The design of cold chain risk management system of frozen tuna product in Aceh using fuzzy logic

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Abstract. Frozen tuna is a perishable product that sensitive to temperature changing, therefore a good cold chain system is needed. As a part of the supply chain, cold chain system aims to maintain the temperature of the product in order to keep its quality from upstream to downstream. There are various problems encounter the cold chain process that effected to the streamline. In consequence, it is important to build a continuous improvement to reduce the risk in the cold chain. The aims of this research are to discover the risk that can be found on the cold chain process, what is the causes, and the connection between both risks and its causes. This matter to develop risk management system on frozen tuna products in Aceh. This research using House of Risk (HOR) method to capture the most critical risk and risk management system is carried out Fuzzy Inference System (FIS) by Mamdani approach. The results of risk evaluation using HOR phase 1 show that there are 2 risks from 20 existing agents and 33 risk events that must be managed with the risk management, namely human errors and temperature during initial handling that is not according to standard.

1. Introduction
Supply chain activities very hard to be managed, because it involves both internal and external sides of a company. The structure of supply chain is complex, in addition to involving with various parties, uncertainty also often occurs suddenly, this is a challenge for that their supply chain management. This might cause vulnerable to risk so as to give any negative impact on of business process [1].

Risk is an unexpected effect emerging from a purpose to be achieved, in terms of internal and external. Risk management is required to avoid the risk that will emerge. Risk management on supply chain is an approach to managing risks arising in the supply chain like scheduling, technology, and unexpected cost [2]. The purpose of risk management on supply chain is to reduce the possibility of risks and to enhance resistance, the ability to avoid disruption [3].

Supply chain management in the processing and refrigerated production industry that applies a cold chain is to always maintain the quality of its products. A cold chain is a temperature-controlled supply chain of a product uninterrupted during the distribution process with a certain value. In cold chain temperature is an important factor that must be considered. Cold chain distribution processes are carried out on products that are easily damaged at high temperatures [4, 5]. There are several previous studies that applied cold chains to their products, including frozen shellfish [2], drugs [6], vaccines [7], frozen shrimp [8], meat [9], agricultural products [10] and fishery products [11].
One of the potentials of Aceh's marine resources which have a very high selling value is tuna. Cold chain system applied in the process of making frozen tuna products in Aceh, there are several problems that occur, the availability of unstable raw materials because tuna processing companies are very dependent on catches from fishermen raw materials that are easily damaged so that it requires handling as soon as received, the quality of raw materials that cannot be fulfilled by suppliers, unstable cold storage which results in several activities that are not in accordance with predetermined standards, as well as a lack of understanding of the cold chain itself among workers who make mistakes at the very beginning.

The purpose of this study is to identify risks and causes of risk, determine the causes of risk that must be prioritized and carry out risk management for the causes of risk that occur in cold chain activities of frozen tuna in Aceh. House of Risk (HOR) is a development method of FMEA (Failure Modes and Effect of Analysis) and House of Quality (HOQ) which is used to prioritize which sources of risk will be chosen first for action to reduce risk from the most risk effective source [3, 8, 12].

Meanwhile the Fuzzy logic method is used to identify the causes of problems or failures that occur through consideration of failure criteria. Fuzzy logic method can help decision making in mitigating risk and mapping problems as prevention and mitigation of risks that occur [13, 14]. So that this research is expected to be an alternative design of a risk management system used to overcome the risk of cold chains of frozen tuna in Aceh.

2. Methodology
Based on the literature study and the results of interviews with tuna production businesses in Aceh, 33 risk events and 20 causes of risk agent risk were obtained. The data is then developed into several questions and the questionnaires are distributed to respondents who have been determined to see the value of risk on the severity, assurance and correlation. Risk assessment is based on scale values from 0 to 10; where the value of 0 reflects the lowest scale and value 10 indicates the highest scale at each risk that occurs.

The next phase is to do mapping of cold chain activities that occur by using the supply chain operations reference (SCOR) model. The activities that occur are divided into four steps: plan, source, make, and deliver. Based on the SCOR activity mapping model that has been made, the next step is to carry out the process of identifying risk events that occur, and identify the causes of risk (risk agents) using the House of Risk (HOR) method.

Then, severity value is calculated from risk phase in order to find out how big of an impact of that risk affects the cold chain system. After that the calculation the occurrence value from the risk causes to see the probability of that risk from happening. Finally, correlation calculation is conducted to see the relationship between risk event and risk agent.

After severity, occurrence and correlation values are obtained, and then Aggregate Risk Potential (ARP) values are calculated. ARP values are calculated by accumulating each value which is then ranked based on the high ARP risk value to the lower risk value. Then with the help of pareto diagram, risk evaluation process can be done in order to decide which risk because that can be managed. Based on the pareto diagram it can be decided the agent risk that is included in the 20% of risk cause.

After the priority risk measures prevention have been obtained, then a risk management risk is designed using Fuzzy Inference System (FIS) to help in decision making. FIS that is used in the Mamdani Fuzzy logic, where there are four stages that must be done, they are: formation of fuzzy sets, implication function application, rule composition and defuzzification.

The final step in this research is to create risk management design. Risk management is used to anticipate or to reduce the risk causes that happened. Recommendation for repairing the said risk cause will cause a bad effect on the cold chain system. There is management risk system that is shaped into a tree diagram.
3. Results and Discussion
Identification is conducted based on literature study, which is then is made suitable with interview process with the company related; in order to find out the risks and risks causes that may potentially have happened in the company. After the risks are identified then they will be classified according to the activities, they are: plan, source, make and deliver. The risks are then coded based on SCOR model. Table 1 shows that there are 33 risk events where there are 6 risks in the plan activity, 6 risks in the source activity, 18 risks on the make activity and 3 risks on deliver activity.

| Activity | Code | Risk Event |
|----------|------|------------|
| Plan     | E1   | Uncertain weather conditions |
|          | E2   | Uncertain tuna stocks for production process |
|          | E3   | Uncertain raw materials |
|          | E4   | Increase in delivery prices |
|          | E5   | Fluctuating demands from customers |
|          | E6   | Raw materials do not arrive according to schedule |
|          | E7   | Instability of tuna prices in the market |
|          | E8   | The quality of tuna that is not according to the demand |
|          | E9   | Tuna deficiency in the market |
| Source   | E10  | Power blackout |
|          | E11  | Unsuitable packaging (reject) |
|          | E12  | Unavailability of raw materials |
|          | E13  | Damaged production process equipment |
|          | E14  | Tuna contaminated with other substances |
|          | E15  | Presence of bacteria in tuna |
|          | E16  | Uncertain production capacity |
|          | E17  | Delay in production process |
|          | E18  | Overheating of water pumps |
|          | E19  | Bad handling of raw materials |
|          | E20  | Limited number of weighing equipment where the raw materials must wait for the production process |
|          | E21  | Damaged products during production process |
| Make     | E22  | Accumulated products that are being kept |
|          | E23  | Inefficient water filtering |
|          | E24  | Production process came to a halt |
|          | E25  | Production targets are not achieved |
|          | E26  | Incorrect sizes during sorting of fish according to size |
|          | E27  | Incorrect checking when raw materials arrived |
|          | E28  | Inadequate process of fish preparation therefore there are many fish organs being thrown away |
|          | E29  | Decrease in fish quality |
|          | E30  | Employees are not careful during fish preparation process |
|          | E31  | Failure in delivery process |
| Deliver  | E32  | Changes in delivery times that depends on the availability of fish |
|          | E33  | Vehicles shortage for product distribution process |
Table 2 shows that there are 20 risk agents identifies, where one of the risk cause can start one or more risk events. These risks are then given ratings to see how far they can affect the risk activities of frozen tuna cold chain system. The identified risks are then given risk ratings to mark severity, occurrence and correlation. The result of each criterion is then cumulated with the ARP values calculation. Table 3 shows the recapitulation of ARP values from all risks that have happened.

The next step is to do a depiction using pareto diagram to see what risks that must be mitigated based on the pareto diagram principles. The principles of the pareto diagram is that 20/80, where 80% of the risk condition came from the 20% of the main cause of the risk condition. The pareto diagram for ARP values can be seen in Figure 1. Based on figure 1, it can be suggested that the risk because chosen was A9 (human error) and A20 (temperature during initial handling that is not up to standards). A9 and A20 became the first and second highest risk causes because of having the higher ARP value. After sorted from highest to lowest, there were high percentages, they are: 12,263% and 8,152%, so that when it was done cumulatively it reached 20,415%.

Table 2. Risk Agent Identification

| No | Code | Risk Agent                                                      |
|----|------|----------------------------------------------------------------|
| 1  | A1   | Simultaneous fish catch/yield                                   |
| 2  | A2   | Prediction errors in the need of raw materials                   |
| 3  | A3   | Disturbance in electricity supplies                              |
| 4  | A4   | Changes in sales plans                                          |
| 5  | A5   | Uncertain fishermen catch                                       |
| 6  | A6   | Employees not working according to SOP                           |
| 7  | A7   | Lack of product stock                                           |
| 8  | A8   | Machines that are very old                                      |
| 9  | A9   | Human error                                                     |
| 10 | A10  | Unexpected product demands from customer                        |
| 11 | A11  | Blockage in water filter                                        |
| 12 | A12  | Demands increase significantly                                  |
| 13 | A13  | Supplier cannot keep up with the demands of raw materials       |
| 14 | A14  | Nature factor                                                   |
| 15 | A15  | Employees are doing double duties                                |
| 16 | A16  | Instability of freezer temperatures, so then fish do not freeze according to schedule |
| 17 | A17  | Thermoking experienced technical problems, so the frozen fish has problems during distribution process |
| 18 | A18  | Fish shipped in by suppliers are not using standard company vehicles |
| 19 | A19  | Inadequate sanitation during handling conducted by supplier     |
| 20 | A20  | Temperature during initial handling that is not according to standard |

Table 3. ARP Values Recapitulation

| Rank | Code | ARP  | Percentage | Cumulative Percentage |
|------|------|------|------------|-----------------------|
| 1    | A9   | 2.085| 12,263     | 12,263                |
| 2    | A20  | 1.386| 8,152      | 20,415                |
| 3    | A18  | 1.302| 7,658      | 28,073                |
| 4    | A13  | 1.280| 7,529      | 35,602                |
| 5    | A7   | 1.244| 7,317      | 42,918                |
| 6    | A19  | 1.188| 6,987      | 49,906                |
| 7    | A6   | 1.144| 6,729      | 56,635                |
| 8    | A1   | 1.017| 5,982      | 62,616                |
| 9    | A5   | 1.017| 5,982      | 68,598                |
| 10   | A14  | 0.888| 5,223      | 73,821                |
| Rank | Code | ARP | Percentage | Cumulative Percentage |
|------|------|-----|------------|----------------------|
| 11   | A16  | 831 | 4.888      | 78,708               |
| 12   | A3   | 816 | 4.799      | 83,508               |
| 13   | A20  | 556 | 3.270      | 86,778               |
| 14   | A17  | 448 | 2.635      | 89,413               |
| 15   | A15  | 441 | 2.594      | 92,007               |
| 16   | A8   | 423 | 2.488      | 94,495               |
| 17   | A4   | 417 | 2.453      | 96,947               |
| 18   | A11  | 351 | 2.064      | 99,012               |
| 19   | A12  | 108 | 0.635      | 99,647               |
| 20   | A10  | 60  | 0.353      | 100,000              |

**Pareto Diagram for ARP Values**

![Pareto Diagram](image)

**Figure 1. Pareto Diagram for ARP Values**

The scenario preparation is conducted to see if the risks that happen are either easy to handle or hard to handle. Table 4 shows the fuzzy sets used in the Mamdani fuzzy logic.

**Table 4. Fuzzy Sets**

| No | Function | Variable | Fuzzy Sets     | Range   | Parameters       |
|----|----------|----------|----------------|---------|------------------|
| 1  | Input    | A9       | Very Easy to Handle | 0-417  |                  |
|    |          |          | Easy to Handle     | 417-834|                  |
|    |          |          | Can be Handled     | 834-1251|                  |
|    |          |          | Hard to Handle     | 1.251-1.668|              |
|    |          | A20      | Very Hard to Handle| 1.668-2.085|              |
|    |          |          | Very Easy to Handle| 0-277  |                  |
|    |          |          | Easy to Handle     | 277-554|                  |
|    |          |          | Can be Handled     | 554-832|                  |
|    |          |          | Hard to Handle     | 832-1.109|              |
| 2  | Output   | Risk Status | Easy to Handle | 1.386-2.085|              |
|    |          |          | Hard to Handle     | 1.386-1.736|              |
Based on the results processing using Mamdani fuzzy logic, A9 Variable is on the Fuzzy 1043 set that can be handled, because the membership function that is placed in parameters 834-1.251. For A20 Variable it in the Fuzzy 639 set which can be handled, because its membership function is placed on parameters 554-832. Meanwhile the risk status is on 1.536 that is placed in parameters 1.386-1.736, therefore the mitigation status is easy to handle.

Human error (A9) can cause many other risks, they are: broken production processing equipment, tuna can be contaminated with other substances, presence of bacteria in tuna, incorrect tuna preparation process that causes a lot of the fish’s organs to be thrown away, the decrease of tuna quality and errors of tuna preparation. There are 5 risk managements that can be practiced to prevent the human error risk cause (A9) on level 1, that are: giving work trainings based on standard operational procedure (SOP) that have been made, the company must practice the Standard Operational Procedure principles in a simple way, conducting employees’ evaluation regularly, evaluating the root cause of a problem and improving work discipline.

On level 2 A9 risk management there are 9 mitigations that can be practiced they are: giving work trainings, placing SOP banners in each room, conducting kaizen project, conducting performance ratings for employees, conduct regular meetings, routine supervision, creating a conductive working environment, give rewards or punishment and create a workplace that is in accordance to 5S principles. Figure 2 shows A9 risk management.

Temperature risk during initial handling that is not according to standard (A20) can cause other risks, they are: tuna that are not up to standards, contaminated tuna, presence of bacteria in tuna and the decrease of tuna quality. There are 2 risk managements that can be practiced to prevent the temperature-caused risk during initial handling that is not according to standard (A20), they are: choosing suppliers.
based on the good quality of raw materials and the supplier must use vehicles that are in accordance to fish shipping standards.

In the Level 2 risk management there was 4 mitigations that were performed, they are: analyzing the strengths and weaknesses of the supplier, make absolute work cooperation contract, using pick up cars that are included with ice, and using motorcycle or becak that is equipped with insulation. Figure 3 shows A20 risk management.

4. Conclusion
There are 33 risk events and 20 risk events that were identified on the cold chain system of tuna freezing process in Aceh. A9 variable (human error) and A20 (the temperature during initial handling that is not according to standards) were 2 risk causes with the highest ARP values which are prioritized to create a risk management design. The processing result with Fuzzy Mamdani method was a status that gives the risk cause for both variables, therefore it was easier to handle. The risk managements level 1 was carried out for A2 were to give work training, the practice of SOP principles, conducting employees’ evaluations, evaluating root cause and improving work discipline. Meanwhile A20 is around choosing suppliers and suppliers must use vehicles that are appropriate with the shipping fish standards.

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Figure 3. A20 Risk Management Variables
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