost operational improvements such as PA9 and PA2 may be introduced in the short term, while strategic actions such as PA1 and PA8 should be implemented as medium-term priorities because of their greater long-term impact on supply chain performance.

Discussion

The present study demonstrates that a single operational failure does not generate supply chain risks in Telur Murjani; rather, they emerge from the interaction of multiple managerial and operational factors, including inadequate demand planning, transportation constraints, supplier dependency, and environmental conditions. This finding supports the fundamental perspective of supply chain management (SCM) theory, which conceptualizes a supply chain as an integrated network of interdependent actors whose collective performance depends on the coordination of material, information, and financial flows. Within this perspective, disruptions occurring at one point of the network inevitably propagate to downstream activities, affecting inventory availability, delivery performance, product quality, and customer satisfaction. Consequently, effective risk management requires a system-wide approach rather than isolated improvements at individual operational stages.

The identified risk pattern is also consistent with the principles of supply chain risk management (SCRM) and ISO 31000, which define risk management as a continuous process of identifying, analyzing, evaluating, treating, monitoring, and reviewing risks throughout organizational activities. The house of risk (HOR) method operationalizes these principles by shifting managerial attention from observable disruptions (risk events) toward their underlying causes (risk agents). Instead of merely responding to incidents after they occur, HOR emphasizes preventive actions targeting the dominant sources of risk. The findings indicate that the absence of a structured demand forecasting system (A11) generated the highest aggregate risk potential (ARP), demonstrating that managerial planning deficiencies contribute more significantly to supply chain vulnerability than many physical operational problems. This result illustrates the practical value of proactive risk management, particularly for small enterprises whose limited resources require selective allocation toward the most influential sources of operational risk.

The dominance of A11 (absence of a structured demand forecasting system) deserves particular attention because it represents a managerial capability issue rather than a technological limitation. Inventory replenishment decisions at Telur Murjani are currently based on visual observation of remaining stock and personal experience instead of systematic analysis of historical demand. Under stable market conditions, such informal decision-making may appear sufficient; however, fluctuations in consumer demand frequently lead to either excessive inventory or stock shortages. Since eggs are highly perishable commodities, inaccurate purchasing decisions not only increase storage costs but also accelerate quality deterioration and product losses. This finding aligns with SCM theory, which recognizes information quality and planning accuracy as critical determinants of supply chain performance. Reliable demand information reduces uncertainty across procurement, inventory management, and distribution, enabling organizations to synchronize supply with actual market requirements.

Prioritizing demand forecasting as the most effective mitigation strategy further strengthens previous empirical findings. Nurdina et al. (2022) demonstrated that the weighted moving average forecasting method improved production planning in food SMEs by reducing inventory imbalance through better utilization of historical sales data. Although the operational characteristics of Telur Murjani differ from those of manufacturing-oriented SMEs, both studies indicate that relatively simple forecasting techniques can substantially improve planning accuracy without requiring sophisticated information systems or significant financial investment. This finding highlights that improving managerial decision-making capability may generate greater operational benefits than investing exclusively in physical infrastructure.

In addition to planning deficiencies, transportation-related risks emerged as major contributors to overall supply chain vulnerability. Poor road infrastructure (A1), delayed deliveries from partner farms (A7), and dependence on a limited number of suppliers (A6) collectively accounted for a substantial proportion of the cumulative aggregate risk potential. These findings reflect the geographical characteristics of Berau Regency, where transportation routes connecting poultry farms and urban distribution centers remain vulnerable to road damage, weather conditions, and travel delays. Unlike distributors operating in metropolitan regions with diversified logistics networks, Telur Murjani has limited flexibility in selecting transportation routes and sourcing alternative suppliers. Consequently, upstream disruptions directly influence downstream inventory availability and customer service performance. This observation reinforces the SCM principle that external environmental conditions constitute an inseparable component of supply chain risk because organizations cannot completely control infrastructure quality or supplier reliability.

The importance of supplier diversification identified in this study is consistent with previous research on agri-food supply chains. Khusnaini et al. (2023) reported that pineapple-processing SMEs experienced similar vulnerabilities due to dependence on a limited number of raw material suppliers, while Rahman & Destiarni (2024) found that inadequate planning and supplier-related uncertainties dominated operational risks in traditional food SMEs. Likewise, Kinasih & Immawan (2025), who applied the House of Risk to commercial egg supply chains, identified delayed supply and coordination problems as the most influential operational risks. Although these studies investigated different commodities and organizational settings, they consistently indicate that small-scale food enterprises tend to exhibit similar structural weaknesses, namely limited supplier networks, informal planning systems, and restricted managerial resources. Therefore, the findings of the present study reinforce the growing body of evidence that proactive risk management is particularly important for SMEs operating within agri-food supply chains.

Another noteworthy finding concerns the discrepancy between the quantitative mitigation priorities generated by the House of Risk analysis and the practical preferences expressed by the business owner. Based on the ETD analysis, implementing demand forecasting (PA1) and expanding the supplier network (PA8) produced the highest overall contribution to risk reduction. In contrast, the business owner considered warehouse ventilation improvements (PA9) and digital inventory recording (PA2) to be more feasible because they require lower initial investment and can be implemented immediately. This difference illustrates an important managerial issue frequently observed in small enterprises, where operational decisions are often influenced by short-term financial considerations rather than long-term strategic risk reduction. From the perspective of decision theory, managers naturally prioritize actions perceived as affordable and easy to implement. In contrast, the house of risk framework evaluates alternatives according to their overall effectiveness in reducing aggregate supply chain risk. Consequently, quantitative decision-support tools should not replace managerial judgment but rather complement it by providing objective evidence for prioritizing improvement initiatives.

The findings also demonstrate the practical flexibility of the house of risk framework for application in resource-constrained organizations. Previous HOR studies have primarily focused on manufacturing industries (Marchello et al., 2023; Vandhana, 2025; Wali et al., 2022), food-processing SMEs (Elviani et al., 2025; Rahman & Destiarni, 2024), fisheries (Rizqi, 2022), and integrated supply chain models incorporating SCOR or bow tie analysis (Asrory, 2023; Primadhiya et al., 2026). In contrast, the present study applies HOR within a small-scale egg distribution agency, where operational activities are considerably simpler and managerial resources are substantially more limited. Despite these contextual differences, the HOR framework successfully identified priority risk agents and generated feasible mitigation strategies, demonstrating its adaptability across different organizational scales and supply chain configurations. This finding contributes to the broader literature by extending empirical evidence regarding the applicability of HOR beyond manufacturing environments into regional agri-food distribution systems.

From a theoretical perspective, this study contributes to the advancement of supply chain risk management by providing empirical evidence that managerial capability, particularly demand planning and supplier coordination, may represent more critical determinants of supply chain resilience than physical operational factors in small-scale agri-food enterprises. While previous studies have predominantly emphasized transportation disruptions, production failures, or product quality issues, the present findings indicate that deficiencies in planning systems often function as the root cause from which multiple operational risks originate. Thus, strengthening planning capability should be viewed as a strategic investment that enhances organizational resilience across the entire supply chain rather than merely improving inventory management.

From a practical perspective, the study provides a structured decision-support framework for small egg distributors operating under limited financial and organizational resources. Instead of attempting to mitigate all identified risks simultaneously, managers can allocate available resources toward the relatively small number of dominant risk agents identified through the Aggregate Risk Potential analysis. Furthermore, the phased implementation strategy proposed in this study, beginning with low-cost operational improvements such as digital inventory recording and warehouse ventilation, followed by demand forecasting implementation and supplier diversification, offers a realistic roadmap for progressively improving supply chain resilience without imposing excessive financial burdens on the business. Such an approach is particularly relevant for small and medium-sized agri-food enterprises in developing regions, where resource limitations often constrain the adoption of comprehensive risk management systems.

Despite these contributions, several limitations should be acknowledged. The assessment of severity, occurrence, correlation, implementation difficulty, and mitigation effectiveness relied primarily on a single key informant, which may introduce subjective judgment into the evaluation process despite the respondent's extensive operational experience. Moreover, the proposed demand forecasting strategy has not yet been validated using historical sales data; therefore, its expected effectiveness remains theoretical rather than empirically verified. Future research should involve multiple expert respondents, incorporate longitudinal sales and inventory data, compare different forecasting techniques, and examine the integration of the house of risk framework with complementary approaches such as SCOR, ISO 31000, or multi-criteria decision-making methods to improve the robustness and generalizability of supply chain risk mitigation strategies for agri-food SMEs.

Conclusions

This study applied the house of risk (HOR) approach to identify, prioritize, and mitigate supply chain risks in the egg distribution network of Telur Murjani, a small-scale egg wholesaler in Berau regency, Indonesia. The analysis identified 10 risk events and 12 risk agents, of which seven risk agents were classified as priorities based on the aggregate risk potential (ARP) and Pareto 80/20 analysis. The most critical risk agent was the absence of a structured demand forecasting system, followed by poor road infrastructure, delayed deliveries from partner farms, dependence on a limited number of suppliers, high warehouse temperatures, demand fluctuations, and unsafe driving practices. The house of risk Phase 2 analysis further revealed that implementing a simple demand forecasting method represented the highest-priority mitigation strategy because it offered the greatest reduction in aggregate supply chain risk relative to its implementation difficulty. These findings indicate that managerial planning capability, particularly demand forecasting and supplier management, plays a more significant role in improving supply chain resilience than addressing individual operational problems in isolation.

From a theoretical perspective, this study extends the application of the house of risk framework to the context of small-scale egg distribution businesses. This setting has received limited attention in previous supply chain risk management research. The findings reinforce the principles of supply chain risk management by demonstrating that proactive identification of dominant risk agents enables organizations to allocate limited resources more effectively toward preventive actions. From a practical perspective, the study provides an evidence-based prioritization of mitigation strategies that can assist small agri-food distributors in improving inventory planning, supplier coordination, transportation management, and warehouse operations. The proposed phased implementation strategy also offers a realistic roadmap for enhancing supply chain resilience under financial and operational resource constraints, making the findings potentially applicable to other small and medium-sized agri-food enterprises with similar characteristics.

Despite these contributions, several limitations should be acknowledged. The assessment of severity, occurrence, correlation, implementation difficulty, and mitigation effectiveness relied primarily on a single key informant, which may introduce subjective bias into the evaluation process. In addition, the proposed demand forecasting strategy has not been validated using historical sales data or evaluated after implementation, limiting the ability to quantify its operational impact. Future research is therefore recommended to involve multiple expert respondents, integrate longitudinal sales and inventory data, and empirically evaluate forecasting techniques such as weighted moving average, exponential smoothing, or other quantitative forecasting models within the house of risk framework. Further studies may also compare the effectiveness of HOR with other supply chain risk management approaches, such as ISO 31000, SCOR, or multi-criteria decision-making methods, to develop more comprehensive and generalizable mitigation strategies for agri-food supply chains.

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