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RISK ASSESSMENT AND RISK MITIGATION IN A SUSTAINABLE TUNA SUPPLY CHAIN

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Abstract: This study aimed to conduct a risk assessment and minimize the risk of sustainable tuna supply chains in Ambon. The House of Risk (HOR) approach was utilized in this study to identify risk occurrences and risk agents in three aspects of sustainability. The study results identified 15 risk events and 26 risk agents consisting of four risk events and five risk agents on the environmental dimension, five risk events and eleven risk agents on the social dimension, six risk events, and ten risk agents on the economic dimension. The HOR phase I shows that the risk agent with the highest Aggregat Risk Priority (ARP) value is the lack of environmental management system standards (A4), and the risk agent with the lowest ARP value is inhumane treatment/harassment (A12). Based on the Pareto principle, 7 Risk Agents will be prioritized to be handled according to the highest ARP value, such as lack of environmental management system standards (4170), lack of quality control inspection (3790), lack of maintenance management (3346), lack of quality control from suppliers (3000), lack of enthusiasm for work (2984), decreased level of discipline (2832). The internal communication system of the company is poor (2538). Furthermore, 15 mitigating techniques are proposed. Twelve mitigation technique steps are chosen from 15 recommended solutions to prevent the causes of risk based on the effectiveness to difficulty (ETD) value from HOR phase II.

1 Introduction

Currently, the supply chain management system has developed not only by looking at the process of flow of goods, information, and money from upstream to downstream [1,2], but has now developed by looking at environmental, social, and economic aspects [3-5], even discusses the institutional aspects [6] in achieving company goals. This is what is better known as a sustainable supply chain [7].

The basic concept of sustainable supply chain management refers to the definition of sustainable development from the Brundtland Report [8], which includes three aspects of sustainability, namely economic, social and environmental aspects commonly known as the triple bottom line [9-11] which are interrelated with each other. The goal is that the managed supply chain can meet consumer desires (responsiveness) in terms of quality, quantity, delivery time, environmentally friendly, and sensitivity to social conditions [12-16].

Sustainability issues have become an important issue in recent times. One of the critical issues in sustainable supply chain management is managing uncertainty and risk [17]. In an uncertain business environment, the risk is always present. Risk is the chance of occurrence of something undesirable or the uncertainty of future events. Risk can not be avoided, but the risk can be minimized its impact on the overall supply chain performance with proper risk management [18-20].

Risk management in supply chain management is not much different from risk management in general, meaning that the basic concepts in risk management can be applied as usual, starting with understanding the risk management cycle [21]. Risk management is a planned and structured process that aims to help make the right decisions to identify, classify, measure risks, and then manage and control them [22].

Research on supply chain risk management (SCRM) is mainly done using several methods. [23-25] Identifying supply chain risks using the Failure Mode Effect Analysis (FMEA) method based on occurrence, severity, and detection, which results in a Risk Priority Number (RPN), which is combined with several multi-criteria decision-making methods to see essential risk factors for mitigation [10]. [20,26] uses the Supply Chain Operation Reference (SCOR) technique to identify supply chain processes like Plan, Source, Make, Deliver, and Return risks. The House of Risk (HOR) technique is then used to assess the identified risks. [27] developed the HOR technique by combining the FMEA and the House of Quality (HOQ) models in the Quality Function Deployment (QFD). The advantages of this method are in the framework that can cover the whole process of risk management, and this method focuses on preventive actions determining the main risk agents and the priority of preventive actions.

Many studies have been conducted in supply chain risk management, but only a few focused on sustainable supply chain risk control for tuna fish products. Several studies developed a multi-stakeholder HOR technique for risk control of tuna commodities in North Sulawesi and East Java [28,29]. Others studied a risk mapping of the tuna supply chain in the Eastern Indian Ocean [30] and risk control of tuna commodities during the pandemic of Covid-19 in Ambon city [20]. Those research only identify risk factors on economic aspect and does not provide an analysis about sustainabilities aspects for tuna. The problem is what mitigation strategies must be carried out to prevent the risk of tuna's sustainable supply chain risks in Ambon City.

Issues about sustainability are exciting themes in terms of scientific studies and a business perspective [31]. Therefore, this study has a novelty in sustainable supply chain risk management (SSCRM) for tuna commodities. The purpose of this study is to map the most dominant risk priorities according to the Aggregate Risk Potential (ARP) value and to formulate a risk mitigation strategy for the company.

With the importance of sustainable supply chain risk management (SSCRM), companies can plan, implement, and control the supply chain management process in a sustainable manner so that it does not interfere with the supply chain and the sustainability of the fishing industry.

2 Methodology

Research methodology is a systematic step used to achieve the desired goal. This study discusses risk control in the sustainable supply chain of tuna fish products at companies in Ambon. This research refers to the stages in risk management, as shown in Figure 1.

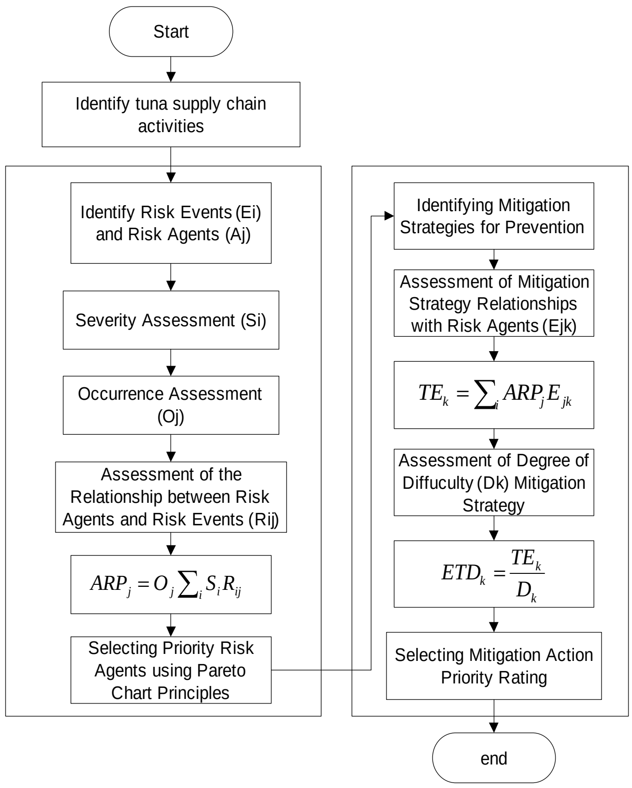

Figure 1 The steps of risk assessment of the sustainable tuna supply chain

1. Conduct initial mapping of the tuna supply chain in Ambon city based on interviews and literature studies from previous research.
2. Identify risk events (E_i) and risk agents (A_j) for the three dimensions of sustainability, namely the environmental, social, and economic dimensions through the collection of literature studies, brainstorming, and interviews with related experts such as the environmental service, academics, managers of fishing companies and fishers who which will then be used in the preparation of the assessment questionnaire as well as the relationship of causes and risk events that will be input to the House of Risk phase I model [27] in table 1.

Table 1 Model HOR Phase I

Sustainable Dimension	**Risk Event** (E_i)	**Risk Agent (Aj)** A_1	A_2	…	A_{n+1}	**Severity of Risk Event** (S_i)
Environment	E_1	R_{11}	R_{12}		$R_{1(n+1)}$	S_1
Social	E_2	R_{21}	R_{22}			S_2
Economic	E_3	R_{31}				S_3
Occurance of Agent j (O_j)		O_1	O_2	…	O_{n+1}	
Agregat Risk Potential (ARP$_j$)		ARP_1	ARP_2	…	ARP_{n+1}	
Priority Rank of Agent j						

3. Conduct a severity assessment (S_i) with a value range of 1-10, where 10 represents the extreme impact shown in table 2.

Table 2 Severity Rating

Score	Effect	Score	Effect
1	None	6	Significant
2	Very Minor	7	Major
3	Minor	8	Extreme
4	Low	9	Serious
5	Moderate	10	Hazardous

4. Conduct an Occurrence (O_j) assessment of each risk cause with a scale of 1-10, shown in table 3.

Table 3 Occurrence Rating

Score	Occurrence rate	Score	Occurrence rate
1	Almost never occurred	6	Rather Hight
2	Slight	7	Sufficient hight
3	Low	8	Hight
4	Relatively Low	9	Very Hight
5	Moderate	10	Almost certain to happen

5. On a scale of 0 to 1, 3, 9, assess the relationship between the risk agent and the risk events (R_{ij}), with 0 indicating no relation and 1, 3, 9 indicating a weak, moderate, and strong relationship.
6. Calculate the ARP_j value using equation 1. The ARP_j value is obtained from the product of the occurrence value (O_j) and the aggregate severity (S_i) and risk event (R_{ij}) values.

$$ARP_j = O_j \Sigma_i S_i R_{ij} \quad (1)$$

7. Determine the ranking of priority risk causes based on the highest to the lowest ARP values.
8. Selecting the priority risk causes, using Pareto analysis of ARP_j for treatment in HOR phase II in table 4 below.

Table 4 Model HOR Phase II

Priority Risk (A_j)	Preventive Action (PA_k)				ARP_j
	PA_1	PA_2	....	$PA_{(n+1)}$	
A_1	E_{11}				ARP_1
A_2					ARP_2
A_3					ARP_3
$A_{(n+1)}$					ARP_{n+1}
Total Effectifness (TE_k)	TE_1	TE_2	...	$TE_{(n+1)}$	
Degree of Difficulty (Dk)	D_1	D_2	...	$D_{(n+1)}$	
Effectiveness to Difficulty (ETDk)	ETD_1	ETD_2	...	$ETD_{(n+1)}$	
Rank of Priority	R_1	R_2	...	$R_{(n+1)}$	

9. Identify the relevant preventive actions (PA_k) to prevent or reduce the impact of risks..
10. On a scale of 0 to 1, 3, 9, assess the relationship between the priority risk (A_j) and preventive actions (PA_k), with 0 indicating no relation and 1, 3, 9 indicating a weak, moderate, and strong relationship.
11. Calculate the total value of effectiveness (TE_k) using the following formulation:

$$TE_k = \Sigma_i ARP_j E_{jk}, \forall k \quad (2)$$

12. Assess the level of difficulty (D_k) in carrying out each preventive action. Assessment can use the Likert scale approach, which is shown in the following table 5.

Table 5 Degree Of Dificulty Scale

Scale	Description
1	Preventive actions are very easy to implement
2	Preventive actions are easy to implement
3	Preventive actions are quite easy to implement
4	Preventive actions are difficult to implement
5	Preventive actions are very difficult to implement

13. Calculating the value of effectiveness to difficulty (ETD_k) using the following formulation:

$$ETD_k = {}^{TE_k}/_{D_k} \quad (3)$$

14. Determine the priority ranking of mitigation actions; the first rank is the mitigation action with the highest ETD_k value.

3 Result and discussion

3.1 Initial Mapping of the Fish Supply Chain

The initial mapping of the supply chain management of fish companies in Ambon City was adapted from [32] shown in Figure 2.

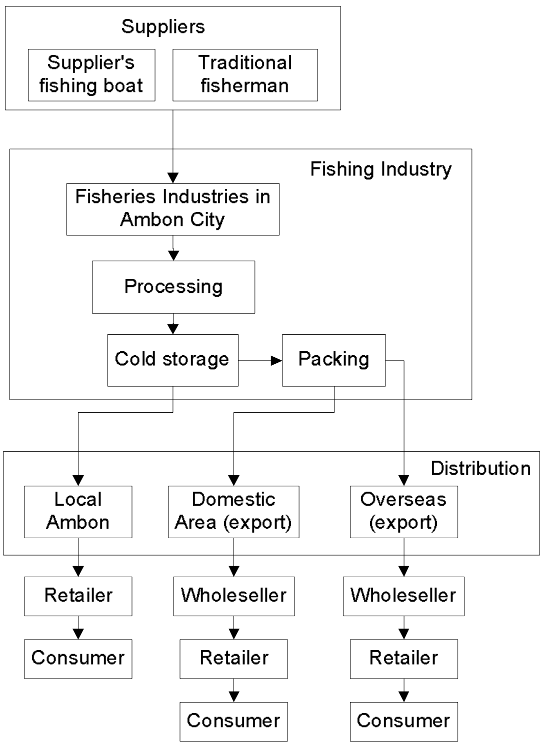

Figure 2 Tuna fish supply chain in Ambon city

The stages from upstream to downstream of a fishery industry supply chain system from each company are integrated. However, for the fish suppliers who are the most dominant in supplying fish to each company, namely the fishermen, the fishermen come from various regions and villages in Maluku province. Each raw material supplied to the 11 companies that are still actively operating will then be processed and stored in the cold storage of each company. Each company's product marketing distribution system is generally marketed to three locations, such as in the city of Ambon, regional areas, and exported abroad.

The distribution system of each company is carried out in a vertical marketing system, which starts from producers directly marketed to consumers, some from producers to retailers to consumers, and some from producers to wholesalers continued to retailers to consumers. In general, product marketing in the Ambon city area has happened because the company does not distribute products to consumers or retailers, but consumers and retailers who come directly to the company buy products using vehicles for both parties. Product marketing for regional areas is more dominant than any fishing company in Ambon city, namely in Jakarta, Surabaya, and Bali, because in these areas into various types of products. Transportation of product shipments to out of the region and overseas, using sea transportation and planes which shipping service companies own.

3.2 Risk Identification and Risk Assessment

Risk identification is carried out through literature studies from previous studies and by interviewing or brainstorming with experts to obtain the accurate information as possible on risk events, the causes of risk, and where the risk occurs for the three dimensions of sustainability (environmental, social, and economic). The process of identification and risk assessment uses the Failure Mode of Effect Analysis (FMEA) approach to measure the level of risk impact (severity) of the risk events that have been identified and the level of probability of the occurrence of risk (occurrence) from risk agents [20].

The results of risk identification and risk assessment that experts have verified produce 15 risk events and 26 risk agents consisting of 4 risk events and five risk agents on the environmental dimension, five risk events and eleven risk agents on the social dimension, six risk events, and ten risk agents. Risk agent on the economic dimension. Risk events and risk agents may occur in the sustainable supply chain of tuna in Ambon City, as shown in table 6.

Table 6 Identification of risk events, risk agents, value of severity and value of occurrence

Sustainable Dimension	Risk event and supported references	Code	Severity	Risk Agent and supported references	Code	Occurrence
Environment	Water pollution and marine biota degradation [33,34]	E1	8	Domestic waste water [35]	A1	7
				Production waste water [35]	A2	9
	Degradation of fish population [34]	E2	8	Overfishing [36]	A3	7
	Non-compliance with sustainability laws [37]	E3	8	Lack of Standard Environmental Management System (EMS) [38]	A4	10
	Uncomfortable working conditions [6,39]	E4	5	Poor work environment (the ceiling, house floor, ventilation, waste disposal facilities) [40]	A5	2
Social	Lack of occupational health and safety [41]	E5	7	Inadequate personal protective equipment [41,42]	A6	3
				Lack of management support for OHS [43-45]	A7	2
	Unfriendly relation between top management and workers [46-48]	E6	6	The internal communication system of the company is poor [20]	A8	6
				Resistance and Lack of trust of workers with management [49]	A9	3
	Lack of work culture [39,47]	E7	6	Lack of enthusiasm for work [50]	A10	8
				Declining discipline level [51]	A11	8
	Social Instability/unrest [37]	E8	7	Inhumane treatment/harassment [52]	A12	1
				Fewer local workers [53]	A13	5
	Labor strike//mass demonstrations [54]	E9	5	Unfair wages) [33]	A14	7
				Discrimination [37]	A15	4
				Excessive working time [37]	A16	2
Economic	High maintenance cost [47,48]	E10	8	Lack of maintenance management [55]	A17	7
	Demand volume uncertainty [20,54]	E11	5	Error in planning calculation [20]	A18	3
				Order changes from customer [20]	A19	2
	Quality of finished product [20,54]	E12	8	Lack of quality control from suppliers [20,29]	A20	10
				Lack of quality control inspection; [20,29]	A21	10
	Production flow [20,54]	E13	5	Delay in receiving raw materials (tuna fish) [20]	A22	6
				Lack of raw materials (tuna fish) ; [20,29]	A23	7
	Timelines of delivery [20,54]	E14	5	Late delivery for costumer; [20]	A24	2
				Error in recording shipping documents; [20]	A25	3
	Product stock out [20,54]	E15	5	Distortion of demand and supply [54]	A26	3

3.3 HOR Phase 1

HOR phase I is a stage to identify the risks that need to be addressed first. This is calculated using the severity, occurrence, and correlation values of each risk. The first phase of HOR processing results produce the Aggregate Risk Priority (ARP) value calculated using equation (1) and is shown in table 7. This ARP value aims to determine the risk agent's priority be handled or mitigated first.

Table 7 HOR Phase I Matrix

Risk Event (E_i)	Risk Agent																										Severity
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	(S_i)
E1	9	9	9	9	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	8
E2	9	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
E3	9	9	9	9	9	9	9	1	9	0	9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
E4	0	0	0	9	9	0	0	9	9	9	1	3	0	0	3	0	9	1	0	0	1	0	0	0	0	0	5
E5	0	0	0	9	9	9	9	1	1	1	1	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	7
E6	0	0	1	0	1	3	9	9	9	9	9	9	9	9	9	9	9	3	3	3	3	3	3	3	3	3	6
E7	1	1	0	1	3	3	1	9	3	9	9	1	1	1	1	9	9	3	3	3	3	3	3	3	3	3	6
E8	0	0	3	1	1	1	3	9	3	3	1	9	9	9	9	9	9	3	3	3	9	3	3	3	3	3	7
E9	0	0	0	0	3	0	3	3	9	9	0	0	9	0	0	9	9	3	3	3	3	0	0	3	0	0	5
E10	3	3	0	1	9	0	0	0	0	0	0	0	0	0	0	0	9	3	9	3	0	0	1	1	1	1	8
E11	0	0	3	0	0	0	0	3	1	3	3	0	0	0	0	0	3	9	9	9	9	9	9	9	9	9	5
E12	3	3	1	9	9	0	3	9	9	9	9	0	0	0	0	3	3	1	3	3	9	9	9	9	9	9	8
E13	0	0	1	0	3	0	0	9	9	9	9	0	1	3	0	0	3	9	9	9	9	9	9	9	9	9	5
E14	0	0	0	0	3	0	0	9	3	3	3	0	0	0	0	0	3	9	9	9	9	9	9	9	9	9	5
E15	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	3	9	9	9	9	9	9	9	9	9	5
Occurrence (O_j	7	9	7	10	2	3	2	6	3	8	8	1	5	7	4	2	7	3	2	10	10	6	7	2	3	3	
ARP_j	1890	2430	2212	4170	800	534	510	2538	1197	2984	2832	138	865	966	552	480	3346	888	696	3000	3790	1854	2219	664	951	951	
Ranking	11	8	10	1	19	23	24	7	13	5	6	26	18	14	22	25	3	17	20	4	2	12	9	21	15	15	

From the HOR phase I matrix results, it is generally seen that the risk agent with the highest ARP value lacks an environmental management system standard (A4). On the environmental dimension. The risk agent's ARP value is high because it has a reasonably high impact on the sustainability of the tuna supply chain; besides that, the correlation with other risk events is also vital. The risk agent with the lowest ARP value is inhumane treatment/harassment (A12) on the social dimension because it has a small impact and correlation on other risk events.

Furthermore, preventive actions will be conducted to prioritized risk agents based on the Pareto principle. The Pareto diagram for the risk agent is shown in the figure 3.

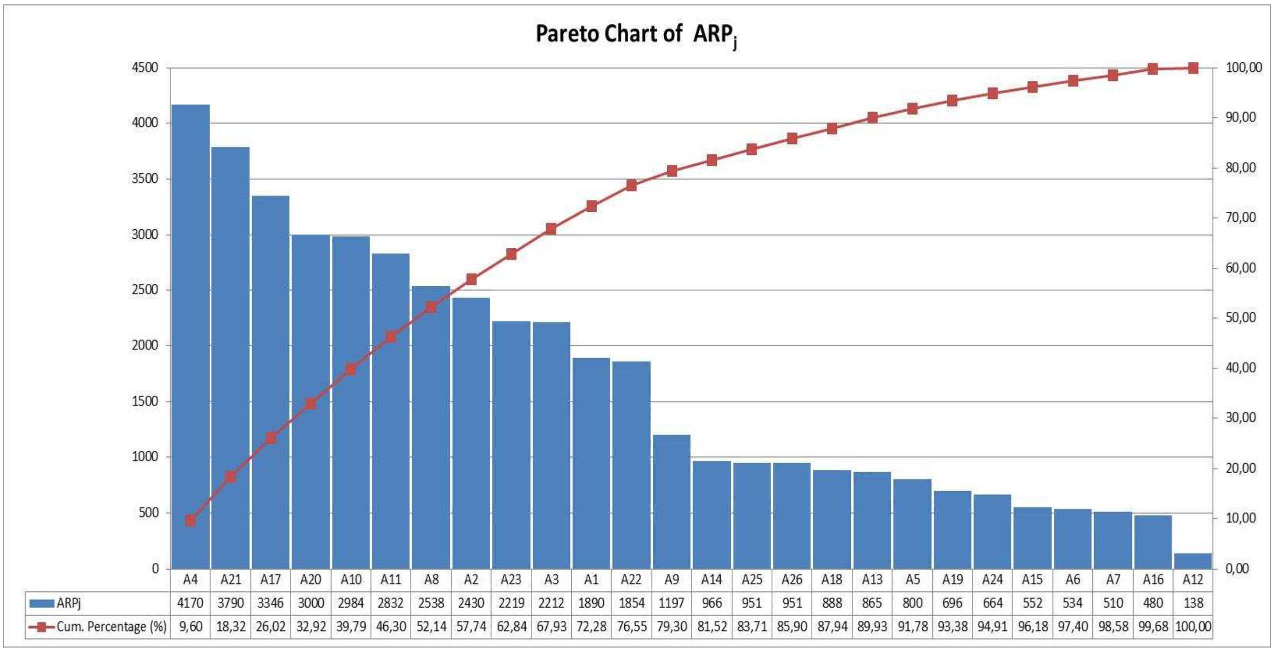

Figure 3 Pareto chart for HOR phase I

The Pareto principle used in risk evaluation is the 80:20 rule. In this study, 26.9% of risk agents were taken to design a treatment strategy that is expected to improve the other 73.1% risk agents. From the diagram above, the following are seven risk agents for which preventive measures will be taken:

- A4 (Lack of Standard Environmental Management System (EMS))
- A21 (Lack of quality control inspection)
- A17 (Lack of maintenance management)
- A20 (Lack of quality control from suppliers)
- A10 (Lack of enthusiasm for work)
- A11 (Declining discipline level)
- A8 (The internal communication system of the company is poor)

The social and economic dimensions are the highest priority for handling, followed by the environmental dimension. By choosing a priority risk agent, it is possible to concentrate more on the risk agent at the design stage of the treatment strategy. The focus of handling selected risk agents may indirectly reduce the impact of risks on the sustainable supply chain of the tuna fishing industry.

3.4 HOR Phase 2

After the HOR phase I is complete, the next step is to design a mitigation strategy to prioritize handling actions on the seven leading risk causes by considering adequate resources and costs. Identifying preventive measures is carried out through literature studies, interviews, brainstorming with related experts (environmental service, academics, managers of fishing companies, and fishers). Table 8 shows mitigation strategies for the seven priority risk agents.

Table 8 Preventive Action

No	Risk Agents	Preventive Action	Kode
1	A4 (Lack of Standard Environmental Management System (EMS))	Committed to the environment in the implementation of ISO 14001 environmental management system	PA1
2	A21 (Lack of quality control inspection)	Regular training for workers	PA2
		Routine audits on the production floor and receipt of raw materials (tuna fish)	PA3
3	A17 (Lack of maintenance management)	Programmed maintenance scheduling such as preventive, corrective and predictive maintenance systems.	PA4
		Ensure that Maintenance SOPs are implemented effectively and efficiently	PA5
4	A20 (Lack of quality control from suppliers)	Post-catch fish handling according to SNI standards, the temperature is less than 4 degrees and the histamine content is less than 50 ppm	PA6
		Improved Equipment and environmental Sanitation to reduce bacterial contamination	PA7
5	A10 (Lack of enthusiasm for work)	Workload Reduction	PA8
		Incentive Increase	PA9
		Improved friendly work atmosphere	PA10
6	A11 (Declining Discipline Level)	Improved 2-way Communication	PA11
		Implementation of reward and punishment policies according to company rules	PA12
		Placement of employees according to their expertise	PA13
7	A8 (The internal communication system of the company is poor)	Frequent discussions between top management and employees	PA14
		Family Gathering program at the company regularly	PA15

After the design phase of the handling strategy, the next steps in HOR phase II are evaluating the level of correlation between the handling strategy and the current risk agent, calculating the Total Effectiveness (TE_k) and Degree of Difficulty (D_k) values, and calculating the Effectiveness to Difficulty (ETD_k) ratio calculated and shown in table 9 below.

Table 9 *HOR Phase II Matrix*

Risk Agen	Preventive Action															ARP
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	PA13	PA14	PA15	
A4	9	3		3	1	1	3									4170
A21	9	9	9		1	9	9	3	1				3			3790
A17	1	1		9	9				1	1	1		3			3346
A20	9	9	9			9	9	3	3	1	1		1			3000
A10			1	1	1			9	9	9	9	9	3	3	3	2984
A11		1	3	1	1			9	9	9	3	3	9	3	3	2832
A8		3	1	1	1			9	9	9	9	3	3	9	9	2538
TEk	101986	87412	75128	50978	46428	65280	73620	95556	91322	81532	64540	42966	66462	40290	40290	
Dk	3	2	2	3	3	4	1	3	2	2	1	3	2	3	1	
ETD	33995	43706	37564	16993	15476	16320	73620	31852	45661	40766	64540	14322	33231	13430	40290	
Rank	8	4	7	11	13	12	1	10	3	5	2	14	9	15	6	

The most considerable ETD value indicates that the handling technique has the highest effectiveness to be carried out. To make it easier to find out the handling strategies that are carried out, a Pareto diagram is made as shown in the following figure 4.

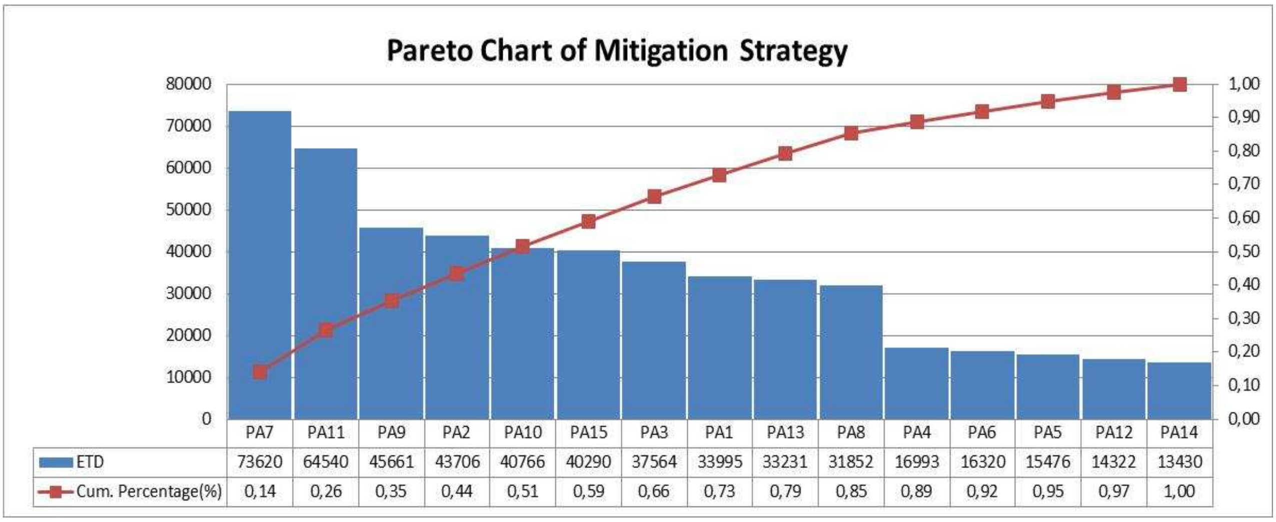

Figure 4 Pareto chart of mitigation strategy

With consideration and hope that the effective treatment strategy applied, only 80 percent of the total cumulative ETD value will be taken. As a result, 12 top strategies are suggested. The first possible prevention strategy is to improve equipment and environmental sanitation to reduce bacterial contamination (PA7), improve 2-way communication (PA11), incentive increase (PA9), regular training for workers (PA2), improved friendly work atmosphere (PA10), family gathering program at the company regularly (PA15), routine audits on the production floor and receipt of raw materials (PA3), committed to the environment in the implementation of ISO 14001 environmental management system (PA1), placement of employees according to their expertise (PA13), workload reduction (PA8), programmed maintenance scheduling such as preventive, corrective and predictive maintenance systems (PA4), post-catch fish handling according to SNI standards, the temperature is less than 4 degrees, and the histamine content is less than 50 ppm (PA6).

4 Conclusions

Sustainable Supply chain risk assessment has been carried out using the House of Risk method, so it can be concluded that there are 26 risk agents identified and consist of 5 risk agents on the environmental dimension, 11 risk agents on the social dimension, and 10 risk agents on the economic dimension. The risk assessment in HOR Phase I is based on the Pareto principle with the 80:20 rule. There are seven risk agents to be prioritized for handling, namely Lack of Standard Environmental Management System (EMS) (A4) with an ARP value of 4170, lack of quality control inspection (A21) with an ARP value of 3790, Lack of maintenance management (A17) with an ARP value of 3346, lack of quality control from suppliers (A20) with an ARP value of 3000, lack of enthusiasm for work (A10) with an ARP value of 2984, declining discipline level (A11) with an ARP value of 2832, the internal communication system of the company is poor (A8) with an ARP value of 2538.

HOR phase II is the stage to get a treatment strategy that can be done to reduce the possibility of risk agents. Based on 7 risk agents from HOR phase I, 15 possible handling strategies were proposed and after calculating the ETD value, 12 treatment strategies were obtained with the highest effectiveness value, namely improve equipment and environmental sanitation to reduce bacterial contamination (PA7) with an ETD value of 73620, improve 2- way communication (PA11) with an ETD value of 64540, incentive increase (PA9) with an ETD value of 45661, regular training for workers (PA2) with an ETD value of 43706, improved friendly work atmosphere (PA10) with an ETD value of 40766, family gathering program at the company regularly (PA15) with an ETD value of 40290, routine audits on the production floor and receipt of raw materials (PA3) with an ETD value of 37564, committed to the environment in the implementation of ISO 14001 environmental management system (PA1) with an ETD value of 33995, placement of employees according to their expertise (PA13) with an ETD value of 33231, workload reduction (PA8) with an ETD value of 31852, programmed maintenance scheduling such as preventive, corrective and predictive maintenance systems (PA4) with an ETD value of 16993, post-catch fish handling according to SNI standards, the temperature is less than 4 degrees, and the histamine content is less than 50 ppm (PA6) with an ETD value of 16320.

This research may be further developed by including Interpretive Structural Modeling (ISM) or dynamic modeling to determine the future cost of risk.

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