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RISK IDENTIFICATION AND ASSESSMENT IN COLD CHAIN LOGISTICS FOR DURIAN EXPORTS FROM THAILAND TO CHINA: INSIGHTS FROM PACKING HOUSE PERSPECTIVES

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Abstract

Exporting agricultural products requires strict compliance with regulatory standards, careful transportation monitoring, and efficient risk management. This study examines the risks within the cold chain system for agricultural products, focusing on Thailand's durian industry. The data collection methods consist of two parts: (1) risk identification through semi-structured interviews with five stakeholder groups: packing houses, export associations, logistics providers, insurance firms, and governmental agencies; and (2) risk assessment from the packing house perspective, using a survey of 86 packing houses. The findings reveal two key results: (1) Sixteen risk factors were identified from five stakeholder groups, categorized into operational (e.g., inexperienced workers, quality control issues, improper loading), supply (e.g., supply shortages, invalid GAP certifications), and logistical risks (e.g., container and trailer shortages, outdated and malfunctioning temperature control equipment); and (2) The risk assessment conducted with packing houses identified six medium-risk factors, including invalid GAP certification, supply shortages, container shortages, malfunctioning temperature control equipment, outdated temperature control equipment, and vehicle breakdowns, with invalid GAP certification being the most critical risk. These findings were used to develop mitigation strategies and contribute to the cold chain logistics literature by identifying key risks in the durian export process. Additionally, the study provides valuable insights into risk perceptions from packing houses, enhancing the understanding of risk management in this context.

Keywords: Cold Chain, Logistics, Agricultural products, Durian, Risk Assessment

1. INTRODUCTION

Cold chain logistics has gained increasing significance in recent years due to the growing global demand for fresh and high-quality agricultural products (Chen et al., 2022). It plays a critical role in the international export of these goods, with its primary objective being to maintain appropriate temperatures throughout the supply chain, ensuring the preservation of

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both product quality and safety (Chaudhuri et al., 2018; Han et al., 2021; Zhang, 2020). Fresh-cut fruits and vegetables, in particular, require efficient temperature and humidity control systems in order to prolong their shelf life (Mahmood et al., 2019). Any disruption in the cold chain can lead to substantial financial losses, including diminished product quality, failure to meet export standards, and missed opportunities in the market (Goedhals-Gerber & Khumalo, 2020; Lengai et al., 2022;).

Existing literature on agricultural products predominantly addresses the general management of perishable goods (Ali et al., 2018; Han et al., 2021; Sharma & Pai, 2015; Shen & Liao, 2022), advancements in cold chain logistics technology, temperature control, and tracking and monitoring systems (Zhang et al., 2017; Z. Zhang et al., 2022; X. Zhang et al., 2022). Additionally, studies have explored the application of data analytics for business decision-making (Chaudhuri et al., 2018), including vehicle routing (Zhu et al., 2021) and distribution system planning (Zhang et al., 2019). However, studies on cold chain logistics from a risk assessment perspective, remain limited (Guo et al., 2018; Khalid et al., 2024; Zhang et al., 2020). Most studies on risk have primarily investigated a single party involved in the agricultural supply chain, rather than considering multiple parties. Therefore, a research gap exists in the lack of studies exploring risks through multiple stakeholders in an agricultural supply chain network.

Thus, this study aims to address such a gap by including perspectives from agricultural specialists, packing house managers, export inspectors, logistics providers, insurance agents, and government officials. Specifically, this study focuses on analyzing risk factors within the cold chain system for agricultural products, paying particular attention to Thailand's top export fruit, durian. Research on cold chain risk management is relatively new, yet it is crucial and urgent for businesses to enhance operational efficiency, meet customer expectations for product quality, and minimize potential losses for stakeholders. It is also important for the government to develop policies and regulations that facilitate export activities. In this study, risk factors are identified through a review of pertinent literature and further validated and expanded upon by practitioners across the supply chain, including agricultural specialists, packing house managers, export inspectors, logistics providers, insurance agents, and government officials. This approach is taken due to the unique characteristics of the product and the strict regulatory standards enforced by both exporting and importing countries. Each identified risk factor is then assessed by evaluating the likelihood of occurrence and the impact or loss associated with such events. The findings from this research will provide valuable insights for supply chain practitioners to mitigate risks, ultimately improving operational efficiency in cold chain management.

The remainder of this paper is structured as follows. The following section reviews the literature on cold chain logistics and its associated risk management. Section 3 outlines the empirical study and the methodology employed to assess the risks. The findings of the research are presented and discussed in section 4. Finally, section 5 concludes the study and discusses its limitations.

2. LITERATURE REVIEW

2.1 Cold Chain Logistics

With the rise of e-commerce and the increasing demand for fresh and safe products, cold chain logistics has grown significantly and become an important component of modern supply chains. Cold chain logistics refers to the system of transporting and storing perishable goods, including food, pharmaceuticals, and biological materials, to ensure that temperature-sensitive products are maintained within a specified temperature range throughout their

journey, from production to consumption (Rodrigue & Notteboom, 2024). This system plays a crucial role in preserving the quality, safety, and efficacy of temperature-sensitive products. The effectiveness of cold chain logistics largely depends on maintaining consistent temperatures, which requires the implementation of advanced monitoring and control systems (Chaudhuri et al., 2018). Additionally, the cold chain must adhere to stringent regulations that vary globally, demanding ongoing adaptations to comply with changing safety standards.

Cold chain operations require a well-structured logistics process to maintain shipment integrity by maintaining consistent temperature control. This process involves several stages: shipment preparation, transportation, customs clearance, and last-mile delivery (Ding et al., 2022). At each stage, appropriate cooling systems are essential to maintain the products within the required temperature range. The shipment preparation stage involves multiple key activities, including goods processing, packaging, and storage (Rodrigue & Notteboom, 2024). In the transportation phase, selecting the appropriate mode of transport is a critical consideration, influenced by factors such as available transportation options, cost, transit time, and the product's condition. Additionally, essential activities include preparing and pre-cooling the load unit or container, properly loading the shipment, and maintaining control over temperature and humidity to ensure compliance with required conditions throughout transit (Han et al., 2021). Customs procedures are crucial for cross-border shipments, as cold chain products are time-sensitive and subject to stricter inspections compared to regular freight. These procedures, as well as potential delays, can vary by country and customs requirements. The final stage of cold chain logistics, last-mile delivery, involves the shipment's delivery to its final destination with verification of shipment integrity upon arrival. When planning in this stage, it is essential to consider delivery timing while ensuring product quality. Therefore, the chosen transportation mode must meet the specific requirements for handling cold chain goods.

Studies on cold chain logistics for agricultural products cover a wide range of aspects, such as risk management, data analytics for decision-making, and technological infrastructure (Chaudhuri et al., 2018; Han et al., 2020). Regarding the technological infrastructure, numerous studies have focused on advancements in temperature control technologies, and tracking and monitoring systems (Lutjen et al., 2013; Pang et al., 2015). In the area of data analytics for decision-making, several studies have employed mathematical programming to analyze the problem and propose solutions. For instance, Blackburn and Scudder (2009) examined optimal batch sizes for transporting harvested fruits from farm to cooling facilities. Research has also addressed vehicle routing challenges and distribution system planning (Zhang et al., 2019; Zhu et al., 2021). Additionally, some studies have investigated the temperature of fruits during transport from farm to store to evaluate the rate of decay and the economic losses resulting from temperature fluctuations during transit (Nakandala et al., 2016).

2.2 Risk Management in Cold Chain

Risk management plays a crucial role in improving managerial decision-making and reducing the adverse effects of both internal and external events (Singh, 2020). It involves a systematic process of identifying, assessing, mitigating, and monitoring risks (Ho et al., 2015). In the context of cold chain logistics, the literature emphasizes that temperature and time are two key factors that significantly influence product quality and safety (Guo et al., 2018; Srivastava et al., 2015). This presents a challenge for operators to maintain proper temperature control and manage timing throughout processing and distribution within the supply chain, in order to minimize risks that could lead to potential economic losses (Sharma & Pai, 2015).

2.2.1 Risk Factors

Previous studies have identified a range of risk factors that may affect the effectiveness of cold chain logistics. These risks can be classified into three categories: external, internal, and supply-chain (Ho et al., 2015; Lin & Zhou, 2011; Vilko & Hallikas, 2012). External risks arise from factors outside the supply chain, including environmental events such as natural disasters, political instability, and biological factors such as the degradation of product quality during transit (Ali et al., 2018; Sharma & Pai, 2015; Zhao et al., 2020). Supply chain risks include demand and supply fluctuations (demand risk and supply risk), variability in the quality of products or raw materials, changes in laws and regulations, and transportation and infrastructure challenges such as inadequate capacity and underdeveloped transport systems (Ali et al., 2018; Sharma & Pai, 2015; Tummala & Schoenherr, 2011; Zhao et al., 2020). Internal risks, on the other hand, originate within the organization and are typically associated with operational and information systems (Khalid et al., 2024; Vilko & Hallikas, 2012; Ho et al., 2015). Operational system risks involve problems related to equipment, technology, or the methods used, as well as issues of insufficient capacity, unfamiliarity with declaration documents, and problems with inventory management (Ding et al., 2023; Manuj & Mentzer, 2008; Sharma & Pai, 2015; Wu & Hsiao, 2021; Zhang et al., 2019). Meanwhile, information system risks are characterized by limited information visibility and inadequate infrastructure for effective information sharing (Sharma & Pai, 2015; Shen & Liao, 2022).

The assessment of these risks was introduced by taking into account both the likelihood of their occurrence (P) and the magnitude of their impact (I) with a formula for assessing supply chain risks: Risk = P x I (Curtis & Carey, 2012; Manuj & Mentzer, 2008; Tubis, 2018). Additionally, research on risk assessment in the supply chain has used various analytical methodologies, including the Bayesian model (Cai & Liu, 2018; Sharma & Pai, 2015; Zhang et al., 2019), the fault tree approach (Cigolini & Rossi, 2010; Zhang et al., 2019), the fuzzy TOPSIS method (Baranauskaite & Jurevičienė, 2021), the analytic hierarchy process (AHP) (Blackhurst et al., 2008; Ho et al., 2011; Shen & Liao, 2022), mathematical programming and data envelopment analysis (DEA) (Wu & Olson, 2010), as well as the failure mode and effect analysis (FMEA) technique (Chaudhuri et al., 2013; Wu & Hsiao, 2021).

2.2.2 Risk Mitigation

The purpose of risk mitigation strategies is to minimize the adverse effects of critical risks as well as the likelihood of loss through prevention (Ding et al., 2023). Strategies to mitigate risk include enhancing worker skills, fostering collaboration among stakeholders, maintenance of equipment, and adopting technology to streamline the logistics process. For example, supply risk can be mitigated by building relationships with suppliers, or adopting business planning (Hallikas et al., 2005; Zsidisin et al., 2005). Significant research has been conducted relating to supply risk mitigation (Ho et al., 2015). Wu and Hsiao (2021) proposed that warehouse staff should receive training on handling techniques and contingency plans for adverse weather or road conditions, to reduce delays. Meanwhile, truck drivers should receive training on safe and efficient driving practices to prevent losses, while training staff in proper product handling and implemention of quality checks at each stage of the cold chain are critical to avoiding product damage. Various types of technology and information technology are adopted to mitigate risks: real-time monitoring using IoT sensors to track the temperature, location, and other key parameters; data analytics and AI to leverage data to identify potential issues before they occur (Han et al., 2021; Wu & Hsiao, 2021; Z. Zhang et al., 2022), and blockchain to enhance traceability and transparency (Han et al., 2021; Wu & Hsiao, 2021).

Previous research in general supply chain studies has indicated that supply risk accounts

for a higher proportion of risks compared to other types of risk. However, studies on operational, transportation, and information risks, when compared to supply risks, remains relatively limited (Ho et al., 2015). In the context of agricultural products, although cold chain logistics has become increasingly important in global trade, much of the existing research has primarily focused on specific technologies, such as temperature-control systems, monitoring or tracking systems, and environmental measures to maintain the biological characteristics of the products. However, these studies often concentrate on a single stage of the cold chain, and thus lack a comprehensive perspective (Han et al., 2021), particularly from the perspective of risk assessment (Zhang et al., 2017). To fully understand the cold chain, it is essential to consider risks across all stages, including supply, operations and processing, transportation, information, and regulatory aspects. Comprehensive studies and analyses are crucial for enhancing the overall efficiency of the cold chain.

3. EMPIRICAL STUDY AND METHODOLOGY

3.1 The Exportation of Thai Durian to China

Thailand is a leading global producer and exporter of durians, with Thai durians making up 65.15% of China's total import volume in 2023 (Xinhua, 2024). Key factors driving this growth include the Regional Comprehensive Economic Partnership (RCEP), improved infrastructure under the Belt and Road Initiative (BRI), and the China-Laos Railway, which reduces transportation time. Enhanced agricultural practices in Thailand have also boosted the quality of durians and consequently the quantity of durians meeting export standards, supporting China's growing fruit market (FAO, 2023; Tantrakoonsab & Tantrakoonsab, 2021).

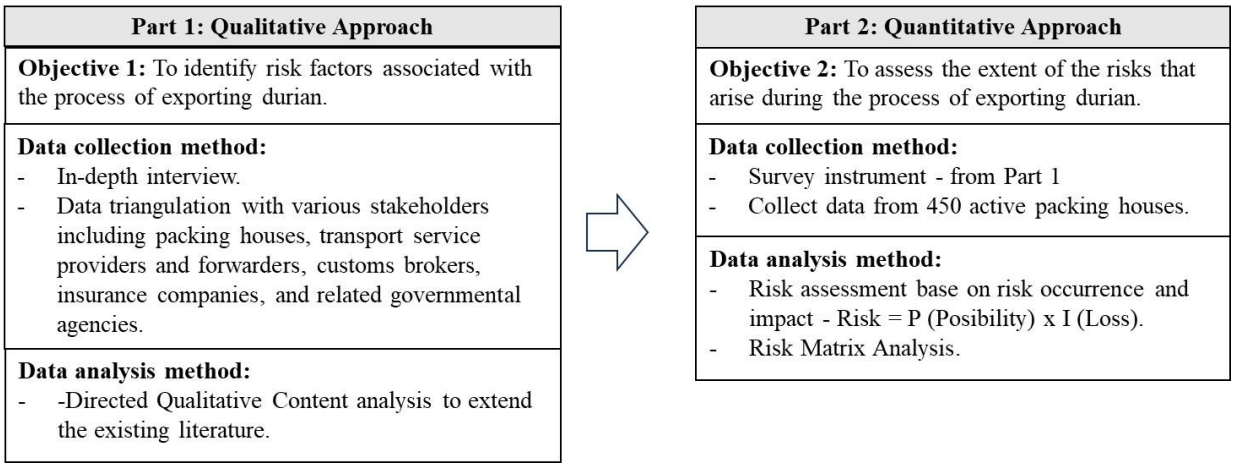
RCEP has simplified export processes, but compliance with Chinese regulations is mandatory. This requires GAP-certified orchards, GMP-certified packing houses, and phytosanitary inspections by quarantine officers (FAO, 2023; Logistics, 2024). Durian transport demands careful handling, particularly time and temperature control, as maturity before harvest influences eating quality (Supapvanich & Youryon, 2022). A shorter transit time supports exports of mature fruit, prompting a shift from maritime to road transport, which accounted for 70.63% of shipments in 2021 (Office of Agricultural Economics, 2021). Maintaining refrigerated containers at 13–15°C with 15–20% ventilation is critical for quality preservation (Gill, 2020).

Packing houses play a central role in ensuring durian quality, overseeing procurement, quality assessment, sanitization, packaging, and compliance with temperature guidelines during logistics. Risks such as delays, or temperature fluctuations directly impact quality (Bureau of Agricultural Economic Research, 2020). Therefore, this study examines the risks faced by Thai durian packing houses exporting to China, with two main objectives: 1) identifying risk factors in southern Thai durian exports to China, and 2) assessing these risks to provide insights for packing houses and policymakers.

3.2 Research Method

This study adopts an exploratory-sequential approach, integrating qualitative findings with quantitative analysis (Creswell & Clark, 2011). Figure 1 illustrates the research design and methodology.

Figure 1 Research Design and Methodology



3.2.1 Methods to Identify Risk Factors

Part 1 of the study employed directed qualitative content analysis (DQCA) to validate and expand on the risk factors identified in existing literature; this is a common method used by researchers who want to build on previous work (Hsieh & Shannon, 2005). The study adheres to Kibiswa's (2019) three-step process of preparation, organization, and reporting, for conducting a DQCA. Such a study begins with the establishment of a framework and operational definitions, followed by the identification of the unit of analysis and data collection.

In accordance with the principles of data triangulation, interviewees belonged to diverse stakeholder groups (Campbell et al., 2018), with the unit of analysis including five stakeholder groups: packing houses, export associations, logistics providers, insurance firms, and related governmental agencies. Additionally, the recruited interviewees were either experts or held a minimum of five years of experience in durian exportation. The data collection methods consisted of semi-structured interviews, with purposive sampling and snowball techniques used to identify appropriate participants. The interviews were conducted in August 2023, after the alleviation of COVID-19 restrictions and the initiation of freight transportation via the Lao-China railway.

3.2.2 Methods for Analyzing Risks from the Packing House Perspective

Part 2 employed quantitative analysis using a survey to assess the probability and impact of various risks. The study focused on the operations of packing houses, which are crucial in the Thai durian supply chain for ensuring quality, reducing post-harvest losses, and maintaining compliance, all of which enhance the value and competitiveness of Thai durians. This resulted in a limitation whereby the risk assessment was derived from packing houses in the southern part of Thailand. To provide a 90% confidence level, a sample of 86 packing houses was drawn from a total population of 450 (Yamane, 1967). Data collection occurred through in-person meetings with respondents at packing houses completing paper-based questionnaires from August to September 2023. The questionnaire included three sections: respondent background, likelihood of occurrence, and impact assessment of risk events.

The likelihood of occurrence was classified into four levels: rarely (highly unlikely to occur), unlikely (most likely not to occur), sometimes (possible to occur), and often (likely to occur). The impact of these events was categorized into four levels: negligible, low, medium, and high. Negligible was used to indicate having very little or no effect in terms of cost and time. A low impact was defined as an increase in cost or time of less than 10%, or an effect on

a few minor areas. The term "medium impact" refered to an increase in cost or time of between 10% and 20%, or a significant impact on some major areas. High impact was defined as an increase in cost or time of more than 20%, or an unacceptable outcome. The risk level for each event was then derived by multiplying its impact by the probability (Curtis and Carey, 2012) and was evaluated using a risk assessment matrix.

4. RESULTS AND DISCUSSION

4.1 Identifying Risk Factors of the Packing House Processes

This study collected empirical data from both packing houses and experts involved in exporting Thai durian to China. Interviews, conducted onsite and online via Zoom, lasted 45–60 minutes on average. Table 1 provides detailed information about the interviews and participant backgrounds.

Table 1 Detailed Information about the Interviewees

Type of Stakeholder	Position of Interviewees	No. of Interviewees
1. Packing houses (PK)	Business Owner – PKB	2
	Clerk - PKC	4
2. Export Association (EA)	President	2
3. Logistics providers (LP)	Sale manager	3
4. Insurance Company (IC)	Manager – marine and cargo insurance	1
5. Governmental Agency	Officer - Plant Quarantine station - PQ	2
	Officer - Agricultural Extension Research and Development Division - AE	2

Packing house operations begin with receiving an order from the exporter or importer, followed by initiating procurement and notifying the exporter or importer to arrange transport. Once the durians arrive, workers grade them into market categories (A, B, C, D), assess ripeness, and prepare the necessary chemical solutions. The cleaning and packing team then clean the durians to meet phytosanitary standards before packing. Next, the clerk coordinates with the logistics provider to prepare export documents (e-Phyto and export clearance) and organizes the container in the loading area. The packing house handles loading of the durians, regulating transportation temperature, and coordinating with the plant quarantine office for inspection and approval. Before departure, the plant quarantine officer seals the container for land transport or re-inspects it at the port for sea transport.

The empirical findings revealed no risks related to weather, political or regulatory issues, or demand in packing house operations. All interviewees from packing houses, logistics providers, and a single insurance company confirmed that cargo insurance is purchased for all durian shipments, covering their total value. However, the owner of PKB1 expressed concerns about delays and transit times: "Insurance companies are not liable for guaranteeing the quality of durians but will be accountable for accidents… Insurance companies will reject claims if the trailer is delayed at a checkpoint for an extended period, even in cases of force majeure… We choose the fastest choice, land transportation (Trailer) because it will take 4 days to reach Kunming."

The respondents did not identify demand issues as a concern, as exporters or importers analyze customer behavior and determine durian quality and quantity. Packing house operations only begin upon receiving an order. Interestingly, the interviewees did not view

changes in policies and regulations as risks. They emphasized that holding GAP, GMP, and phytosanitary certificates ensures a smooth export process. As the clerk of PKC3 explained: "You need to enter the GAP and GMP numbers in the e-Phyto application system... Then wait for inspection... If the plant quarantine officer inspects the cargo and then allows you to seal the container without additional instructions, your shipments already comply with the regulation."

Although weather, political, regulatory, and demand-related risks were not found to be present, internal operational risks and supply chain risks still pose significant challenges. Operational risks include inexperienced workers, inadequate quality control, improper loading and stacking, labor shortages, and human errors in documentation. Supply chain risks focus on two primary issues: supply shortages and invalid GAP numbers. Logistical and infrastructure risks are divided into three categories: governmental infrastructure and services, such as insufficient plant quarantine officers, heavy traffic at customs checkpoints, and a lack of GMP certification officers; transport provider operations, which face challenges like container shortages and trailer shortages; and transport equipment issues, including outdated or malfunctioning temperature control systems, trailer truck breakdowns, and poorly conditioned containers.

The top three risks mentioned included "Invalid GAP certification" (8 out of 16), followed by "Poor quality control" (6 out of 16) and "Inexperienced workers" (5 out of 16). Managing GAP (Good Agricultural Practices) numbers is a significant challenge, as highlighted by two packing house owners, the president of the export association, and an officer from the Agricultural Extension Research and Development Division. Instances of other firms using GAP numbers from farmers complicate traceability, affecting logistics, accurate e-Phyto system tracking, and transparency in aggregating produce from small farms as mentioned by PKB1 "…The size of the durian farms in the southern part of Thailand is smaller than the eastern part. We may need 2 or 3 farms to fill up a container…Some packing houses use only one GAP number from the largest farm for entry in the e-Phyto system instead of entering all of them…"

Durian ripeness evaluation is another critical concern, as it directly impacts quality. The owner of PKB2 remarked, "the grading worker is the heart of the packing house". Additionally, the president of the export association and two plant quarantine officers emphasized risks related to pest management and inspection. They stressed adherence to GACC regulations, meticulous cleaning and testing to prevent contamination, comprehensive inspections, and effective pest control measures for compliance and to avoid shipment delays. The interviewee from EA2 mentioned that "…The GACC is extremely strict…. If you encounter even one mealybug, there will be a notification. Thus, every durian must be blown and tested for contamination. Your container will easily pass the border check."

4.2 Risk Assessment and Analysis

The risk factors identified in the prior stage were used to develop a questionnaire aimed at gathering quantitative data on both the likelihood and impact of each risk factor. This section presents the findings that reflect the perspectives of respondents from 86 durian packing houses, providing general insights into the characteristics of these businesses, as shown in Table 2. This data indicates that nearly 80% of durian exporters have over four years of experience. Such extensive experience enhances the credibility of the risk assessment regarding the risks that these businesses face.

Table 2 General Information of Durian Packing Houses

Establishments/Experience	n	%
Operational duration		
1) less than 1 year	1	1.16
2) 1-3 years	18	20.93
3) 4 - 6 years	26	30.23
4) more than 6 years	41	47.67
Exporting duration		
1) less than 1 year	2	2.33
2) 1-3 years	17	19.77
3) 4 - 6 years	25	29.07
4) more than 6 years	42	48.84

The overall risk level for each factor, along with the average likelihood and impact as perceived by the packing houses, is presented in Table 3. The findings reveal that packing houses regard most risk factors as having a very low probability of occurrence, with the exception of the validity of GAP certification, which is perceived to have a periodic likelihood of occurrence. The results further indicate that most risk factors are considered to have a minor impact, with the majority classified as negligible or low. In contrast, the validity of GAP certification is assessed as having a low to moderate impact.

Table 3 Probability of Occurrence, Impact Level, and Risk Level of Risk Factors

Risk factor	Average level		Risk level
	occurrence	impact	
I. Operational risks			
1. Inexperience worker	1.31	1.40	1.83
2. Poor quality control	1.55	1.38	2.14
3. Improper loading and stacking	1.17	1.22	1.43
4. Labor Shortage	1.59	1.45	2.31
5. Human error in documentation	1.50	1.34	2.01
II. Supply risks			
6. Supply shortage	1.65	1.52	2.51
7. Invalid GAP certification	2.90	2.23	6.47
III. Logistical and Infrastructure risks			
-Governmental infrastructure and services			
8. Insufficient plant quarantine officers	1.22	1.17	1.43
9. High traffic at customs border checkpoint	1.23	1.13	1.39
10. Insufficient GMP certification officers	1.19	1.19	1.42
-Transport provider operations			
11.Container shortage	1.76	1.64	2.89
12. Trailer truck shortage	1.30	1.31	1.7
-Transport Equipment			
13. Outdated temperature control equipment	1.88	1.66	3.12
14. Malfunction of temperature control equipment	2.01	2.00	4.02
15. Trailer truck breakdown	1.58	1.59	2.51
16. Poor condition of container (e.g., unclean, odorous)	1.34	1.22	1.63

Based on the results of this risk assessment, the identified risk factors were categorized into four distinct levels, as described by Gul and Guneri (2016), and outlined as follows:

1) Extreme Risk (scoring 16) denotes risks necessitating immediate resolution.
2) High Risk (scoring between 8-12) identifies risks demanding prompt attention and resolution planning.
3) Medium Risk (scoring between 3-6) indicates risks warranting preventive planning.
4) Low Risk (scoring between 1-2) represents risks considered acceptable.

Using the Risk Assessment Matrix, these risk factors can be prioritized and classified into two categories: medium risk and low risk. Six factors are identified as medium risk, as illustrated in Figure 2. Each group can be described as follows:

Figure 2 The Risk Level Associated with Factors Influencing the Transportation of Durians

Likelihood of occurrence	**Impact**			
	Negligible	**Low**	**Medium**	**High**
Often				
Sometimes		7		
Unlikely	2, 4, 5	6, 11, 13, 14, 15		
Rarely	1, 3, 8, 9, 10, 12, 16			

Group 1: Medium-risk factors, which necessitate the development of a management plan in the event of their occurrence. This involves planning and preparation to mitigate the likelihood of these events. The risk factors in this category include the inability to utilize the farmer's Good Agricultural Practices (GAP) number, inability to reserve a container at the desired time, incomplete filling of the container with durians at the scheduled time, malfunctioning temperature control system within the container, extended waiting time for temperature adjustment in old containers, and breakdown of transportation vehicles.

Group 2: Low-risk factors, which are considered acceptable and may not require immediate action. These factors are likely to be perceived as low-risk because they are managed within operational processes, resulting in a minimal probability of occurrence and limited impact. This group includes all factors other than those specified in Group 1.

The findings for Group 1, comprising medium-risk factors, reveal several important risk factors associated with durian exports from Thailand to China. The highest risk level observed in this study is for the invalidity of GAP certification. Although its average risk level is medium, the value is significantly different from the other identified risks. This risk factor indicates the importance of maintaining up-to-date and accurate documentation, which requires government agencies to promote relevant information and encourage farmers to comply. Previous research has also revealed that GAP certification strengthens the trade effect of agrifood exports (Fiankor et al., 2020; Oya et al., 2018). Failure to comply with certification requirements can lead to reduced trade volume, trade barriers (Chen et al., 2020), market exclusion (Handschuch et al., 2013), and global inefficiencies (Podhorsky , 2013). Thus, it is important for packing houses to establish an effective certification management system and develop partnerships with certified farmers.

One significant transportation risk observed was the unavailability of containers, which can cause transportation delays for packing houses. This finding is consistent with

previous studies. That is, the imbalance between import and export volumes influences container exchange among shipping lines, with organizational factors playing a crucial role (Edirisinghe et al., 2018). Additionally, inefficient management at container depots leads to longer empty container receiving times and poor inventory control, which reduces supply chain efficiency and customer satisfaction (Tangkham & Ongkunaruk, 2019). Addressing this issue requires greater efficiency in supply chain management and a robust network of effective shipping lines.

Furthermore, delays due to product accumulation, consistent with previous studies on agricultural exports, are often caused by insufficient knowledge and experience among agricultural producers and certification shortcomings (Mitrofanova et al., 2021). These challenges highlight the importance of improving supply chain management to reduce delays and ensure timely delivery.

The findings also emphasize the risks associated with failure of temperature control systems or delays in temperature adjustment within containers, which are common problems in agricultural exports (Badia-Melis et al., 2016; Lee et al., 2018). Partnerships and collaboration with reliable transportation service providers might help to mitigate these transportation-related risks. Through such collaborations, exporters can benefit from these service providers' experience and resources to optimize transportation routes, reduce delays, and ensure the integrity of temperature-controlled containers.

Additionally, although operational risks such as poor durian cleaning and inaccuracies in assessing ripeness are classified as low-risk factors in Group 2, they can still significantly affect product marketability and consumer satisfaction. These findings are consistent with previous studies (Fernandes et al., 2015; Melo et al., 2014; Vélez et al., 2015), which revealed that rigorous quality control in essential for maintaining export quality standards. To effectively reduce these risks, it is recommended to implement training programs and invest in advanced quality evaluation techniques or technologies.

4.3 Risk Mitigation and Implications for Managers and Policymakers

Risk management strategies were proposed based on the analysis of key risk factors identified in the Medium-risk Group (Group 1).

To address the issue of unusable GAP certification numbers, the following strategies are recommended: establishing networks between collectors or packing houses and GAP-certified farmers; planning purchases from GAP-certified farmers at the beginning of the durian season; encouraging government agencies to issue GAP documents on a proactive basis; and implementing a system to systematically record durian trade information between farmers and buyers. This approach reflects a management innovation, boosting enterprise performance (Shan et al., 2020). Additionally, a trade recording system would serve as an innovative technological solution, improving information exchange and traceability, leading to greater operational efficiency (Friedman & Ormiston, 2022; Kumar et al., 2022).

To address the issue of limited durian supply in containers, similar strategies are suggested, including building networks with GAP-certified farmers and arranging early-season purchases to ensure a consistent and sufficient supply. Additionally, collaboration with product collectors will also streamline the collection process, minimizing delays and reducing the risk of overripe durians.

Further recommendations focus on resolving issues related to container reservations, temperature control systems, and truck breakdowns. These include establishing partnerships with international transportation providers to ensure container availability and efficiency, as well as inspecting containers on a regular basis before receiving them. With collaboration, exporters may optimize transportation routes, ensure the integrity of temperature-controlled

containers and reduce delays thereby lowering the risk of overripe durians. Notably, such collaboration can encourage service innovation among service providers, giving them a competitive advantage (Dai et al., 2020).

Additionally, the absence of external risks in the empirical findings suggests a lack of awareness among respondents. To address this, a risk awareness and education program is recommended for packing houses and exporters in the durian export supply chain. This program should highlight potential external risks, their impacts, and mitigation strategies, helping stakeholders improve their understanding, preparedness, and resilience against disruptions.

The proposed risk management strategies provide recommended guidelines for government agencies to mitigate the associated risks, as outlined below:

1) Issuance of Good Agricultural Practice (GAP) Documents: Government agencies should adopt proactive measures to issue GAP documents to farmers, including updating the outdated format to meet current standards.

2) Improvement of GAP Information Transmission to Chinese Authorities: Government agencies should streamline the registration for GAP-certified farmers and expediting exports to China.

3) Development of a Durian Trading Entry System: A comprehensive system should be established to record transactions between farmers and buyers, capturing trading volumes and GAP certifications for transparency and verification.

Furthermore, the recommendations for packing houses are as follows:

1) Partner with GAP-Certified Farmers: Packing houses should collaborate with GAP-certified farmers to ensure a steady supply of certified durian, aligning production with export schedules.

2) Collaborate with Other Packing Houses or Collectors: Building partnerships with other packing houses or product collectors will help manage inventory effectively, ensuring supply consistency and mitigating potential shortages.

3) Engage with International Transportation Providers: Forming partnerships with reputable international transportation providers will ensure timely deliveries, reliable temperature control, and refrigeration systems.

5. CONCLUSION

5.1 Conclusion

The research findings reveal a variety of risks associated with exporting durians from Thailand to China. These findings can be summarized in two parts:

1. Identification of risk factors: Sixteen risk factors were identified from five key stakeholders involved in Thai durian exports: farmers, collectors, packing houses, transportation service providers, and government agencies. These risks were grouped into three main categories. **Operational risks** (5 factors) included inexperienced workers, inadequate quality control, improper loading and stacking, labor shortages, and human error in documentation. **Supply risks** (2 factors) encompass supply shortages and invalid GAP certification numbers. **Logistical and infrastructure risks** (9 factors) including limited availability of plant quarantine officers, high traffic at customs checkpoints, shortage of GMP certification officers, container and trailer shortages, outdated and/or malfunctioning temperature control equipment, vehicle breakdowns, and poor condition of containers.

2. Risk assessment from the packing house perspective: The assessment revealed that six factors are considered of medium-risk by packing houses, including invalid GAP certification numbers, durian supply shortages, container shortages, malfunctioning and

outdated temperature control equipment, and transportation vehicle breakdowns. To address these risks, risk management strategies are proposed as guidelines for government agencies and packing houses to mitigate the associated risks.

5.2 Limitations

While the research on risk factors affecting the transportation of durians from southern Thailand to China provides valuable insights, it is important to acknowledge several limitations inherent in this study:

1) Subjectivity in Risk Assessment: Risk evaluations, including likelihood and impact, may be influenced by participant perspectives, leading to variations in prioritization and strategy development. Moreover, the accuracy and reliability of data collected, particularly through interviews and questionnaires, could be compromised by factors such as recall bias, respondent bias, or incomplete information. Ensuring the validity and reliability of data is essential for drawing robust conclusions and making informed decisions.

2) Lack of Longitudinal Analysis: The study examined the risk factors and proposed management strategies at a specific point in time. However, a longitudinal analysis observing changes in risk factors and their management over time could provide deeper insights into the risk factors and the effectiveness of various risk mitigation efforts.

3) Omission of External Factors: The study may not have taken into account all external factors that could significantly impact durian exports, such as changes in transportation regulations, regulations for exporting to China, economic fluctuations, or natural disasters. Future research should incorporate these elements for a more comprehensive risk analysis.

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