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Risk Management Analysis and Business Development Strategies for Cage Aquaculture in Tomini Bay

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A B S T R A C T

Tomini Bay holds tremendous potential for the development of marine fish farming, particularly through the environmentally friendly and economically valuable Floating Net Cage (FNC) system. This study aims to analyze risk management and formulate development strategies for a fish farming business based on the Teaching Factory (TeFa) model at SMKN 1 Popayato, serving as an integrated vocational education model aligned with industry needs. A qualitative descriptive approach was employed, with data collected through observation, in-depth interviews, and questionnaires. The data were analyzed using SWOT analysis and a risk matrix. The results indicate that most identified risks fall into the moderate category, with one operational risk classified as high. Risk management strategies were implemented through mitigation and risk-sharing approaches, including competency-based training, human resource capacity building, partnerships with industry stakeholders, and adaptive cultivation practices in response to environmental changes. The study recommends enhancing human resource competencies and strengthening partnerships as key strategic actions to ensure the sustainability of the TeFa FNC business. These findings are expected to serve as a valuable reference for the development of productive vocational education units in the fisheries sector.

1. INTRODUCTION

Tomini Bay holds significant potential in terms of natural resources, one of which is the mangrove forest along the Torosiaje coast. The existence of mangrove forests provides substantial benefits for the livelihoods of local communities, particularly because the majority of the population depends on fishing as their primary source of income. The mangrove ecosystem in Torosiaje plays a critical role as a protective buffer for both marine biodiversity and the surrounding human settlements.

In addition, Tomini Bay also presents vast potential for the development of aquaculture through floating net cage systems (Keramba Jaring Apung or KJA). This fish farming practice has become one of the main sectors within Indonesia's fisheries industry, contributing significantly to both local and national economies. However, as with any business activity, aquaculture using KJA systems entails a variety of risks that must be effectively managed. These include production risks, market or price volatility, technological uncertainties, temperature fluctuations, as well as threats from pests and diseases (Selvia, 2021).

Risk management analysis can be applied across all types of business organizations, including micro, small, and medium enterprises (MSMEs). Risk management is crucial as it prepares MSMEs to deal with unpredictable circumstances. Therefore, it is essential to assess the risks faced by MSMEs, particularly through the use of SWOT analysis. Several studies related to business risk management (Sajjad et al., 2020) emphasize the role of risk management in assisting MSMEs in maintaining business operations (Sajjad et al., 2020), and in determining marketing and sales strategies. This study applies SWOT analysis within the context of risk management (Benzaghta et al., 2021), stressing that SWOT not only aids in planning risk mitigation strategies but also in identifying market opportunities in the face of uncertainty (Teoli et al., 2023).

SWOT analysis is a method used to systematically identify a company's strengths, weaknesses, opportunities, and threats in order to develop appropriate strategies (Jesslyn et al., 2022). This analysis is based on the logic of simultaneously enhancing strengths and opportunities while minimizing weaknesses and threats. The use of SWOT analysis is advantageous as it serves as an effective tool for examining the challenges and dangers a business might encounter.

Risk management in aquaculture has become increasingly vital due to the dynamic nature of marine environments, with threats such as climate change, pollution, fish diseases, and other external factors that could impact production success. Therefore, risk management analysis is key to ensuring the continuity and sustainability of fish farming operations in the Torosiaje coastal area of Tomini Bay.

One of the aquaculture actors using the KJA system is the Teaching Factory (TeFa) at SMKN

1 Popayato. The TeFa concept, as an approach in vocational education, emphasizes real production-based learning, where students not only acquire technical skills but also gain hands-on experience in business risk management. This learning model integrates an industrial work environment into the educational institution, enabling students to learn in settings that closely resemble actual workplace conditions.

In this study, risk management analysis becomes essential to gain a better understanding of the various risks faced by KJA aquaculture practitioners in Tomini Bay. With a comprehensive understanding of these risks, effective mitigation strategies can be designed and implemented to reduce their negative impact on production and business sustainability.

The objective of this paper is to develop strategic alternatives for the advancement of aquaculture using the SWOT analysis approach, as well as to conduct an in-depth analysis of risk management in floating net cage aquaculture at TeFa SMKN 1 Popayato. Unlike previous studies that typically focused solely on technical aspects of aquaculture or general SWOT analysis, this study integrates a comprehensive risk management approach within the context of TeFa as a vocational education model. Through this approach, it is expected that specific risks can be clearly identified, assessed, and effectively addressed, thereby enhancing the resilience and success of aquaculture enterprises.

RESEARCH METHODS

Data collection. Data collection was conducted through interviews and observations. The interview stage aimed to obtain information regarding conditions, issues, and sources of risk occurring in the Teaching Factory (TeFa) of Floating Net Cages (Keramba Jaring Apung/KJA) at SMKN 1 Popayato. A structured questionnaire was administered to relevant stakeholders, including TeFa KJA managers, the school principal, vice principals, teachers, supervisors, and industry partners.

Meanwhile, the observation phase was carried out to assess the surrounding conditions of the research object, identify the environment, and categorize findings into Strengths, Weaknesses, Opportunities, and Threats (SWOT). The SWOT analysis was then used to evaluate the risk matrix. Overall, the problem-solving process can be illustrated in the research flowchart in Figure 1.

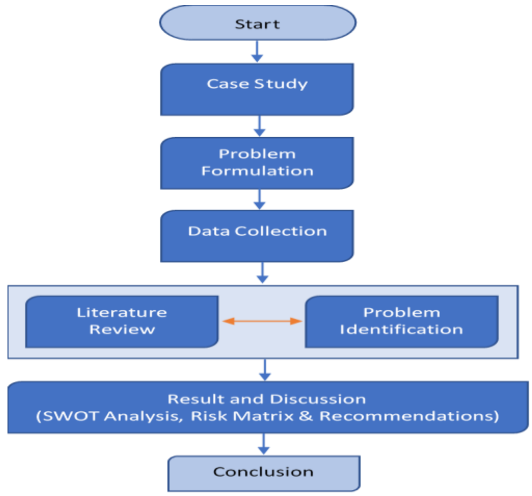

Figure 1. Research Flowchart

This study began with the identification of the research object, located at the TeFa Floating Net Cage (KJA) in Tomini Bay, Popayato District, Pohuwato Regency. The next step involved problem formulation based on the actual conditio SWOT Matrix

The SWOT matrix is a component of SWOT analysis that involves identifying strengths, weaknesses, opportunities, and threats based on the data collected (Hardana & Syafruddin, 2019). The matrix is essential for formulating four types of strategies: S-O (Strengths-Opportunities), W-O (Weaknesses-Opportunities), S-T (Strengths-Threats), and W-T (Weaknesses-Threats). The SWOT matrix is presented in Table 1.

NS and challenges faced at the TeFa KJA site. Using SWOT analysis and risk matrix assessment, data collection was conducted through interviews, discussions, and observations, supported by a literature review to strengthen the theoretical foundation of the study. Interviews were guided by a set of questions, and the responses were later analyzed using SWOT and risk matrix methodologies. Based on the analytical outcomes, strategic recommendations were formulated to address the specific constraints encountered in the TeFa KJA operations.

SWOT Matrix. The SWOT matrix is a component of SWOT analysis that involves identifying strengths, weaknesses, opportunities, and threats based on the data collected (Hardana & Syafruddin, 2019). The matrix is essential for formulating four types of strategies: S-O (Strengths-Opportunities), W-O (Weaknesses-Opportunities), S-T (Strengths-Threats), and W-T (Weaknesses-Threats). The SWOT matrix is presented in Table 1.

Tabel 1. SWOT Matrix

Internal External	Strength	Weakness
Opportunity	S-O Strategy	W-O Strategy
Threaths	S-T Strategy	W-T Strategy

Source:David (2004)

The descriptions of the four strategies in the SWOT matrix are as follows:

a) S-O Strategy: Leveraging internal strengths to seize external opportunities.

b) W-O Strategy: Reducing internal weaknesses by capitalizing on external opportunities.

c) S-T Strategy: Utilizing internal strengths to avoid or mitigate external threats.

d) W-T Strategy: Defensive tactics aimed at minimizing internal weaknesses while avoiding external threats.

Risk Management Process. Risk management can be defined as a proactive effort to recognize and manage internal events and external threats that may affect the success of an organization (Prayudi & Yulistria, 2020). Through risk management, potential risk events can be identified. Once identified, the consequences of each event can be assessed, allowing for the mitigation of potential impacts (Malihah et al., 2021).

Risk management activities are conducted before risks occur, making it a preventive action that includes creating a contingency plan to be implemented should risks arise, in order to reduce negative impacts on organizational sustainability (Qintharah, 2019). The general stages of the risk management process are illustrated in Figure 2.

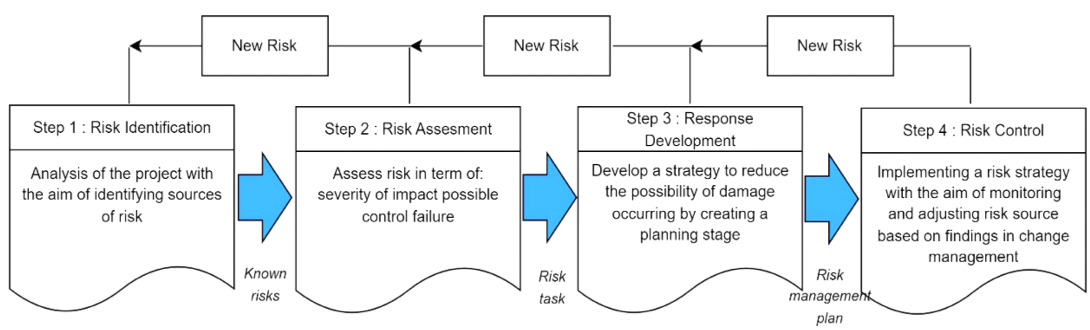

Figure 2. Risk Management Process

Source: Qintharah (2019)

1) Risk Identification. This stage involves identifying what, why, and how various factors contribute to the emergence of risks and determining the sources of those risks. Several methods can be used in this stage, including brainstorming, checklists, SWOT analysis, Risk Breakdown Structure (RBS), root cause analysis, Delphi method, and interviews (Alifiana & Susanti, 2018; Sari et al., 2017).

2) Risk Assessment. Risk assessment involves determining the level of probability, consequences, and the difficulty of detecting the risks. This assessment can be carried out either quantitatively or qualitatively. Afterward, risks are prioritized for management according to their assessed severity and likelihood (Jikrillah et al., 2021).

3) Developing a Risk Response Plan. Based on the risk assessment, potential risks and their impacts can be identified (Awaloedin et al., 2022; Bahari et al., 2018). Risk responses may include: Elimination: Removing all possible causes of loss, Minimization: Reducing the severity or likelihood of risk occurrence, Retention: Accepting the risk and bearing the consequences, Transfer: Shifting the risk to a third party, such as an insurance company.

4) Risk Control. Risk control occurs through change management processes. If new risks are identified, the cycle may return to the initial stages. This stage also includes continuous monitoring and reviewing of the risk management system and identifying necessary adjustments. Risk management can be applied at all organizational levels—strategic, operational, or even specific projects—to support decision-making or manage region-specific risks (Setiawan et al., 2022).

Risk criteria are derived from a combination of probability and severity levels Kerzner (2017). To determine probability levels, Figure 3 can be used. Severity levels, used to assess the impact of activities, can be referenced in Figure 4.

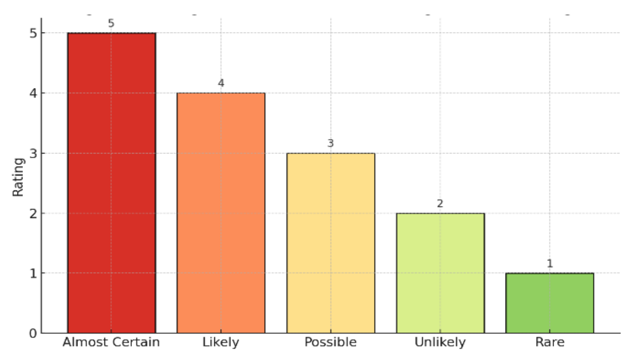

Figure 3. Risk Probability Scale
Source: Kerzner (2017)

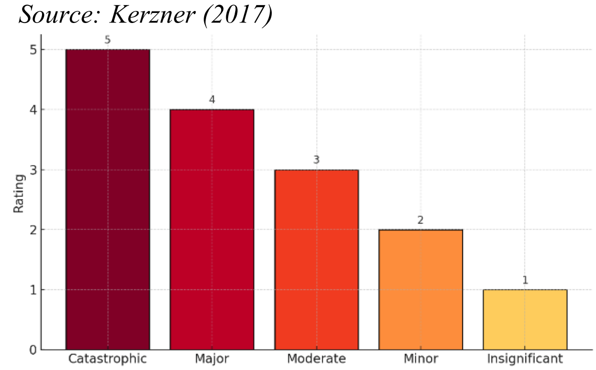

Figure 4. Risk Severity Scale

Source: Kerzner (2017)

Subsequently, risk assessment and analysis are carried out to determine the risk magnitude. Risk is formulated as a function of likelihood and impact. Thus, the risk index = likelihood × impact (Soputan et al.,2014).

Risk analysis is conducted to evaluate risk magnitude by considering both its severity and probability. This is visualized using a Risk Matrix, as shown in Figure 5.

Likelihood / Severity	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Rare (1)	Low (1x1)	Low (1x2)	Low (1x3)	Low (1x4)	Medium (1x5)
Unlikely (2)	Low (2x1)	Low (2x2)	Medium (2x3)	Medium (2x4)	High (2x5)
Possible (3)	Low (3x1)	Medium (3x2)	Medium (3x3)	High (3x4)	High (3x5)
Likely (4)	Low (4x1)	Medium (4x2)	High (4x3)	High (4x4)	Very High (4x5)
Almost Certain (5)	Medium (5x1)	High (5x2)	High (5x3)	Very High (5x4)	Very High (5x5)
Adapted from the AS/NZ 4360 Standard Risk Matrix and NHS QIS Risk Matrix					

Figure 5. Risk Matrix: Severity vs. Likelihood

Source: Ramli (2011)

To determine or assign the risk level, the risk score is calculated and categorized based on the classification provided in Table 2:

Table 2. Risk Level Scale

Risk Rank	Description	Color
17-25	Very High Risk	Red
10-16	High Risk	Brown
5-9	Medium Risk	Yellow
1-4	Low Risk	Green

Source: Ramli (2011)

2. RESULTS & DISCUSSION

As an innovative effort in the development of a Teaching Factory (TeFa) in the marine and fisheries sector, SMKN 1 Popayato has optimized local potential through fish farming using the Floating Net Cage (Keramba Jaring Apung/KJA) system. Located on the coast of Tomini Bay, this area offers highly supportive water conditions—from temperature and salinity to water quality—for the growth of snapper, grouper, and milkfish. This KJA-based TeFa initiative not only enriches industry-based learning but also serves as a strategic solution to increase fish production efficiently and sustainably. The KJA system enables better environmental control, more efficient feeding, and results in higher-quality harvests.

The *Aquaculture Agribusiness in Brackish and Marine Water* program, implemented through TeFa KJA, provides real-world learning experiences for students. They are equipped not only with technical skills but also with training to manage aquaculture operations professionally, producing market-ready products. Based on observations, the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the TeFa KJA at SMKN 1 Popayato is presented in Table 3.

Table 3. SWOT Matrix of TeFa KJA at SMKN 1 Popayato

Internal / Eksternal	**Strength**	**Weakness**
	a) The facilities and infrastructure for practical work at TeFa KJA are already available and sufficient. b) The location of TeFa KJA, in relation to SMKN 1 Popayato, can be reached by foot and boat, with a distance of approximately 1 km. c) The products or fish harvest from TeFa KJA have already provided benefits to the community.	a) Knowledge and procedures related to Occupational Health and Safety (OHS) at TeFa KJA have not yet been fully understood by students and relevant teachers. b) The management of TeFa KJA has not yet become an independent business unit and is still under the responsibility of the Fisheries Agribusiness program in brackish and marine aquaculture; performance and human resources are still not optimal. c) The availability and supply of fish feed are still limited.
Opportunity a) The distance between TeFa KJA and the settlement, community, and marketing areas is relatively close, only separated by mangrove forests. b) Government support (from the Marine and Brackish Water Aquaculture Fisheries Center - BPBLP) provides fish seed assistance. c) Partnerships and collaboration with the Business and Industrial World (DUDI) in the supply of feed and operational monitoring of TeFa KJA.	**S-O Strategy** **1)** Optimizing aquaculture practices and marketing of results. **2)** Partnership with DUDI and local government.	**W-O Strategy** 1) Improving human resources competence and collaboration between TeFa KJA and various DUDI parties or partners. 2) Transforming TeFa KJA into an independent business unit. 3) Diversifying feed and fostering aquaculture independence.
Threaths a) High levels of juvenile delinquency, which encourage theft. b) During the rainy season or climate changes, there could be a decline in water quality in Tomini Bay.	**S-T Strategy** 1) Enhancing security and monitoring systems at TeFa KJA. 2) Risk management for climate change impacts. 3) Establishing rules and social sanctions.	**W-T Strategy** 1) Strengthening governance at TeFa KJA. 2) Socialization and mentoring. 3) Strengthening the network of fish suppliers.

Based on the observations, discussions, and SWOT analysis of the current condition of TeFa KJA at SMKN 1 Popayato (Table 3), a total of 11 alternative strategies were identified: 2 S-O strategies, 3 W-O strategies, 3 S-T strategies, and 3 W-T strategies. One recommended alternative for the development of the KJA fish farming business is the strategy: "Improving HR competencies and collaboration between TeFa KJA and various industry partners (DUDI or others)", as it aligns with both internal weaknesses and external opportunities, as well as the school's ongoing programs.

The risk assessment for TeFa KJA SMKN 1 Popayato was conducted using a risk matrix derived from the probability and consequence values of each risk source. The risk mapping matrix is categorized by frequency into: rare, unlikely, likely, and almost certain. The consequence aspect is categorized into: minor, moderate, major, severe, and catastrophic. The results of the evaluation based on the risk matrix—frequency of occurrence and impact—are illustrated in Figure 5.

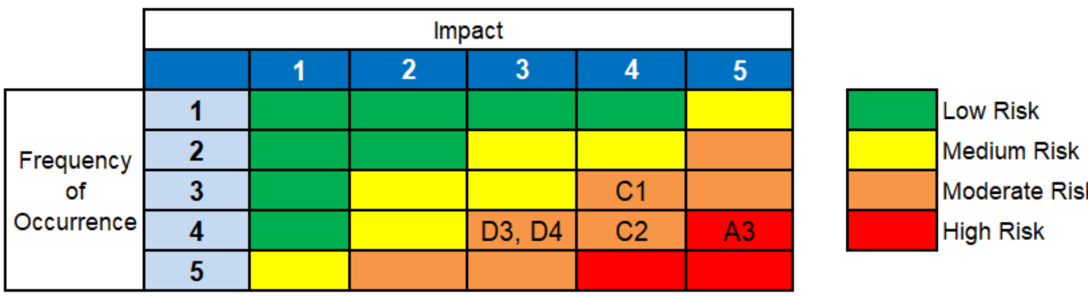

Figure 5. Risk Matrix – Frequency and Impact

Source:Ramli (2011)

The risk assessment for each part or aspect of the aquaculture business can be seen in the matrix cells, which contain various codes. Code A3 refers to the *operational* aspect, codes C1 and C2 represent the *human resource* aspect, and codes D3 and D4 refer to the *environmental* aspect. All codes within this matrix are located in the moderate risk zone (brown zone), making these areas the primary focus for improvement and strengthening of management at TeFa KJA SMKN 1 Popayato.

To determine risk treatments, the process begins by identifying the root causes of issues at TeFa KJA SMKN 1 Popayato. Based on SWOT analysis and risk identification, the risk treatment strategy involves risk mitigation, or reducing the impact of the identified risks. A contingency plan approach is used to find solutions for the risks, as presented in Table 4.

Table 4. A contingency plan approach is used to find solutions for the risks

Risk Type	Code	Risk	Strategy	Strategy Description
High	A3	Operational: Limited availability of fish feed	Risk Sharing	a) Participate in training provided by local government agencies on fish feed production b) Build partnerships with alternative feed suppliers and universities through community service programs

Moderate	C1	Human Resources: Inadequate understanding of OHS (Occupational Health and Safety) procedures among students and teachers	Risk Mitigation	Engage actively in socialization and training programs on OHS in the KJA aquaculture system
Moderate	C2	Human Resources: Low performance in TeFa KJA management	Risk Mitigation	a) Leadership provides guidance and regular evaluations through periodic reports b) b) Provide rewards and supporting costs for TeFa KJA activities
Moderate	D3	Environmental: Youth delinquency and theft potential	Risk Mitigation	Create a security shift schedule outside operational hours to improve facility safety
Moderate	D4	Environmental: Location in bay area – seasonal or weather changes affecting water quality	Risk Mitigation	Adjust cultivation patterns and harvest timing based on seasonal cycles and water condition changes

Risk Analysis of TeFa KJA SMKN 1 Popayato. Based on the mapping results using the risk matrix, it is identified that the Teaching Factory of Floating Net Cage (TeFa KJA) at SMKN 1 Popayato faces several potential risks across operational, human resource, and environmental aspects. The matrix combines two main indicators: the likelihood of risk occurrence and the level of consequence. From the assessment, most risks fall under the moderate risk zone, represented by the brown area on the matrix. Risks in this category indicate a reasonably significant threat to operational continuity if not properly addressed. The only high-risk area identified is in the operational aspect (code A3), particularly regarding the limited availability of fish feed. Meanwhile, risks related to human resources (codes C1 and C2) and environmental aspects (codes D3 and D4) fall within the moderate category. While not considered extreme, these risks may undermine the effectiveness of the production-based learning program and the sustainability of the aquaculture activity if left unmitigated.

Risk Mitigation Strategies. In response to the risk findings, TeFa KJA SMKN 1 Popayato employs two main risk treatment approaches: risk mitigation and risk sharing. These strategies are formulated based on SWOT analysis and the identification of root causes for each risk aspect.

- For the operational risk (A3), a risk sharing strategy is implemented through participation in training programs provided by local authorities on fish feed production and establishing partnerships with alternative feed suppliers and higher education institutions. This approach aims to enhance internal capacity while fostering external collaboration as part of a diversified solution framework.
- For human resource risks (C1 and C2), a risk mitigation strategy is applied in two ways:
  a) To improve understanding of Occupational Health and Safety (OHS) practices in aquaculture, regular socialization and training sessions are conducted.

b) To enhance management performance in TeFa activities, school leadership provides periodic guidance, a structured reporting system, and performance-based incentives.

- For environmental risks (D3 and D4), mitigation efforts focus on strengthening environmental security through scheduled guard shifts and adapting cultivation patterns to seasonal weather and harvest cycles. This approach is expected to minimize potential losses caused by uncontrollable external factors.

Limitations of this study include the lack of in-depth exploration of internal dynamics such as school organizational culture, budget constraints, and teacher readiness. The descriptive approach used—based on frequency and impact—provides a limited scope. Nonetheless, the risk sharing and mitigation strategies implemented through training and partnership synergies have proven effective in the local context. However, generalizing these strategies to other vocational schools in coastal areas requires further validation, particularly by considering differences in geographic, social, and institutional characteristics.

Managerial Implications. The findings and strategic responses in this study yield several critical managerial implications for both TeFa KJA managers and vocational education institutions more broadly:

1. Periodic risk mapping is essential to detect changes in both internal and external dynamics.
2. It is necessary to strengthen risk management capacity, including training for human resources, the development of standard operating procedures (SOPs), and the integration of monitoring and evaluation systems.
3. Risk handling strategies should be not only reactive but also proactive and data-driven.
4. Collaboration with external stakeholders—such as local governments, service providers, and higher education institutions—represents a strategic step in building a sustainable support ecosystem.
5. Successful risk management at TeFa KJA can serve as a replicable model for similar units, both in other vocational high schools and in the development of teaching factories at other levels of vocational education.

Thus, effective risk management becomes a crucial instrument in supporting the quality achievement of vocational education that is adaptive, productive, and responsive to real-world challenges.

3. CONCLUSION & SUGGESTION

The development of aquaculture through the Teaching Factory (TeFa) model of Floating Net Cages (KJA) at SMKN 1 Popayato has produced eleven strategic alternatives. Among these, the most relevant and promising strategies include enhancing human resource (HR) competencies and strengthening collaboration between TeFa KJA and the business and industry sectors (DUDI) as well as external partners. These strategies align with the school's program direction and serve as the foundation for building an adaptive and competitive vocational learning ecosystem.

Risk matrix analysis, based on the frequency of occurrence and its impact, reveals that the highest risk lies within operational aspects, while moderate risks are associated with human resources and environmental conditions. Therefore, risk management cannot rely on conventional approaches; instead, it requires careful and collaborative strategies. The risk sharing approach is implemented through continuous training and partnership synergy, particularly in feed supply and fish disease control. Meanwhile, mitigation strategies focus on strengthening the management structure and consistently executing the main duties and functions of TeFa in a disciplined manner.

More than just a learning project, TeFa KJA at SMKN 1 Popayato has become a real platform for nurturing vocational youth who are resilient, skilled, and capable of creating local potential-based solutions. The implemented strategies are not solely intended to manage risks, but also serve as a foundation for building a sustainable, inclusive, and highly competitive fisheries sector in coastal areas.

The strategies applied by TeFa KJA SMKN 1 Popayato can be adopted by other vocational schools, particularly those located in coastal regions or those with fishery expertise programs. However, adoption must be tailored to local contexts, especially in developing partnerships and conducting training that addresses specific regional challenges. To strengthen the foundation of these strategies, it is recommended to conduct quantitative studies to measure the effectiveness of risk mitigation efforts. Such studies may employ performance indicators such as productivity, cost efficiency, and the success rate of risk control, thereby providing an empirical basis for evaluating and expanding the implementation of the Teaching Factory model in aquaculture ventures on a national scale.

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research will contribute meaningfully to the strengthening of vocational education in the field of marine and fisheries, and serve as inspiration for the development of school-based business units in other regions.

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