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Risk Analysis of Supply Chain Food Loss on Fishery Products Using Failure Mode Effect and Supply Chain Operation Reference Model

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ABSTRACT

One of the Sustainable Development Goals (SDGs) currently rife is Global Food Loss and Waste. This Food Loss and Food Waste (FLFW) harms the environmental and economic sectors. FLFW occurs a lot in the food supply chain, especially in the fishery product. There are potential risks in each process for each stakeholder. So this study tries to prioritize FLFW reduction actions by using the integration of risk measurement and the supply chain operation reference model (SCOR). Risk management is carried out to identify and prioritize FLFW risks. The actor analysis identify the characteristic of the actors such as their needs, problems, and characters. Data selection used the purposive technique. The data were collected by investigators through depth interviews. The result of this method is a risk analysis metric to find out the critical risks. It wasexpected to be considerations to develop policy recommendations in reducing the level of FLFW in the fishery supply chain using SCOR and risk analysis (FMEA). We found that the highest risk for fishers is Poor quality of cold storage after fishing (R3); the highest risks for collectors are Poor quality of cold storage (R5) and Long storage time (R7); The highest risk for The tuna processing company is Unclean cold storage (R16).

Keywords: FMEA, Risk Identification, SCOR, Supply Chain Management, Perishable Product

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1. INTRODUCTION

Food loss and food waste are global problems that impact social, economic, and environmental life (Moult *et al.*, 2018). The most significant contributors to Food Loss globally are developing countries, one of which is Indonesia. Indonesians waste an average of 300 kilograms of food per person every year despite poverty and malnutrition (TRTWorld, 2018). FLFW occurs along the supply chain from suppliers to final consumers, dominated by households.

As a maritime country, Indonesia is one of the largest marine product-producing countries in the world. South Sulawesi, especially in Makassar, is Indonesia's largest supplier of fishery products. Its very strategic location and geographical conditions make the supply of marine products very high, making Indonesia as one of the largest exporters of marine products in Indonesia. According to FAO (2018), the global food loss rate for fishery products is 35%. Marine products are products that are classified as fresh products. Fresh products are bulky and perishable. The longer the time, the more prone to damage (Gokarn and Kuthambalayan, 2017).

Study report by BAPPENAS (2021) in show that the pattern of the rate of the number of supply chain FLFW in

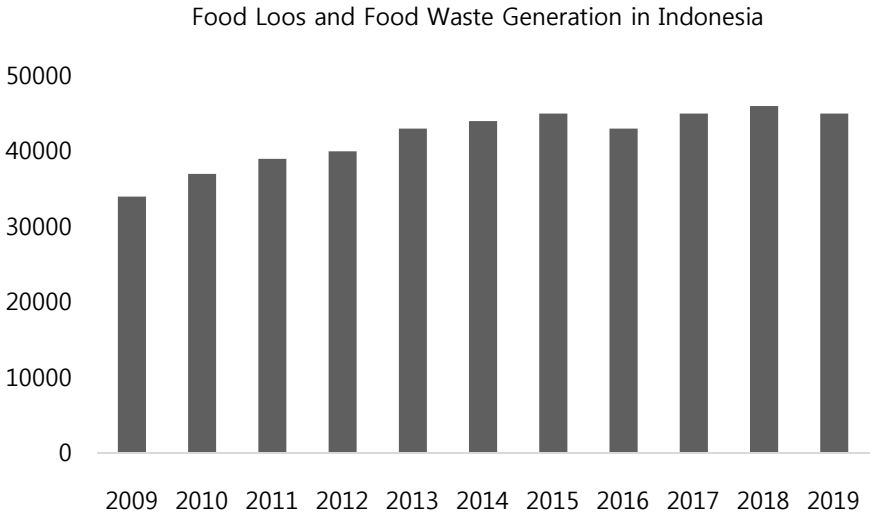

Figure 1. Food Loss and Food Waste Generation in Indonesia 2009-2019.

Indonesia tends to increase every year as shown in Figure 1. Bappenas (2021) show that number of FLFW of fish product is 29.9%. It can increase the risk of disruption to the supply chain. One of the disruptions or risks that has occurred recently can be seen in the supply chain of perishable products (Deng *et al.*, 2019).

Tuna is a marine product that is widely exported and is Indonesia's flagship product. According to FAO (2016), there are 7.7 million metric tons of tuna and tuna-like species caught worldwide. Indonesia succeeded in supplying more than 16% of the world's total production, with the average production of tuna, skipjack, and tuna in Indonesia reaching more than 1.2 million tons/year. Meanwhile, Indonesia's tuna export volume reached 198,131 tons with 569.99 million USD in 2017. The flow of tuna products from fishers to consumers is quite long because tuna is the most frequently exported product. So this research tried to examine tuna as a representative of marine products that are very potent in terms of business.

Supply chain risk occurs because of uncertainty that positively impacts the economy (Rostamzadeh *et al.*, 2018). The longer the supply chain structure, the higher the potential risks. Furthermore, supply chain risk for the perishable product also potentially increases because of the characteristics of this product that are easy to be bruised. So as the risks can occur in every process in every chain. The risk in each process has a different priority scale, so it is necessary to have a risk associated with determining which risk plays the most role in the whole system. There are several parameters in measuring success or failure. Parameters of cost, time, people, machines, and quality of goods play a critical role in the magnitude of a process or system (Rezaee *et al.*, 2018). This parameter can be described by the Supply Chain Operation Reference Model (SCOR) which can describe the process by those parameters in the whole system. Risk identification also should be conducted that involve all relevant stakeholders to identify the concerns of all stakeholders (Heckmann *et al.*, 2015; Chairany *et al.*, 2022). The next step after risk identification and multi actor analysis is risk assessment. One of the methods used for risk assessment is Failure Mode and Effect Analysis (FMEA).

FMEA is a technique used to achieve several proposals, such as identifying defects and failures in the system and their causes, evaluating their effects on system performance, and determining ways to decrease the chances of occurrence and the effects (Dong and Cooper, 2016). Several previous studies have discussed FMEA in the food industry. Arvanitoyannis and Varzakas (2008) used FMEA to evaluate salmon processing and packaging risks. In 2013, Mariajayaprakash and Senthilvelan (2013) used FMEA and the Taguchi method to determine the failure of sugar commodities. In their study, Deng *et al.* (2019) identified and measured the risk of perishable products, namely yogurt products.

Application of the SCOR method on supply chain management provides process observation and measurement supply chain as a whole. Risk assessment and mitigation in the supply chain requires process information consisting of make-deliver-process-return throughout the supply chain (Saroyo and Aulia, 2020). SCOR assists researchers in establishing a risk framework in the supply chain. The use of FMEA-SCOR integration is still rarely found in the food industry, especially for fishery products. So this research will discuss supply chain risk analysis on fishery products using FMEA and SCOR integration.

Considering the phenomenon of increasing food waste in the world in general and in Indonesia, in particular, every year, this study tries to analyze the causes of food loss and food waste. This study tries to analyze the

potential risks in the supply chain of fishery products using the FMEA and SCOR integration.

2. LITERATURE REVIEW

Risk management in the supply chain is a system approach that is carried out in the supply chain structure with the aim of mitigating risks in the supply chain. Risks that arise in supply chain activities include; scheduling, technology, and costs are uncertain. They can be managed separately based on the critical of those risks. The increased risk is primarily due to the complexity of the network (Pujawan and Geraldin, 2009). Today, the global business environment is affected by unstable finances, timely outsourcing, company mergers, new technologies, e-business, shorter time to market, etc. This forces organizations to adopt new ways of doing business. However, supply chains that are simpler but with longer processing times are often more vulnerable to the risk of operational and external disruptions (natural and artificial). This vulnerability is defined as exposure to severe disruptions arising from an internal supply chain or external supply chain risks (Ghadge *et al.*, 2012).

Perishable products are easily damaged, have a short shelf life, and the value can decrease regularly over time due to damage, failure, or evaporation. Perishable products tend to rot and spoil during transportation and storage, so their supply chain problems are more complex, uncertain, and vulnerable. Perishable products or products that are easily damaged have a fairly complex supply chain, strict time requirements, and are highly dependent on the environment (Deng *et al.*, 2019). Perishable food, according to Shukla and Jharkharia (2013) in Prakash *et al.* (2017) described as food that easily deteriorate or rot over time. Examples of perishable foods are fish, meat, milk, eggs, fruits, flowers, and vegetables. The risk of perishable products has the potential to result in food loss.

According to Goh *et al.* (2007), risks in perishable products can be classified into risks that arise from within the supply chain network and risks outside of it. After knowing the various types of risks in perishable products, risk management is carried out to identify risks and analyze the risk in order to reduce the risk of food loss along the supply chain.

Food loss risk cases increase every year and require risk management to mitigate potential food loss risks. Several risk management methods can be used. Risk can be measured based on the likelihood of it happening (severity) and its consequences (consequences). Risk can be measured and assessed to reduce or eliminate risk. Measurement or risk assessment should consist of identifying hazards, evaluating preventive safety measures and their functions, estimating exposure to hazards, and evaluating consequences (Modarres, 2006).

The first steps in risk management is risk identification. Risk identification is defined by mapping the characteristics and sources of risk that trigger the efficiency and effectiveness of the performance of a process. After the risk is identified, an assessment is carried out to measure the consequences and opportunities of a risk. The final step is to conduct a risk evaluation to manage and control the results of recommended solutions to the work process (Nasution *et al.*, 2014). One of the benefits of identifying risk is that the potential risk can be reduced. Identifying risk followed by taking appropriate and proactive steps in carrying out risk management can identify various types of existing and future risks in a structured and detailed manner. Risk identification consists of several steps starting from determining the subject under consideration and collecting information in the form of known risks and previously unknown risks that can be identified. Subsequently, a more detailed analysis can be initiated and carried out (Klöber-Koch *et al.*, 2018).

Research related to Food Loss and risk is limited to the literature review and also the processing secondary data obtained from NGOs and related government agencies. Previous studies have mainly used Factor analysis, Life Cycle Assessment, Optimization, and more, only in literature reviews. It is still rare for anyone to discuss the potential risk of food loss in the food supply chain. Uncertainty in the supply chain triggers risk in every process. The risk is defined as the chance that reality does not match expectations that causing loss (Huang, 2008). The main factors for the emergence of risk in the supply chain are complex networks, dependence on suppliers, the life cycle of a product (generally perishable products have a high risk), and how the interaction between stakeholders in processing and solving problems (Waters, 2011).

The food supply chain with perishable products and materials and potential FLFW certainly has a high enough risk. However, this has not been studied in previous studies. Rostamzadeh *et al.* (2018) examine supply chain risk and its relationship to the chemical industry's sustainability issues using a sustainable supply chain-risk management approach. In this case, Deng *et al.* (2019) discuss risk management strategies for perishable products, namely yogurt products. This study examines risk management with its relation to sustainability in general but not explicitly to the realm of FLFW. Deng *et al.* (2019) developed the TROPOS GOAL-RISK model for yogurt products. Ali *et al.* (2019) designed a framework to evaluate risks in the food supply chain to reduce food waste. In the literature on SCRM, some methods are used by researchers to examine risk, for example, failure effect analysis (FMEA) using a risk priority number (RPN) (Prakash *et al.*, 2017). In a study, Prakash *et al.* (2017) tried to analyze risk with risk ranking methods and risk mitigation, referring to the International Safety Management (ISM) for perishable products in the form of milk.

In 2013, Mariajayaprakash and Senthilvelan (2013) used FMEA and the Taguchi method to discover the failure of sugar commodities. Purwaditya *et al.* (2019) also discussed the risk of perishable products, namely fish, using the house of risk (HOR) method regarding supply chain mapping using SCOR. The results they get are risk mitigation strategies. In addition, Wahyudin and Santoso (2016) also use HOR to identify risks in the development of yogurt products. They found 20 potential risks from 27 identified risk agents. The results of the risk identification are used to find the best risk mitigation. Looking at reviews of previous studies, they only focus on overall risk without considering the sustainability aspect and the potential risk of food loss that can be caused by errors that occur in input, process, and output.

Several previous studies also discuss the risk of food loss in the food supply chain. Ali *et al.* (2019) build a framework for food supply chain risks related to risks of food wastage. The study used Pareto analysis to identify the risks of 130 food companies. Brancoli *et al.* (2019) also discuss food loss in bakery products in retail companies. But only in the form of a literature review. The risk of wasted food has also been discussed by Putri (2019); the study uses HOR to identify risks to MSMEs in Roti. Anggrahini *et al.* (2015) also analyzed the quality risk of frozen shrimp products using SCOR and HOR. SCOR is a tool for mapping activities on existing processes company. The reason for using the score method because this method can measure performance supply chain objectively based on existing data and can get subjective data which improvements need to be made. However, the FMEA-SCOR integration is still rarely used, especially to assess the risk of the food supply chain which is the focus of this research. Even though it is known that FMEA is one of the effective methods for finding critical risks. So, this study uses FMEA and SCOR to assess risks in the food supply chain.

This study tries to examine the risk of food loss in the fish supply chain, which is known to be a perishable product. This study uses the FMEA method to identify risks and get the highest value based on the RPN value. This study also conducts supply chain risk mapping based on the SCOR approach, which has been widely used in previous studies.

3. METHOD

This research study focused on analyzing risk based on product quality in the supply chain of fishery products, a case study at Tuna Processing Company in Makassar, Indonesia. The focus of this research is frozen loin tuna. Data collection begins with identifying the outbound logistics of the tuna industry supply chain, which consists of tuna processing and shipping and distribution of tuna for export and local. After that, the identification of stakeholders involved in the outbound logistics of the tuna industry will be carried out in the company's supply chain. The data collection process was carried out by conducting discussions and distributing questionnaires to various stakeholders related to risks in the tuna supply chain. The sample selection process used a purposive method as shown in Appendix 1.

This study uses FMEA to analyze potential risks that occur along the supply chain. The validation of the FMEA framework is carried out through a comparison of research results using gap analysis and qualitative research from expert judgment. Stakeholders made judgments on the FMEA framework as empirical validation. The research stages are carried out starting from the research concept formulation stage, the supply chain configuration analysis, the pre-risk analysis stage, the process using SCOR, and the risk analysis and prioritization stage using FMEA. Figure 2, adapted from Chairany *et al.* (2022), shows the conceptualization of this research.

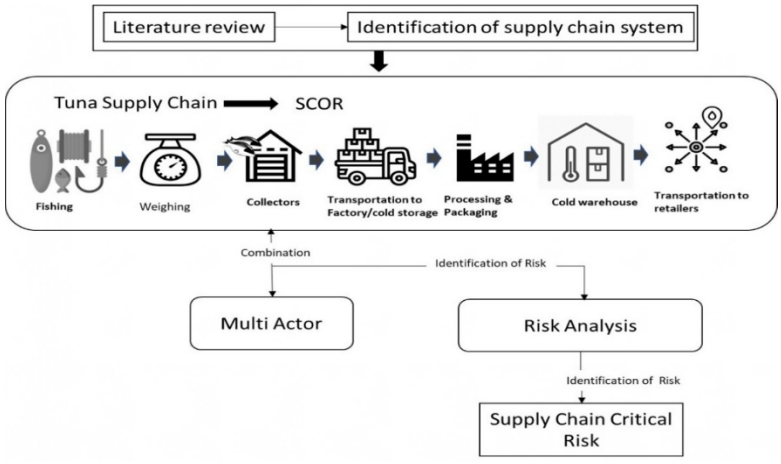

Figure 2. Concept of risk analysis for fishery product.

4. RESULT AND DISCUSSION

4.1 Multi-Actor Analysis

In analyzing the problems in this research, actor analysis is carried out to determine their needs, problems, and strength. Table 1 presents the analysis of actors in the supply chain discussed in this study. Stakeholders in this system are fisher groups, collectors/traders, and fish processing company. Fishers have the lowest capital compared to other actors, so fishers need help in providing cooling facilities which are a crucial element in the cold chain. The collectors' problems are similar to fishermen's: limited resources and facilities. Meanwhile, tuna processing companies have another problem: an imbalance between supply and demand. But all actors have the same interest: to get as much profit as possible. Apart from being interested in their earnings, Tuna processing companies also focus on the quality of their products. All actors have the same goal of providing high-quality products. Even so, they have yet to be made aware of the importance of their role in reducing FLFW, which is waste from products that experience a decrease in quality. Each stakeholder has different interests and problems so in the selection of strategy to mitigate the risks, it is hoped that they will still be able to provide the best win-win solution.

4.2 Determining the Company's Supply Chain Activities (SCOR Approach).

Every activity in the supply chain in the company will be mapped using the SCOR (Supply Chain Operation Reference) approach according to the process, namely plan, source, make, deliver, and return. This approach is carried out to facilitate of identifying risks that exist within the company. In addition, in this process, actor analysis is also carried out to determine the character, problems faced, and the preferences of each actor. Table 2 present the process of the tuna supply chain by SCOR.

Table 1. Actor analysis

Actors	Fishers	Collectors	Fish processing company
Supply chain area	Fishing Storage Distribution to collectors	Distribution to tuna processing companies	Tuna fish processing Tuna fish packaging Delivery of processed tuna to retail
Problem perception	Lack of cold storage Low price Low supply of fish	Low supply Bad quality of fish High buying price Lack of cold storage	Poor quality of fish The low number of requests Excess inventory
Objectives	High price, price fluctuation Clear the inventory High quality of fish	High selling price Satisfy customer's demand Clear the inventory High quality of fish	Fulfill customer demand Reduce inventory Reduce the number of defective products High product quality
Interest	Profit	Profit	Profit Selling high-quality products
Cause of problem	Lack of facility and cold storage Unbalance supply and demand Long storage time	Inadequate facilities Instability between supply and demand. Long storage time Many low-quality products Long distribution time	Long storage time Fast expiration time Instability supply and demand
Resource	Shipowner First supplier	The strong cooperative relationship between fishers, fish processing companies, and also the Government Lobbying power	Capital Lobbying power
Position	Expect help from the government and the private sector to improve infrastructure.	Lobbying fishers to sell at low prices, lobbying fish processing companies and retailers to buy high prices, deficient quality products. Fostering effective communication and connections with supply chain partners.	Lower price negotiation Strive to balance supply and demand through communication and demand forecasting

Table 2. SCOR-Risk table

Value chain & SCOR	Function on supply chain	Risk Activity	Stakeholders	5m+IE
Source	Fish handling after fishing	Poor handling of fish by fishers after fishing	Fishermen	After being caught, the standard of handling fish is cleaning the fish and then soaking the fish in saltwater and ice.
	Storing fish in storage	Contaminated tuna	Fishermen	If the fish did not fit in the Styrofoam box, then the fish will be stored in the hull filled with ice.
	Storing tuna in cold storage	Lack of cold storage	Fishermen	Tuna stored in a styrofoam box filled with ice
	Bringing tuna to the TPI port	There is a queue to drop the fish	Fishermen	The length of time at sea is 10-18 hours. Then the queue time at the port is 1-3 hours.
Source	Weighing tuna	The process of weighing tuna at the collector	Collectors	The weighing process is carried out at TPI by collectors.
	Checking and moving tuna to storage	Poor handling of tuna by people at the point of sale	Collectors	Tuna are checked and then transferred to a collector for storage in cold storage.
	Storing tuna	Long storage time	Collectors	Tuna are stored in cold storage. Some tuna are stored in the freezer if the shelf time is long enough. Fresh tuna are stored in a Styrofoam box filled with ice.
Deliver	Distribution to fish processing companies	Poor cold distribution facility	Collectors	Fish are stored in a styrofoam box filled with ice.
		Broken vehicle		The vehicle uses a pick-up car. Delivery time 1-2 hours from the delivery location.
Make	Operation	The delay in the production of processed tuna	Fish processing company	If the collector experiences delays in shipping, the company is also late in processing tuna
		Improper handling of materials	Fish processing company	Use personal protective equipment. There is a standard process that has been set. However, the human error factor can still occur.
Make	Operation	Pollution and waste due to operation	Fish processing company	Use personal protective equipment. There is a standard process that has been set. The fish cleaning process produces the most waste. But the human error factor can still occur.
		The resulting product is not up to the standard quality	Fish processing company	Use personal protective equipment. There is a standard process that has been set. However, human error and facility error factors can still occur.
Deliver	Storage	Long storage time	Fish processing company	Storage temperature below 0°C. The maximum storage time is three months. There is a temperature control device.
		Low demand	Fish processing company	Price fluctuations and supply quantity affect the quantity demanded
		Unclean cold storage	Fish processing company	There is a schedule for cleaning the storage. However, human error and facility error factors can still occur.
		Damaged cold storage	Fish processing company	power failure and unstable electricity harm the cold storage. There is a maintenance schedule.
	Distribution to retailers	The cold distribution facility is broken	Fish processing company	The age of the machine is a determinant of machine damage, so it needs periodic maintenance. There is a temperature control device.
		Broke transportation	Fish processing company	Vehicles use refrigerated boxcars, and sea routes use ships and containers with refrigeration facilities.

4.3 Prioritizing Risks in the Tuna Supply Chain Using FMEA

Risk identification and analysis are critical to be carried out in supply chains with high complexity. It is done in order to be able to build a mitigation strategy for potential risks that occur in the system (Qazi *et al.*, 2018). After identifying problems, risk identification is carried out at the beginning of the study. This study also uses the FMEA method to identify and analyze the risks that occur and will occur in the system. FMEA is used to assign weights and priorities to risks, making it easier to evaluate and find appropriate strategies to reduce the impact of these risks (Liu *et al.*, 2013). The initial risk identification was carried out to see the risks that occurred in the tuna supply chain with its relationship to FLFW. The most significant risks will be selected for follow-up to avoid or reduce the consequences of these risks. The method used is FMEA. This FMEA is used to find potential risks, the causes of risks, and analyze actions to address these risks. The risk analysis results using FMEA can be seen in table 3. Table 3 shows the lowest to the highest risk along the tuna supply chain.

- Risk to Fishermen

Activities for fishers start from catching and delivering fish at the port to be weighed and deposited to collectors. Based on the results of the multi-actor analysis. Fishers have limited refrigeration facilities, resulting in the highest potential risk occurring in storage activities of catching. Based on the interviews, the duration of time for fishers to sail in the sea is quite long. They spend an average of 10-18 hours catching tuna. The only cooling facility they have is a styrofoam box filled with ice cubes. So the possibility of a decrease in the quality of fish and other marine products. Table 5 shows that Risk (R5) has the highest RPN value of 120. This value is very significant compared to other risks faced by fishers.

In comparison, the smallest risk value is R4. The risk of R4 occurs because of the long queue of ships when they will dock. It is due to the large area of the port area for the Fish Auction Place (TPI), which is not large enough to accommodate the number of fishing vessels. Nevertheless, the resulting risk is small because the length of the queue time is not as long as sailing time. So the risk that occurs is more negligible. The maximum queue time is 1-3 hours.

Table 3. Risk Prioritizing by FMEA

Value chain & SCOR	Activities/ Functions in SC	Potential Failure Mode (Damage)	Potential Effect of Failure-Risk	S	Potential Cause of Failure	O	Current Process Control	D	RPN
Source	Handling tuna after fishing	Poor handling of fish by fishermen after fish are caught (R1)	Fish rot quickly	4	limited facility (C1)	5	Visual Checking	2	40
	Storing tuna in storage	Contaminated tuna (R2)	Fish rot quickly	2	Unclean storage area (C2)	6	Visual Checking	3	36
	Storing tuna in a cold storage	Poor quality of cold storage after fishing (R3)	Fish freshness level decreased	8	Limited and lack of cold storage (C3)	5	Visual Checking	3	120
	Bringing tuna to the TPI port	There is a queue to lower the fish (R4)	Fish freshness level decreased	3	Limited harbor area (C4)	4	Visual Checking	2	24
Source	Storing tuna in the cold storages	Poor quality of cold storage (R5)	Fish freshness level decreased	7	Lack of cold storage (C5)	4	Visual Checking	2	56
	Checking and moving the tuna	Poor handling of fish by people at the point of sale (R6)	Contaminated fish	3	Lack of knowledge (C6)	2	None	5	30
	Storing tuna	Long storage time (R7)	Fish freshness level decreased	7	Low demand	4	Visual Checking	2	56
Deliver	Distribution to fish processing company	Poor cold distribution facility (R8)	Fish freshness level decreased	5	Lack of cold distribution facility (C7)	3	None	3	45
				5	Raise temperature (C8)	3	None	3	45
		Vehicle breakdown (R9)	Delay distribution	8	Bad maintenance (C9)	2	Visual Checking	2	32

Table 3. Risk Prioritizing by FMEA (Continued)

Value chain & SCOR	Activities/ Functions in SC	Potential Failure Mode (Damage)	Potential Effect of Failure-Risk	S	Potential Cause of Failure	O	Current Process Control	D	RPN
Make	Operation	Delay in the production of processed fish (R10)	Fish freshness level decreased	5	Time estimation error (C10)	1	Schedule checking	1	5
		Improper handling of raw materials (R11)	Poor quality of fish	8	Working procedure error (C11)	1	Visual Checking & SOP	1	8
		Pollution and contamination due to operation (R12)	Fish easily spoil	6	Improper management of solid and liquid waste (C12)	3	Visual Checking	2	36
		The products did not meet the quality standard (R13)	Poor quality of fish	9	The quality of fish did not meet the quality standard (C13)	1	Quality checking	1	9
Deliver	Storage	Long storage time (R14)	Fish freshness level decreased	8	Low demand of fish processing company (C14)	3	Inventory checking	1	24
			Product damaged	9	Low demand of fish processing company (C15)	2	Quality checking	1	18
		Low demand (R15)	Excess inventory	8	High forecasting error (C6)	2	Inventory checking	2	32
	Distribution to retailers/ customers	Unclean cold storage (R16)	Product damaged	7	Human error	3	Quality checking	2	42
		Cold storage breakdown (R17)	Fish freshness level decreased	10	Bad maintenance	1	Temperature checking	1	10
		Damage cold distribution facility (R18)	The freshness level of the fish decreases and is potentially damaged	9	Bad maintenance	1	Temperature checking	1	9
		The vehicle broke (R19)	Delay distribution	8	Bad maintenance	1	Visual Checking	2	16

- Risk to Collectors

When the fishers rest at the port, they bring the fish to the weighing center at the port. The rotten catch is thrown away, so food loss is a risk.. The catch is good quality, stored, weighed, and then transferred to a cooler (styrofoam boxes filled with ice cubes). The highest risk values on the part of the collector are R5 and R7. This risk is due to limited cooling facilities on the part of the collector. The risks that occur on the fishers were closely the same Based on the multi-actor analysis, their problems are the same, namely limited facilities and capital. It happens because they are included in the small business category, unlike fish processing companies included in the category of large companies with strong capital. Apart from the risks caused by inadequate refrigeration facilities, lack of demand results in longer product shelf-life. It poses a potential risk of food loss at the storage stage on the part of the collector. The lowest risk value owned by col lectors is R6. This risk is caused by the lack of facilities and knowledge related to perishable fish and marine products. It results in a poor and non-standard handling process.

The value of this risk is small because the time for handling and moving fish from the weighing process to the storage area is not long. So the probability of risk is not significant. The risks in fishers are pretty significant compared to other supply chain actors. In addition to limited capital and facilities, fishers also lack knowledge regarding handling their catch and monitoring the condition of their catch. So that when a risk event occurs, it can be detected as soon as possible. It can reduce the value of the risk that occurs.

- Risk to Tuna Fish Processing Company

The most significant risk value for Tuna processing companies is R16. This risk is caused by human error. The room and storage area for tuna is not clean. So that the product is easily contaminated, which results in the product being easily damaged; itis also in line with the risk R12, which is the risk that occurs due to pollution and waste. It causes the product to spoil and rot quickly. Pollution and waste from the processing of tuna fish that are not cleaned regularly and adequately can contaminate the product resulting in reduced product quality.

The lowest risk value is owned by the risk of R10, namely the delay in processing tuna. From the table, it can be seen that the frequency occurrence is not frequent and easy to detect. Every company, substantial companies, already has operational and scheduling standards. So this event is rare and easy to detect. The risks that occur are in line with the results of the multi-actor analysis.

Occurrence is not frequent and easy to detect. Every company, substantial companies, already have operational and scheduling standards. So this event is rare and easy to detect. The risks that occur are in line with the results of the multi-actor analysis that has been carried out previously.

4.4 Strategy to Reduce Supply Chain Risk

The critical risks found in the measurement and risk priorities are considered in determining risk mitigation strategies in the supply chain. Good risk management in the supply chain aims to optimize supply chain performance (Oliveira *et al.*, 2019). The determination of strategy is based on previous research literature studies relevant to this case study.

Fishers and collectors have common risks. They have a lack of facility to keep the freshness of the product for a long time. The Government subsidies will significantly assist the fishers community in improving their performance and become a form of awareness and responsibility of the Government in support of the SDG concept. Moreover, the subsidy from Government can help the fishers buy cold storage. Furthermore, the collaboration between fishers and collectors also might reduce the FLFW potentially. The relationship between fishers and collectors could be arranged under a contractual agreement. For example, the fishers and the collectors corporate to purchase the cold storage for shared use with applicable and binding provisions between them..

In order to reduce the risks and increase the quality, The company should make continuous improvements (Apornak and Hezaveh, 2019). Related to the highest risk priority of this case is human error; the company should train the staff about work procedures (Das, 2018; Purushothaman *et al*., 2020; Apornak and Hezaveh, 2019) and quality control (Adhitya *et al.*, 2009; Jasti and Kodali, 2015; Oliveira *et al.*, 2019). Moreover, the company should evaluate and control work procedures regularly.

5. CONCLUSION

1. The configuration of the tuna supply chain at Tuna Processing Company in Makassar started with fishers as fish suppliers, then continues with collectors who act as distributors and as intermediaries between fishers and companies. After the company processes the product, the product will be sent to retailers and restaurants. However, this case study only carried out the risk analysis on the tuna processing company as a frozen tuna fish producer.
2. The highest risk value for fishers is R3. R3 is a risk that occurs due to a lousy refrigeration storage area. In comparison, the lowest risk is R4. R4 is a risk because the ship is late anchoring at the TPI Port.
3. The highest risk values for the collectors are R5 and R7. This R5 risk occurs because the collector does not have adequate refrigeration storage facilities. In comparison, the risk of R7 occurs because of the long storage time. Long storage times occur due to a lack of demand. The lowest risk value for collectors is R6. The risk of R6 occurs because handling and moving the product from the weighing station to the storage area is not appropriate.
4. The highest risk value at Tuna Processing Company in Makassar is R16, caused by an unclean storage area. In comparison, the lowest risk value is R10 caused by the delay in handling fish.

6. SUGGESTIONS

1. Based on the risk analysis and multi-actor analysis results, the highest risk along the supply chain is obtained by fishers. It is due to a lack of capital and facilities. Then the role of the Government is needed to improve the supply chain performance and quality of tuna from fishers.
2. Development of risk mitigation in the tuna supply

chain can be continued in further research.

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<APPENDIX A> Consolidated Criteria for Reporting Qualitative Research

Personal characteristic	
Interviewer/ Facilitator	Nurul Chairany (NC)
Credentials	M.T
Occupation	Research Association
Gender	Female
Experience and Training	Academic researcher
Relationship with Participants	
Relationship established	Had no prior relationship with interviewees
Participant knowledge of the interviewers	Participants as experts and actors who haveknowledge related to research issues.
Interviewer Characteristic	No characteristic were reported
Participant Selection	
Sampling	Purposive
Method of Approach	Depth interview
Sample size	4 fishers groups, 1 collectors, and 1 tunaprocessing company
Non-Participation	There is no participation dropped out.
Setting	
Setting of Data Collection	4 fishers groups and 1 collector were interviewedat the port
	1 tuna processing company, presented by its Production manager was interviewed at the office.
Data Collection	
Interview guide	1. The interviewees validated FMEA framework.
	2. The authors wrote the questions and the risk assessment table on papers that would give to the participants
Repeat Interviews	Yes (Repeat interview was conducted formanufacturer).
Audion/Visual recording	Audio recording
Field Notes	Yes
Duration	Depth interview with fishers took 160 minutes, 40 minutes/ fishers in estimation. Depth interview with collectors took 40 minutes. Depth Interview with producer took 120 minutes

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