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Managing Operational Risks with ERM to Boost Tea Supply Chain Productivity

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ABSTRACT

Operational risk analysis in the plantation industry remains underexplored, despite its exposure to weather uncertainty and perishable commodities. This study stands out by employing grounded research to identify supply chain risk variables and focus group discussions (FGDs) to develop risk management solutions. It aims to boost tea productivity at Plantation Company (PT XYZ), a state-owned enterprise in West Java, Indonesia, by examining risks across plantations, processing, and distribution. The research addresses low tea yields in plantations, which reduce factory output and fail to meet consumer expectations. Using a survey-based approach with Enterprise Risk Management (ERM) tools, risk variables were derived from grounded research, and a questionnaire assessed risk probabilities and impacts. Involving 70 respondents, the study used FGDs to finalize risk scores and propose mitigation strategies. The findings identify 39 risks: 16 upstream, 12 internal supply, and 11 downstream. Key risks affecting tea production include human resource challenges, such as work accidents, fatigue, and demotivation from repetitive tasks, alongside fertilizer shortages, fraud risks, and high distribution costs. Effective risk mitigation requires government support for price stability, fertilizer supply, and fuel subsidies, along with strong leadership, continuous risk analysis, and operational monitoring.

Keywords: Enterprise Risk Management; Operational Risk; Risk Mitigation; Supply Chain; Tea Industry

JEL Classification: L66; M11; Q13

INTRODUCTION

Tea ranks among the world's most consumed beverages, with Turkey leading per capita consumption at approximately 1,300 cups (3.16 kg) annually, while China dominates global production with 1.47 million tons per year (Bermúdez et al., 2024). Indonesia, the seventh-largest tea producer, contributes significantly to the 60% of global tea output sourced from Asia, leveraging its tropical climate and fertile volcanic soil. In West Java, Plantation Company (PT XYZ), a state-owned enterprise, manages 25,905 hectares across 14 plantations, producing high-quality green, black (orthodox), and white tea varieties for export to Europe, the Middle East, and Southeast Asia. Despite a projected global tea demand of 7.44 million tons, valued at USD 268.5 billion by 2025, PT XYZ faces a persistent productivity shortfall, achieving only 72% of its 2023 production targets (Table 1). This gap, driven by operational risks such as weather variability, labour inefficiencies, and logistical bottlenecks, undermines financial performance, idles resources, and reduces market competitiveness.

Table 1. Data on Total Tea Production for the Period January to September 2023

Month	Production targets	Realization	Percentage (%)
April	11,635,700	7,736,147	0.66486305
May	11,781,400	11,481,213	0.97452026
June	11,717,100	9,726,492	0.83011086
July	10,840,000	6,815,078	0.62869723
August	9,252,500	6,414,725	0.69329641
September	9,826,900	4,723,757	0.48069656
Total	65,053,600	46,897,412	0.720904

The global tea industry operates in a dynamic environment where supply chain risks are amplified by environmental uncertainties, perishable products, and fragmented logistics. While Enterprise Risk Management (ERM) is well-established in sectors like finance and energy (Anton & Nucu, 2020), its application in agriculture remains limited, despite the sector's unique vulnerabilities (Behzadi et al., 2018). ERM, as outlined by the COSO framework (2004), integrates risk identification, assessment, and mitigation into strategic decision-making, offering a robust approach to address the multifaceted risks in tea production. Recent studies emphasize the need for tailored risk management in agricultural supply chains, noting that fragmented approaches lead to inefficiencies (Murrja & Ndregjoni, 2022). For instance, research on Sri Lankan tea supply chains during the COVID-19 pandemic highlights the role of collaboration and information sharing in enhancing resilience (Fernando et al., 2023), a finding relevant to PT XYZ's challenges.

PT XYZ's consistent failure to meet production targets reflects systemic operational risks across its supply chain, from upstream plantations to downstream distribution. Upstream risks, such as fertilizer shortages (risk severity score: 20/25) and workforce demotivation (16/25), disrupt cultivation, leading to reduced yields. These issues cascade into internal supply chain disruptions, including machine downtime and processing delays, which compromise product quality. Downstream, high distribution costs and traffic congestion further exacerbate inefficiencies, resulting in a 28% production shortfall in 2023. Despite these challenges, no comprehensive ERM framework exists for tea supply chains, leaving critical risks unaddressed. This gap is particularly significant for PT XYZ, a public-sector entity with heightened accountability to stakeholders due to substantial investments (Mahama et al., 2022). The absence of a holistic risk management approach limits PT XYZ's ability to enhance productivity and maintain competitiveness in a growing global market.

This study aims to achieve three main objectives: first, to identify and classify operational risks across the PT XYZ tea supply chain using the Committee of Sponsoring Organizations of the Treadway Commission (COSO, 2004) ERM framework. Second, to measure the probability and impact of these risks through data-driven research and focus group discussions (FGDs). Finally, to propose actionable mitigation strategies to improve productivity, emphasizing collaboration between government and industry, and the adoption of technological solutions.

This research addresses a critical gap in the application of ERM to plantation supply chains, where environmental dependencies and product perishability amplify risks. For PT XYZ, effective risk management aligns with its public-sector mandate to deliver economic and social value, ensuring accountability to stakeholders (Mahama et al., 2022). By developing a tailored ERM framework, the study offers a pathway to improve operational efficiency and financial sustainability, contributing to Indonesia's tea industry competitiveness. Furthermore, it provides a replicable model for other agricultural supply chains facing similar challenges, addressing a noted deficiency in sector-specific risk management strategies (Behzadi et al., 2018).

Unlike prior studies that focus on isolated supply chain segments, such as logistics or production, this research adopts a holistic approach, integrating ERM across upstream (plantations), internal (processing), and downstream (distribution) stages. Methodologically, it combines field-derived risk variables with stakeholder validation through FGDs, offering a context-specific analysis absent in theoretical models (Khandelwal et al., 2021). This integrated and empirical approach distinguishes the study, providing a nuanced understanding of tea supply chain risks.

This study provides several key contributions across academic, practical, and policy domains. Academically, it enriches the supply chain risk management (SCRM) literature by empirically applying and testing the ERM framework in the context of the tea industry. Practically, it offers actionable recommendations to improve operations, such as implementing subsidized fertilizers and automated sorting systems, which can reduce production shortages and enhance overall efficiency. From a policy perspective, the study supports government interventions, including fuel subsidies and infrastructure investments, to address high distribution costs and foster a more supportive environment for the tea sector. By systematically identifying and mitigating operational risks, this research not only enhances PT XYZ's productivity but also provides a scalable framework for sustainable risk management in agricultural supply chains, bridging theoretical advancements with practical, real-world solutions.

LITERATURE REVIEW

Enterprise Risk Management (ERM)

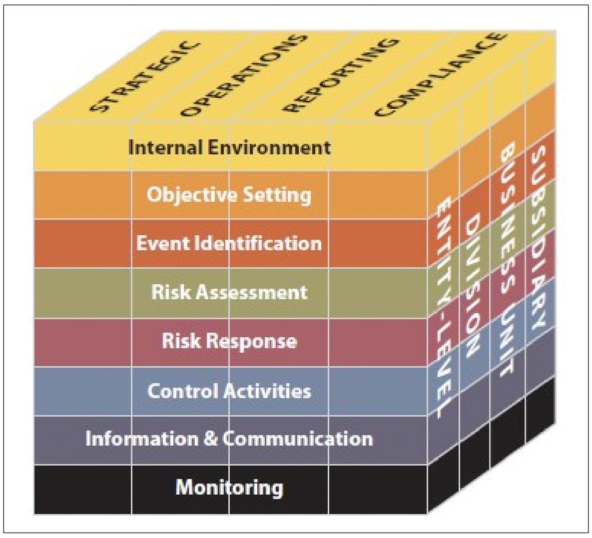
ERM provides a structured approach to identifying, assessing, and mitigating risks across an organization's operations, aligning risk management with strategic objectives. COSO introduced the ERM Integrated Framework in 2004, which has become a foundation for organizations seeking to manage risk holistically (COSO, 2004). These components ensure that risks are addressed systematically, from establishing a risk-aware culture to continuously monitoring the risk management process. The relevance of ERM extends beyond the financial sector, where it is widely adopted, to industries facing complex risks, including agriculture (Murrja & Ndregjoni, 2022).

The implementation of COSO ERM in the agricultural sector has been shown to have a significant impact in supporting the achievement of the economic, social, and environmental pillars of the SDGs (Febrianti & Novita, 2021). In the plantation or agricultural sector, risks must be analyzed starting from the source of raw materials (upstream) because raw materials in the agricultural sector have risks that are significantly influenced by nature, the environment, and the price of inputs such as fertilizers, seeds, and others, not only in the process (internal supply). Furthermore, risks can also occur in the distribution process, especially if the plantation or agricultural products produce perishable products such as tea, sugar, coffee, etc. Therefore, supply chain risk analysis in agriculture aims to identify, analyze, assess, and monitor internal and external risks that impact the performance and sustainability of the supply chain (Dellana et al., 2022). ERM adoption is driven by several factors.

Previous research shows that 68% of US companies implement ERM to reduce financial losses, 64% aim to improve organizational performance, 58% seek regulatory compliance, and 53% focus on improving accountability (PwC, 2008). ERM is defined as a system essential for strategic planning in business, specifically related to managing the process of identifying internal and external risks that can impact organizational objectives, mapping opportunities, and mitigating the probability and impact of losses (Jean-Jules & Vicente, 2021).

In agriculture, ERM facilitates strategic planning and decision-making by identifying positive and negative risks, supporting sustainable development (Murrja & Ndregjoni, 2022). This study shows that ERM implementation in Indonesian companies contributes to financial performance and firm value (Jean-Jules & Vicente, 2021). However, its application in the plantation industry remains underexplored, requiring a tailored framework to address sector-specific challenges (Khandelwal et al., 2021).

Figure 1. ERM Framework



Source: COSO (2004)

From Figure 1, the ERM framework has eight components, namely: Internal Environment, Objective Setting, Risk Assessment, Risk Response, Control Activities, pieces of information & communications, and Monitoring. Four categories of objectives, namely strategic, operational, reporting, and compliance, as well as four organizational functions, each of which must be interrelated and interconnected. ERM is widely used in the business world to reduce operational risks, both in the financial sector, banking, processing industry, and in service industries such as hospitals, logistics, etc. However, it is still rarely used in the plantation and agricultural sectors.

Operational Risk

To identify, analyze, and manage operational risks, an ERM approach is used. Operational risk is defined as the potential for loss or disruption due to inadequate or failed internal processes, human resources, systems, or external events (Astvansh & Simpson, 2026; Parwez, 2025; Thet, 2025). In agriculture, operational risk is amplified by the sector's dependence on natural resources and complex supply chains, as well as the existence of unstable climate, land, and prices (Muzylyov et al., 2024). In some cases, operational risk in the agricultural sector is an absolute must, considering that agriculture is a sector that is highly dependent on nature and has relatively perishable production results. For tea production, operational risk covers the upstream (plantation), internal supply (processing), and downstream (distribution) stages, which affect productivity, quality, and financial performance (Ascrizzi & Piazza, 2024; Bouraima et al., 2025).

Operational risks in agriculture can be classified into several categories, including environmental, labor, process, and system. Environmental risks are related to weather variability, pest infestations, and soil degradation, which directly impact crop yields (Meuwissen et al., 2019). Regarding the tea plantation workforce, the relationship between workers and managers, rooted in the "coolie" system, has created a workforce that is trapped and separated from the mainstream workforce. This ultimately produces and reproduces labor control rooted in slavery.

The opaque yet punitive incentive system, sunset-sunrise work hours, maximum involvement, and restrictions on promotion to managerial positions are constant reminders of the historically rooted system of forced labor. Furthermore, gaps in competency development and occupational health and safety are driving factors behind low tea production, both on plantations and in factories (Shahadat & Uddin, 2022). In almost all countries, the tea plantation workforce is dominated by women, who are highly vulnerable due to poor health, emotional, and physical well-being. Process risks associated with fluctuations in tea production and quality include fluctuations in tea production, low quantity and quality of tea leaves, scattered tea leaves, low quantity and quality of dried tea, delays in the production process, and the presence of weeds and twigs.

These risks stem from extreme weather, leaf pests, smallpox and helopeltis attacks, suboptimal pest and disease control, lack of attention to the picking cycle, limited and late application of fertilizer, uneven harvesting, inadequate leaf sorting, inadequate wilting, human error, scattered dried tea, and damage to picking and transportation machinery (Christy et al., 2023). Meanwhile, Process Risks relate to inefficiencies in the production process, such as damage, machine downtime, and processing delays, jeopardizing product quality (Ziyavitdinovich, 2023). Reputational and System Risks: Fraud, poor management practices, and IT system failures can damage an organization's reputation and efficiency (Febra et al., 2023; Korzhevskyi & Mihus, 2022). Recent studies emphasize the need for integrated risk management to address these challenges, with ERM offering a framework for managing risks holistically across the supply chain (Murrja & Ndregjoni, 2022).

Supply Chain Risk Management (SCRM)

Supply chain management aims to connect multiple companies or activities, from raw material procurement, processing, and distribution to consumers, to provide high-quality services at low costs. Risk management cannot be limited to a single point, such as processing, as processing is influenced by the availability of raw materials in the upstream sector. Therefore, to obtain a holistic and comprehensive picture of risk management, it is necessary to analyse the entire supply chain from upstream to downstream. Operational risk analysis using an ERM approach must be conducted throughout the supply chain to identify and map risks, thereby improving service and reducing the risk of loss (Christopher, 2022).

Risk analysis in a company is influenced not only by internal conditions related to management, culture, leadership, financial management, human resources, etc., but also by external factors. Externally, supply chain risk focuses on various factors that can hinder organizational efficiency and productivity, particularly from increased globalization, resulting in geopolitical uncertainty and regulatory changes, to internal factors related to logistics infrastructure and supplier reliability (Mallick & Roy, 2022; Vadivukarasi & Jothilingam, 2025; Venugopal et al., 2021).

Supply chain risk in the tea industry is related to human factors, with performance, supervision, and work scheduling as key contributors to supply chain risk (Shalihin et al., 2025). SCRM focuses on identifying, assessing, and mitigating risks that disrupt the flow of goods and services from raw materials to consumers (Kumar et al., 2024; Tewu et al., 2024). In agriculture, SCRM is particularly important because this sector is vulnerable to natural disasters, market volatility, and logistical complexity (Tusiimire & Mose, 2025). For tea production, SCRM must address risks at all stages of the supply chain to ensure the timely delivery of high-quality products (Wang et al., 2025).

SCRM in agriculture requires close collaboration among multiple stakeholders, including farmers, processors, distributors, and government agencies (Bhatia & Bhat, 2020; Khandelwal et al., 2021). Key risks span the entire supply chain: upstream risks include environmental factors such as pest infestations and human resource challenges like labor shortages (Meuwissen et al., 2019); internal supply risks involve processing inefficiencies, including machine breakdowns and quality control failures (Koswatta et al., 2025); and downstream risks encompass logistical challenges, such as high distribution costs and traffic congestion (Chandra et al., 2026). These risks are not unique to the tea industry but are common across agricultural supply chains, forming the basis for strategies aimed at enhancing productivity, efficiency, and profitability. Recent literature emphasizes the role of technology in mitigating these risks, highlighting how IoT and blockchain solutions can improve transparency and traceability, thereby reducing fraud and strengthening quality control (Brandtner, 2024).

In addition, data analysis can predict market trends and optimize production planning, reducing market and production risks (Brandtner, 2024). The use of technology allows organizations to analyse data in real time so that decisions can be made quickly and accurately to avoid risks that result in losses and delays in delivery or production. In tea production, synchronizing picking and processing schedules and investing in modern machinery can ensure product quality and reduce delays (Dellana et al., 2025).

ERM Stages

The ERM process provides a structured framework for managing risks in alignment with organizational objectives, encompassing four key stages: risk identification, risk probability, impact criteria, and risk response (COSO, 2004). It begins with risk identification, which involves recognizing potential threats across the supply chain, such as fertilizer shortages, worker fatigue, and logistical bottlenecks (Meuwissen et al., 2019). Next, risk probability assesses these risks based on their likelihood and potential impact, guided by established criteria like those outlined in Tables 2 and 3 (Hery, 2021). Following this, impact criteria are used to determine the appropriate strategies for addressing each risk, whether through mitigation, acceptance, avoidance, or sharing,

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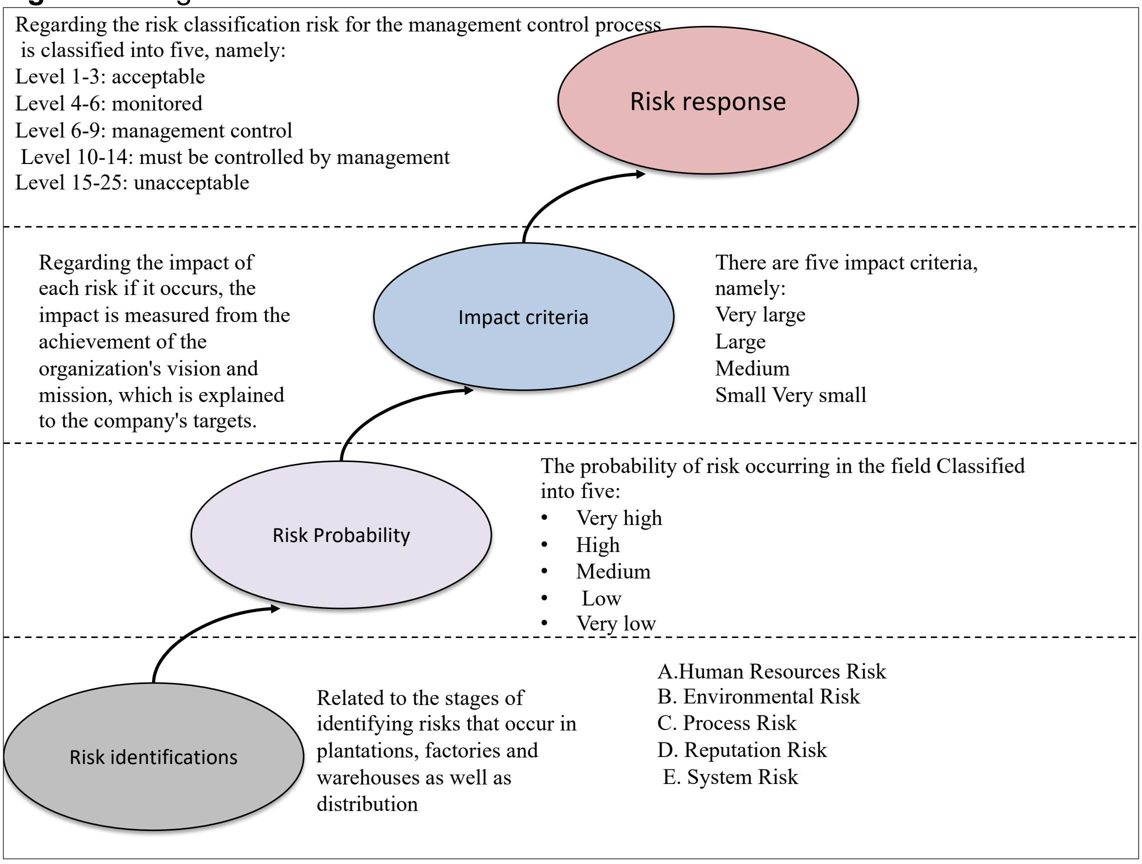
exemplified by measures such as providing transportation for workers or partnering with reliable suppliers (Behzadi et al., 2018). Finally, risk response involves the continuous monitoring and updating of risk management strategies to ensure they remain effective over time (COSO, 2004). This process is visually summarized in Figure 2, which presents the ERM stages alongside the assessment criteria, illustrating how each step contributes to a comprehensive approach to risk management.

Figure 2. Stage of ERM



In tea production, these stages must be adapted to account for the sector's unique challenges, such as seasonal variability and labor-intensive processes (Murrja & Ndregjoni, 2022). For example, risk identification should include seasonal weather patterns, while risk response strategies may involve government subsidies to stabilize input costs.

Table 2. Probability Criteria (Occurrence) Risk

Index	Probability	Description	Percentage
5	Very large	It is very likely to happen	>80%
4	Big	Most likely to happen	60 < p ≤80%
3	Currently	It is equally possible for it to happen or not to happen	40 < p ≤60%
2	Small	It is unlikely to happen	10 < p ≤40%
1	Very small	It is unlikely to happen	≤10%

Source: Hery (2021)

The next stage is to analyze the magnitude of the impact of each risk activity on organizational performance. This impact is categorized into five classes, namely very large, large, medium, small, and very small (see Table 2).

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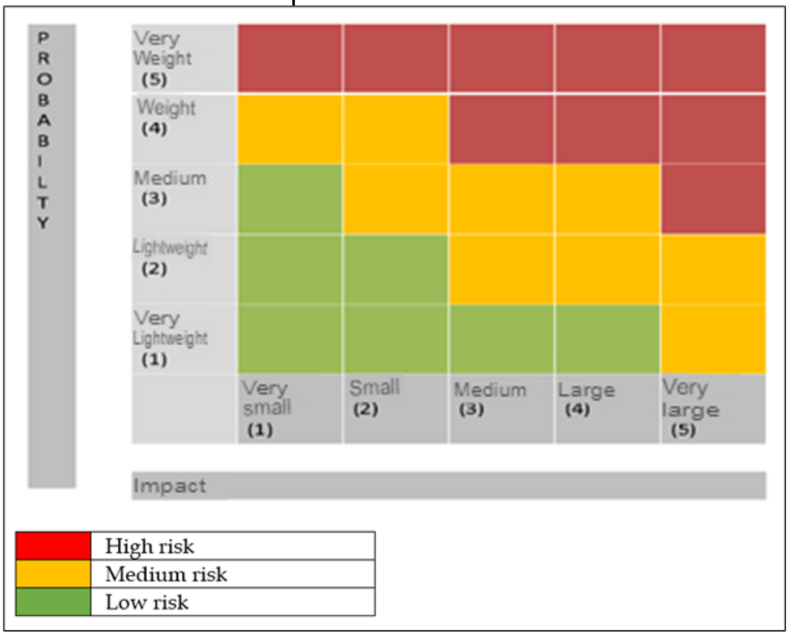
Table 3. Impact Criteria (Severity) Risk

Index	Impact	Impact on Strategic and Performance Goals
5	Catastrophic	Targets are not achieved, and there is a failure to achieve performance
4	Significant	Delays in achieving targets are quite large, and performance is below target.
3	Moderate	Delays in achieving targets are quite large, and performance achievements are below targets
2	Minor	Targets are not achieved, and performance is only slightly below the target
1	Insignificant	It only has a very small impact on not achieving targets, and performance targets can still be achieved

To determine the risk scale, the probability and impact criteria are calculated based on Table 3. For example, if the probability of the risk occurring is very high with a value of five and the impact is moderate, then the value is five, calculated by 3 to 15, and so on. These conditions are then entered into the following box (see Figure 3) for further analysis into three classifications, namely high, medium, and low risk. In determining the risk scale, the impact on the company's operational performance must be ascertained, which can result in significant financial losses (Pylypenko et al., 2025).

Figure 3. Classification of Risk Responses



Gaps in the Literature

Despite advancements in ERM and SCRM, several gaps remain in their application to agriculture. First, empirical studies on ERM in plantation industries like tea production are scarce, with most research focusing on general agricultural risks (Murrja & Ndregjoni, 2022). Second, the integration of ERM with SCRM in agriculture requires further exploration, particularly in understanding how risks propagate across supply chain stages (Behzadi et al., 2018). Third, the role of emerging technologies, such as IoT and blockchain, in enhancing ERM capabilities in agriculture is underexplored (Khandelwal et al., 2021). Future research should develop tailored ERM frameworks for plantation industries, conduct longitudinal studies to assess ERM's long-term impact, and explore technology-driven risk management solutions.

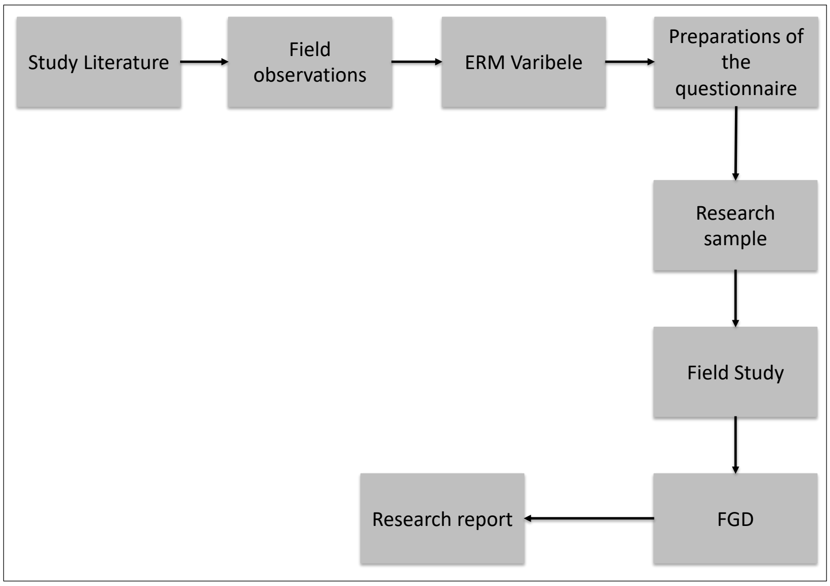
RESEARCH METHOD

Research Design

The study employed a convergent parallel mixed methods design to investigate operational risks in the tea supply chain of PT XYZ in Rancabali, West Java, Indonesia. This design, as described by Creswell and Clark (2018), integrates qualitative and quantitative data collection and analysis concurrently to provide a comprehensive understanding of the research problem. The qualitative component, consisting of grounded research and FGDs, aimed to identify and validate risks from stakeholder perspectives. The quantitative component utilized Likert-scale surveys to assess the probability and impact of these risks. Triangulation of data from multiple sources enhanced the validity of the findings, addressing the complex nature of risks in agricultural supply chains (Murrja & Ndregjoni, 2022).

This approach was chosen to align with the ERM framework established by the COSO (2004). The ERM framework provided a structured methodology for systematically identifying and managing risks across the supply chain. The detailed process of the study can be seen in Figure 4.

Figure 4. Research Methods



Research Setting

This research was conducted from January to June 2023, focusing on the tea supply chain of PT XYZ in West Java, Indonesia. PT XYZ, a state-owned enterprise, manages 25,905 hectares of tea plantations, with its supply chain organized into three main stages. The upstream stage covers tea cultivation and harvesting, encompassing various agricultural practices and labor-intensive processes. The internal stage involves wet-to-dry tea processing, transforming harvested leaves into marketable products. Finally, the downstream stage focuses on warehousing and distribution, including storage and transportation to domestic and international markets. With a reported productivity gap of 28% in 2023, PT XYZ serves as an ideal case study for analyzing operational risks that may impede efficiency and overall output.

Participants

Participants were selected using purposive sampling to ensure representation across all supply chain stages. The sampling strategy targeted individuals with relevant knowledge and experience, as outlined in Table 4.

Table 4. Methods, Number of Participants, and Roles

Method	Number of Participants	Roles
Grounded Research	20	Plantation workers, foremen, factory managers
Survey	70	Staff from plantations, manufacturing, distribution
FGDs	10	Management representatives

This diverse participant pool ensured that the study captured a wide range of perspectives, from operational staff to decision-makers. Based on Table 4, the initial research involved simple interviews to identify the risks that commonly arise in plantations, processing, and distribution. This led to a comprehensive overview of the types of risks that frequently arise. A sample size of 20 people was involved. After obtaining a general overview of the types of risks that frequently arise, the next step was to map them and enter them into a risk list for the tea industry supply chain, from plantations, factories, and distribution.

After identifying the risk types, the next step was to calculate the probability, or frequency, of each variable occurring and its impact on organizational performance. This activity involved 70 people spread across plantations, factories, and distribution. After obtaining the probability and impact figures, in order to obtain clarity and similarity of values, an FGD was conducted involving 10 people from all representatives.

Data Collection

Grounded Research

The grounded research phase involved inductive risk identification through field observations and semi-structured interviews. Observations documented operational inefficiencies, such as labour bottlenecks and equipment malfunctions. Semi-structured interviews with 20 key informants explored the causes of low productivity, guided by risk management themes from the literature. This phase identified 39 risks, categorized into human resources (e.g., labor shortages), environmental (e.g., weather impacts), process (e.g., processing delays), reputational (e.g., brand perception), and system risks (e.g., technological failures).

Survey

A 5-point Likert-scale questionnaire was developed to quantify the probability (1 = very unlikely to 5 = very likely) and impact (1 = insignificant to 5 = catastrophic) of the identified risks. The questionnaire was piloted with five respondents to ensure clarity and reliability before distribution to 70 participants across the supply chain. The survey provided a quantitative basis for prioritizing risks based on their potential severity.

Focus Group Discussions (FGDs)

Two FGDs, each with ten management representatives, were conducted to validate survey findings and develop mitigation strategies. Discussions focused on actionable solutions, such as improving labour welfare and optimizing processing techniques. A consensus-based scoring approach ensured that proposed strategies were collectively agreed upon and feasible for implementation.

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Data Analysis

Data analysis was conducted in three comprehensive stages to ensure a robust understanding of risks and mitigation strategies. The first stage, qualitative analysis, employed thematic analysis as outlined by Braun and Clarke (2006), in which interview and FGD transcripts were coded to identify recurring themes and patterns related to risk factors and mitigation approaches. The second stage, quantitative analysis, applied descriptive statistics to survey data, classifying risks as high (probability and impact scores ≥4), moderate (scores between 3 and 3.9), or low (scores <3), thereby facilitating the prioritization of critical risks. The final stage, triangulation, integrated the qualitative and quantitative findings to reconcile discrepancies and provide a comprehensive, evidence-based view of risks. This three-tiered approach ensured that the resulting risk profiles and mitigation strategies were both rigorous and actionable.

Validity and Reliability

Several measures were undertaken to ensure the validity and reliability of the study. Diverse sampling was employed by involving 70 respondents from various roles, minimizing bias and providing comprehensive representation. Method triangulation was applied by combining observations, surveys, and FGDs, allowing cross-verification of findings and enhancing credibility. Additionally, benchmarking was conducted by comparing the final mitigation strategies with those of similar organizations in the tea industry, ensuring that the strategies were both practical and effective.

Ethical Considerations

The study received approval from the University of Indonesia Ethics Committee, adhering to ethical guidelines for research involving human participants. Participants were informed about the study's purpose, their rights, and the confidentiality of their data. Data were stored securely with restricted access to protect participant anonymity.

Research Process

The research followed a structured workflow, as summarized in Table 5.

Table 5. Research Process

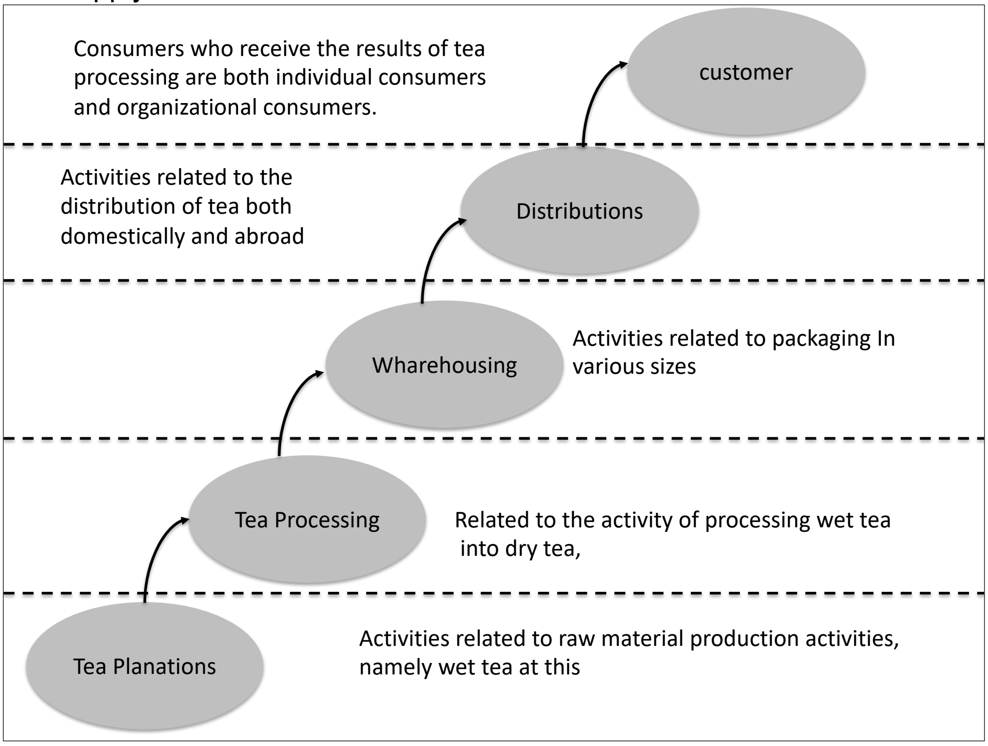
Stage		Activity	Outcome
1	Observation	Document inefficiencies	Initial risk identification
2	Interviews	Explore risk causes	39 categorized risks
3	Survey	Assess risk probability and impact	Quantitative risk prioritization
4	FGDs	Validate findings, develop strategies	Consensus-based mitigation strategies
5	Risk Classification	Analyse and categorize risks	High, moderate, low risk categories
6	Mitigation Strategies	Propose actionable solutions	Practical risk management recommendations

RESULTS

Supply Chain for the Tea Processing Industry

The tea supply chain at PT XYZ encompasses three primary stages: upstream, internal supply, and downstream, each playing a critical role in maintaining productivity while presenting potential operational risks. The upstream stage covers tea cultivation and harvesting across 25,905 hectares of plantations in West Java, forming the foundation of the supply chain. The internal supply stage transforms harvested leaves into dry tea through a series of processes, including withering, milling, drying, sorting, and packing, ensuring product quality and consistency. Finally, the downstream stage manages warehousing and distribution, delivering processed tea to both domestic and international markets, with a primary focus on exports. This structured flow from cultivation to distribution not only underpins the efficiency of operations but also highlights areas vulnerable to disruptions that can impact both efficiency and profitability. Figure 5 illustrates the full supply chain of the tea processing industry produced by PTPN, detailing the progression from upstream to downstream stages.

Figure 5. Supply Chain Tea Industrial PTPN



Upstream

Table 6. Production Data from January to September 2023

No	Garden	Factory	Garden Production (kg)	Factory Production (kg)
1	Big	Gedema	670,890	150,650
2	Mountains	Mountains	1,545,580	349,465
3	Ciater	Ciater	2,191,540	495,415
4	Ciater	Learner	2,338,753	544,655
5	Cisaruni	Cisaruni	2,196,145	2,111,832
6	Rancabali	Worshiped	2,036,895	460,384
7	Rancabali	Rancabali	5,492,379	1,321,282
8	Rancabali	Rancabolang	2,983,611	713,363
9	Malabar	Pasirmalang	3,261,694	727,550
10	Malabar	Kertamanah	3,539,986	759,120
11	Malabar	Malabar	6,809,849	1,498,370
12	Nice	Purbasari	2,589,070	589,085
13	Nice	Talun	4,614,660	1,043,092
14	Nice	Nice	6,625,360	1,446,428
Total			46,896,412	12,210,691
Average			3,349,743.70	872,192.20

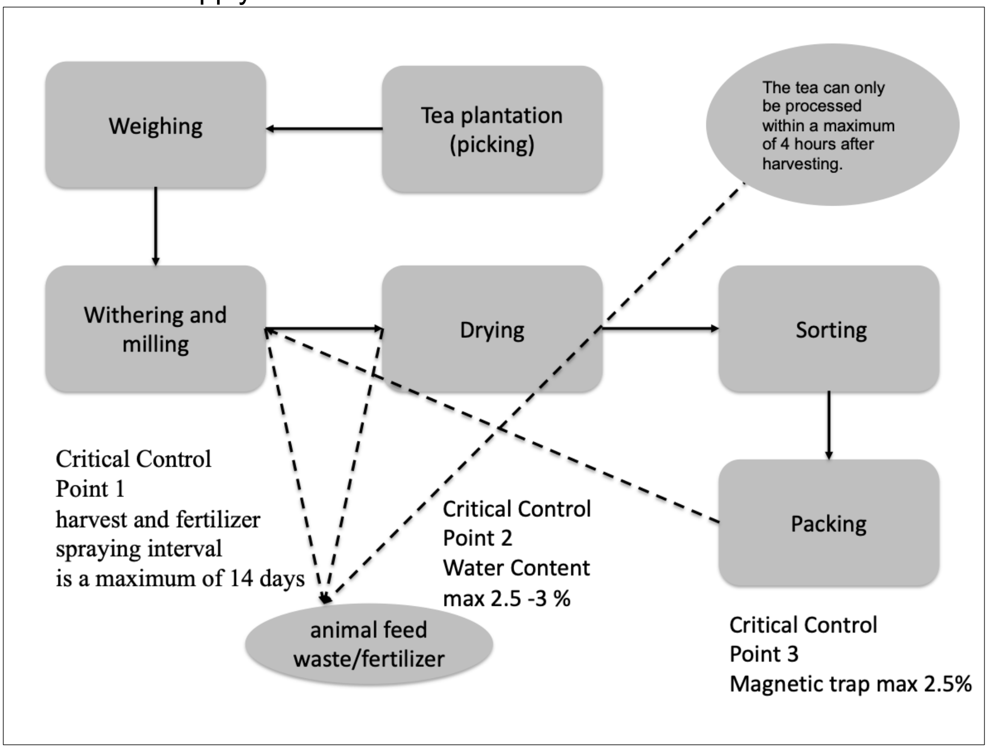
Note: Data Processed from PT XYZ Records (2023)

The upstream stage involves tea cultivation and harvesting across 14 plantations in West Java, with research conducted specifically in the Rancabali plantations in Bandung district. Table 6 presents production data from January to September 2023, detailing garden and factory outputs. The total wet tea production was 46,896,412 kg, and dry tea production was 12,210,691 kg, yielding an average rate of approximately 26%, meaning 1 kg of wet tea produces about 260 grams of dry tea. This lower-than-expected yield (compared to a potential 38%) suggests inefficiencies, likely due to operational risks such as labour issues or environmental constraints.

Internal Supply

In relation to the production process of wet tea into dry tea, the production process flow is as follows in Figure 6.

Figure 6. Internal Supply Process



Downstream

The downstream stage involves warehousing and distribution. Warehousing risks include low inventory turnover, causing quality degradation and higher storage costs. Distribution risks include increased delivery times, work accidents, and poor consumer acceptance due to quality issues. Most of PT XYZ's tea is exported, making timely and high-quality delivery critical.

Identify Risks in the Supply Chain

Using grounded research, interviews, and FGDs, risks were identified and categorized into human resources, environmental, process, reputational, and system risks. The following are risk values based on the results of interviews, observations, and FGDs at each stage of the supply chain.

Table 7. Operational Risk Assessment in Upstream

Supply Chain	Type of Risk	Code	Risk Operational	Occurred	Severity	Risk Scoring
Upstream	Human Resource	A11	Employee Strike	2	5	10
		A12	Fatigue	4	5	20
		A13	Work Accident	3	3	9
		A14	Demotivation	4	4	16
		A15	Employee Skill	3	4	12
	Environmental	B11	Wheater Problems	3	3	9
		B12	Road Damage	4	3	12
		B13	Plant Pests	2	5	10
		B14	Fertilizer Shortage	5	4	20
	Process	C11	Machin Damage	3	4	12
		C12	Transportation Work Accident	1	3	3
	Reputations	D11	Low Absorption of Local Labour	2	2	4
		D12	Worker Welfare	3	4	12
		D13	Fraud	4	4	16
	System	D14	Organization Climate	4	3	12
		E11	Theft	2	4	8
		E12	Sortation System	4	3	12

Source: Data Processed from Interviews, Questionnaires, and FGDs (2023)

The probability and severity values were determined through a combination of field surveys and FGDs, with absolute numbers established by mutual agreement among participants. This approach ensured that both the likelihood and potential impact of risks reflected a consensus view. Based on the results presented in Table 7, the upstream stage of the supply chain, particularly within plantations, exhibited risk scores ranging from a minimum of 3 to a maximum of 20. Within this stage, four risks were classified as high: worker fatigue (A12), demotivation of picker employees (A14), fertilizer scarcity (B14), and fraud (D13). The medium-risk category included work accidents (A11), labor skills (A15), road damage (B12), pests and diseases (B13), picking machine damage (C11), labor welfare (D12), organizational climate (D14), and issues with the sorting system (E12). This categorization provides a clear prioritization of critical risks that require targeted mitigation efforts.

Table 8. Operational Risk Assessment in Internal Supply

Supply Chain	Type of Risk	Code	Risk Operational	Occurred	Severity	Risk Scoring
Internal Supply	Human Resource	A21	Incompetence	2	5	10
		A22	Failed Read a System	3	4	12
		A23	Fatigue and Demotivation's	2	3	6
	Environmental	B21	Environmental Pollutions	3	4	12

		B22	Disturbance Community Around Factory	3	4	12
	Process	C21	Quality Does Match to Specifications	3	3	9
		C22	Defective Tea Leaves	4	5	20
	Reputations	D21	Long Processing Time	3	3	9
		D22	Low Quality Product	3	4	12
		D23	Fraud	4	2	8
		D24	Management	4	4	16
	System	E21	Sorting and Fermentation Technology	2	3	6

Source: Data Processed from Interviews, Questionnaires, and FGDs (2023)

Based on Table 8, several operational risks are categorized as unacceptable, colored red, meaning these risks must be eliminated because they significantly impact the company's target of profitability and customer satisfaction. There are two categories of high operational risks: leaves that do not meet specifications (C22) and management (D24). There are four categories of medium risks: failure to read the system (A22), environmental pollution (B21), disruption to the community around the factory (B22), and low-quality products (D22).

Table 9. Operational Risk Assessment in Downstream

Supply Chain	Type of Risk	Code	Risk Operational	Occurred	Severity	Risk Scoring
Downstream	Human Resources	A31	Demotivation’s	2	3	6
		A32	Low Skill	3	3	9
		A23	Fatigue	2	3	6
		A34	Strike	2	2	4
	Environmental	B31	Distributions Cost	4	5	20
		B32	Long time process	4	3	12
	Process	C31	Traffic	4	4	16
	Reputations	D31	Delivery Quality	3	5	15
		D32	Cooperation Agreement	2	4	8
	System	E31	Selling Price	3	5	15
		E32	inventory	3	4	12

Source: Data Processed from Interviews, Questionnaires, and FGDs (2023)

Based on Table 9, two categories fall into the high-risk category: distribution costs (B22) and traffic congestion (C31). Meanwhile, four categories fall into the medium-risk category: distribution processing time (B32), delivery quality (D31), inventory (E32), and selling price (E31).

Table 10. Identify Risks in the Supply Chain

Supply Chain Stage	HR Risk	Environmental Risk	Process Risk	Reputational Risk	System Risk
Upstream (Plantations)	Job Strike (A11), Fatigue (A12), Work Accident (A13), Demotivation (A14), Employee Skill (A15)	Weather Disturbances (B11), Road Damage (B12), Pests (B13), Fertilizer Scarcity (B14)	Machine Damage (C11), Vehicle Accident (C12)	Low Local Labor Absorption (D11), Low Worker Welfare (D12), Fraud (D13), Organizational Climate (D14)	Theft (E11), Sorting System (E12)
Internal Supply (Manufacturing)	Incompetence (A21), Failed to Read Machine (A22), Fatigue/Demotivation (A23)	Environmental Pollution (B21), Community Disruption (B22)	Quality Mismatch (C21), Leaves Not Meeting Requirements (C22)	Long Process Time (D21), Low-Quality Product (D22), Fraud (D23), Management (D24)	Manual Sorting System (E21)
Downstream (Distribution)	Demotivation (A31), Unskilled (A32), Fatigue (A33), Job Strike (A34)	Work Accident (B31), Slow Processing Time (B32)	Traffic Congestion (C31)	Late Delivery (D31), Poor Customer Relations (D32)	Low Prices (E31), Overproduction (E32)

Source: Data Processed from Interviews, Questionnaires, and FGDs (2023)

These categories align with the COSO ERM framework (COSO, 2004), providing a structured approach to risk identification. HR risks, such as fatigue and demotivation, stem from labour-intensive tasks and low wages. Environmental risks, like fertilizer scarcity, are influenced by external factors like weather and supply chain disruptions. Process risks involve operational inefficiencies, while reputational risks affect brand image, and system risks relate to outdated technologies (see Table 10).

Operational Risk Analysis

Upstream Risks

Table 11. Upstream Risk

Type of Risk	Code	Risk	Probability	Severity	Score
HR	A12	Fatigue	4	5	20
HR	A14	Demotivation	4	4	16
Environmental	B14	Fertilizer Scarcity	5	4	20
Reputational	D13	Fraud	4	4	16

Note: Only high risks shown for brevity; full table includes moderate and low risks.

Risks were evaluated using Likert-scale surveys, assessing both probability (1 = very unlikely to 5 = very likely) and severity (1 = insignificant to 5 = catastrophic), with the overall risk score calculated as the product of probability and severity. Scores were classified into three categories: high risk (≥16), moderate risk (10–15), and low risk (≤9) as summarized in Table 11. The high-risk category included fatigue (A12; score = 20), demotivation (A14; score = 16), fertilizer scarcity (B14; score = 20), and fraud (D13; score = 16), indicating critical areas requiring immediate attention. Moderate risks encompassed employee strikes (A11; score = 10), workforce skills (A15; score = 12), road damage (B12; score = 12), pests (B13; score = 10), machine damage (C11; score = 12), worker welfare (D12; score = 12), organizational climate (D14; score = 12), and sorting system inefficiencies (E12; score = 12), highlighting additional areas where mitigation measures are necessary to maintain operational stability.

Internal Supply Risks

Table 12. Internal Supply Risk

Type of Risk	Code	Risk	Probability	Severity	Score
Process	C22	Leaves Not Meeting Requirements	4	5	20
Reputational	D24	Management	4	4	16

Table 12 presents the assessment of downstream risks, with high-risk items including leaves not meeting quality requirements (C22; score = 20) and management issues (D24; score = 16), signaling critical areas that demand immediate attention. Moderate risks were identified as failure to properly read systems (A22; score = 12), environmental pollution (B21; score = 12), community disruptions (B22; score = 12), and production of low-quality products (D22; score = 12), indicating additional concerns that require careful monitoring and mitigation to ensure smooth operations and product consistency.

Downstream Risks

Table 13. Downstream Risks

Type of Risk	Code	Risk	Probability	Severity	Score
Environmental	B31	Distribution Costs	4	5	20
Process	C31	Traffic Congestion	4	4	16

Table 13 summarizes the downstream distribution risks, highlighting high-risk factors such as distribution costs (B31; score = 20) and traffic congestion (C31; score = 16), which pose significant threats to timely and cost-effective delivery. Moderate risks include long processing times (B32; score = 12), delivery quality issues (D31; score = 15), fluctuations in selling prices (E31; score = 15), and inventory mismanagement (E32; score = 12), all of which require active management to maintain operational efficiency and market competitiveness.

These findings highlight critical areas requiring immediate attention, such as worker welfare, supply chain logistics, and quality control, which significantly impact productivity.

Operational Risk Response

Specific Risk Mitigation Strategies

The key risks across the tea supply chain at PT XYZ span upstream, internal supply, and downstream operations, each addressed with targeted mitigation strategies. Upstream human resource risks include fatigue (A12), which can be alleviated by providing motorcycle transportation, repairing rocky roads to reduce physical strain, offering meals during picking, and ensuring health and safety insurance. Demotivation (A14) is another priority, mitigated through increased wages or benefits to improve worker satisfaction, with government subsidies for fertilizer or fuel allowing resources to be redirected toward employee welfare.

Environmental risks at the upstream stage, such as fertilizer scarcity (B14), are managed by establishing partnerships with suppliers for timely delivery and prioritizing scheduling to maintain plantation productivity. These measures ensure that plantation operations continue smoothly without disruption from resource shortages.

Internal supply risks, including substandard leaf shoots (C22), are mitigated by implementing strict scheduling to synchronize picking, transportation, and processing, ensuring that tea is processed within four hours to maintain product quality. This careful coordination minimizes quality loss and supports the efficiency of internal operations.

Downstream risks include high distribution costs (B31), which can be managed by anticipating fuel price fluctuations through price forecasting and optimizing warehouse management to reduce expenses. Traffic congestion (C31) is addressed by scheduling deliveries at night, reducing delays and fuel consumption. Additionally, reputational and operational risks, such as fraud (D13), are mitigated through IT-based transaction recording, multi-layered monitoring, and increased security personnel. Management risks (D24) are reduced by selecting leaders based on competency analyses, ensuring visionary leadership and strategic planning skills.

This study has systematically identified and classified operational risks across PT XYZ's tea supply chain using the COSO ERM framework (COSO, 2004), quantified their probability and impact through surveys and FGDs, and proposed mitigation strategies emphasizing government-industry collaboration and technological solutions. High risks like fatigue, fertilizer scarcity, and distribution costs require urgent action to enhance productivity and sustainability. The findings reveal that PT XYZ's tea supply chain faces significant challenges, particularly in worker fatigue and demotivation in plantations, quality control during processing, and costly distribution delays. These risks were assessed using a scoring system, identifying high-priority issues that severely impact productivity.

For example, fatigue results from long, rocky walks during tea picking, while quality issues arise when tea exceeds the 4-hour processing window. Proposed solutions, such as providing worker transportation, strict scheduling, and night deliveries, aim to address these issues practically. Collaboration with the government for subsidies and technology adoption, like IT-based monitoring, can further enhance efficiency, making the supply chain more resilient and productive.

DISCUSSION

Comprehensive Analysis and Implications

This discussion synthesizes the findings from the study on operational risks in PT XYZ's tea supply chain, relating them to the three primary objectives: identifying and classifying risks using the COSO ERM framework (COSO, 2004), quantifying their probability and impact through grounded research and FGDs, and proposing actionable mitigation strategies to enhance productivity, emphasizing collaboration between government and industry and technological solutions. The study's findings offer valuable insights for PT XYZ and the broader agricultural sector, with implications for operational efficiency and sustainability.

Risk Identification, Classification, and Quantification of Risk

This study identified and classified 39 operational risks across the PT XYZ tea supply chain using the COSO ERM framework. A mixed-methods approach (observation, interviews, and FGDs) categorized the risks into five types, with high scores being:

Human resource risks (e.g., fatigue, demotivation) in the upstream stage due to labour-intensive tasks. Generally, tea picking activities use machines that predominantly involve human labour.

The open nature of the environment and the vast plantations result in high levels of fatigue. This is further supported by an inadequate wage system, resulting in decreased picking yields. This situation aligns with previous findings that human resource productivity is influenced by physical health, the wage system, competency, and other factors (Tahir et al., 2024; Udokwu et al., 2023). Human resource fatigue and demotivation in the upstream sector are contributing to decreased tea productivity. This also results in the low quality of the tea harvested. Tea should be processed within four hours of picking to achieve maximum quality. There is a causal relationship between fatigue and demotivation and delays in the tea's transportation to the factory.

Reputational risk is another priority that must be incorporated into the risk management strategy in SCM. A company's reputation is a crucial risk because it is linked to consumer trust (Louisot, 2024). Furthermore, a company's reputation is linked to trust and maintaining its brand as an investment for profitability (Oreshile et al., 2025). This chain of risks in SCM creates a cascade of interconnected risks from upstream to downstream. Fatigue and demotivation among human resources at the plantations can lead to delays in tea leaf delivery, resulting in poor quality, which will negatively impact the company's reputation in the future. This classification aligns with the COSO Event Identification component and reflects the findings of Yuwono and Rachmawati (2023) on SCRM-ERM integration, demonstrating its applicability in an agricultural context.

High-risk factors like picker fatigue and processing delays directly reduced productivity. The methodology aligns with COSO ERM applications in agriculture, enabling targeted mitigation prioritization.

Mitigation Strategies
The third objective was to propose actionable mitigation strategies to enhance productivity, focusing on government-industry collaboration and technological solutions. The study developed tailored strategies for high and moderate risks, as shown in Table 14.

Table 14. Mitigation Strategies

Risk	Stage	Mitigation Strategy	Collaboration/Technology
Fatigue (A12)	Upstream	Provide two-wheeled vehicle transportation, repair roads	Collaboration: Company-funded insurance
Demotivation (A14)	Upstream	Increase wages, provide allowances	Collaboration: Government subsidies for fertilizers/fuel
Fertilizer Scarcity (B14)	Upstream	Establish supplier partnerships, schedule deliveries	Collaboration: Institutional partnerships
Leaves Not Meeting Requirements (C22)	Internal Supply	Implement strict scheduling	Technology: Faster transportation methods
Distribution Costs (B31)	Downstream	Anticipate fuel price fluctuations, optimize logistics	Technology: Night deliveries

Traffic Congestion (C31)	Downstream	Schedule deliveries at night	Technology: Route optimization tools
Fraud (D13)	Upstream	Use IT-based transaction recording, increase security	Technology: Layered monitoring systems
Management (D24)	Internal Supply	Select competent leaders, enhance strategic planning	Technology: Data-driven decision tools

These strategies address root causes while leveraging collaboration and technology. For example, government subsidies for fertilizers could reduce financial burdens, allowing funds to be redirected to worker welfare. Technological solutions, such as IT-based monitoring, enhance transparency and efficiency. The emphasis on collaboration and technology ensures that solutions are both feasible and sustainable, addressing PT XYZ's 28% productivity gap.

Implications for PT XYZ and Beyond
The findings have significant implications for PT XYZ and the broader tea industry. By addressing high-priority risks, PT XYZ could improve productivity, reduce costs, and enhance product quality, strengthening its market position. The study's methodology, combining qualitative and quantitative methods within the COSO ERM framework, offers a replicable model for other agricultural supply chains. Beyond productivity, the proposed strategies contribute to sustainability. Mitigating environmental risks like fertilizer scarcity and pollution aligns with SDG 12 (Responsible Consumption and Production), while improving worker welfare supports SDG 8 (Decent Work and Economic Growth). This dual benefit highlights the role of integrated risk management in modern agriculture, where operational efficiency and sustainability are intertwined.

CONCLUSION

This study provides a comprehensive analysis of operational risks in PT XYZ's tea supply chain, offering practical mitigation strategies that enhance productivity and sustainability. By leveraging the COSO ERM framework and emphasizing collaboration and technology, it contributes to both academic literature and industry practice, paving the way for resilient agricultural supply chains. This study seems to have effectively applied the COSO ERM framework to analyse risks in PT XYZ's tea supply chain. It likely identified 39 risks across plantations, processing, and distribution, classifying them into high, medium, and low categories. High-priority risks, such as worker fatigue and distribution costs, were highlighted for their impact on productivity.

The ERM approach appears to help prioritize risks, allowing PT XYZ to focus on critical issues that hinder efficiency. This structured method supports strategic decision-making to achieve organizational goals.

By implementing strategies like worker transportation, strict scheduling, and IT-based monitoring, PT XYZ could reduce risks and improve efficiency. Collaboration with the government for subsidies may further support these efforts, potentially closing the 28% productivity gap.

LIMITATION

The study has several limitations. Self-reported survey data may introduce bias, as participants might underreport risks due to social desirability. The focus on a single organization limits generalizability to other tea supply chains with different contexts. The dynamic nature of risks, influenced by climate change and market fluctuations, suggests that the risk profile may evolve, requiring ongoing monitoring.

While this study provides valuable insights, several limitations warrant consideration. Self-reported survey data may contain social desirability bias, and the single case focus limits generalizability. Additionally, evolving external factors like climate change necessitate ongoing risk monitoring.

Future research should adopt a multifaceted approach to strengthen operational effectiveness and industry insights. First, longitudinal studies are recommended to evaluate the sustained effectiveness of mitigation strategies over time, allowing researchers to track improvements and identify potential areas for refinement. Second, comparative analyses with other tea producers would help establish industry benchmarks, providing a clearer understanding of best practices and competitive standards. Finally, investigating technological solutions, such as automated sorting systems and IoT-based monitoring, could significantly enhance operational efficiency, ensuring that processes are both scalable and optimized for precision. Together, these avenues offer a comprehensive framework for advancing research and practical applications in the tea industry.

This study's application of the COSO ERM framework offers both academic and practical contributions, enabling PT XYZ to prioritize high-impact risks while improving productivity and competitiveness. The findings serve as a foundation for developing more resilient tea supply chains through targeted risk management strategies.

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DECLARATION OF CONFLICTING INTERESTS

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article. This work was conducted solely for academic purposes to advance knowledge in SCRM and production optimization.

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