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Risk Mitigation in Cold Chain Sytem using ANP and FMEA: A Case Study of PT XYZ

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Abstract. PT. XYZ is a company that focuses on exporting marine products, especially products for surimi products, PT. XYZ experienced problems in *cold chain system* activities such as declining quality of fish raw materials, limited cold storage capacity, diversity of supply quality and the risk of overloud storage, resulting in the inhibition of cold chain system activities. The purpose of this study is to identify the causes and provide appropriate mitigation strategies so that risks can be minimized by the Company. This study uses an integration method between ANP and FMEA, so that a WRPN (Weighted Risk Priority Number) value can be produced. Based on the results of the analysis using the integration of the two methods, WRPN was obtained with the highest priority on quality risk factors of 170.713 and storage risk factors of 153.087 so that both risk factors are classified as high risk and need to be mitigated. The mitigation measures provided include separation of contaminated fish, monitoring, microbiological testing, compliance with standards, SOP training, cold storage maintenance, cold storage forecasting, using the FIFO method, supervision of the use of cold storage

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1. Introduction

The risk of implementing a cold chain is a risk arising from cold chain activities that can hindering the smooth running of the supply chain system. Cold chain systems mean maintaining the right temperature in the transportation, storage, and distribution of products that are susceptible to temperature changes [1]. Cold chain systems are generally applied by the food and pharmaceutical industries [2] Risk is the possibility of adverse events due to future uncertainties[3][4]. Risk in the context of a supply chain is defined as a process that involves identifying, assessing, treating, and monitoring risks [5] Risk reduction strategies are actions to manage risks to mitigate negative impacts and increase profitable opportunities [6]. The essence of risk management is in terms of risk events and the main causes of risk [7] PT XYZ is a company engaged in the export of marine products, this company has 3 products, namely frozen surimi, frozen fish and fishmeal. Especially PT. XYZ faces problems in the application of the cold chain system, especially in terms of freezing fish in cold storage. Freezing fish means the process of handling fish to be stored in a cold room with low temperature (cold storage) [8]. which hampers supply chains due to a lack of adequate mitigation analysis. Based on this, a risk mitigation analysis was carried out for the implementation of the cold chain system with an integration method between ANP and FMEA.

The Analytical Network Process (ANP) method is a method to determine the priority of the interests of various parties by considering the dependence between criteria and sub-criteria, [9][10] the ANP results are the weighted value of the most dominant and influential risk factors [11]. The FMEA method is used to help identify, assess, and control potential failures in a process so as to produce a risk priority number (RPN) [12][13]. In the later stage to calculate the weight of each risk and its relationship with risk mitigation, the integration of ANP and FMEA methods is used [14]. The main goal of this method is to obtain a more precise assessment after combining the relationships between the risk factors that have been calculated to be important. [15]. In previous research on cold chain system risk, no risk control strategy was given for the problem that obtained the highest value in data processing using the ANP and FMEA integration methods.

2. Method

The reason for using the ANP and FMEA integration method is for more complex judgment in decision-making [16]. The ANP method to describe the dependency interactions between criteria [17] while when integrated with the FMEA method can be used to identify causes, severity, impacts and corrective actions [18]

2.1. Data Collection

Data collection is carried out by distributing a closed questionnaire only to parties who have experience in the field of cold chain systems [19] in this case will be filled by the Quality Assurance department at PT. XYZ is responsible for the quality of the cold chain system and the quality of frozen surimi raw materials. Data collection was then carried out by distributing questionnaires related to the assessment of the paired comparison matrix [20] against the criteria and sub-criteria tested for the ANP method, as well as assessments related to Severity (S), Occurrence (O) and Detection (D) on the FMEA method for each of the highest modes of failure identified. Before data processing with the ANP method, first make a cold chain system model construction, here are the results of model construction for data processing with the ANP method based on interviews with related experts:

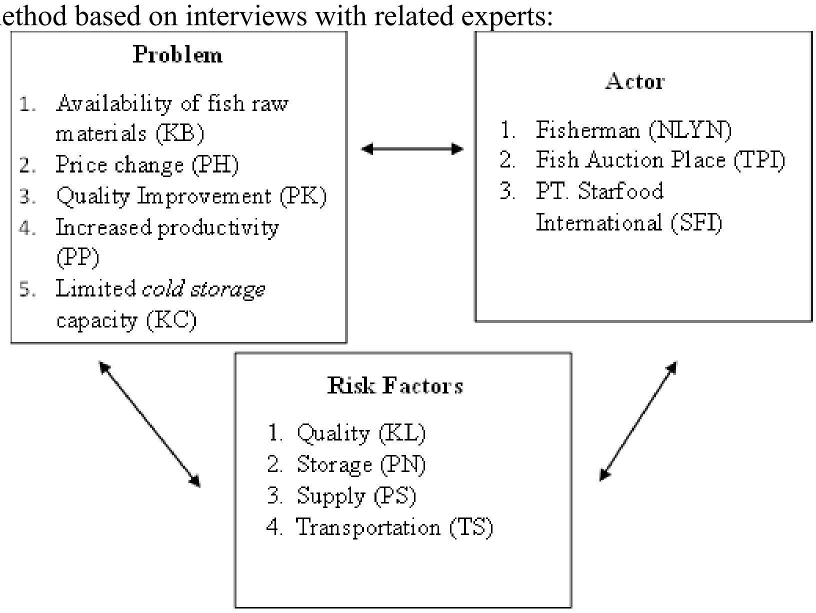

Figure 1. Model Construction *Cold Chain Sytem*

2.2. Data Processing

Data processing was carried out based on the results of the ANP and FMEA questionnaires that had been filled out by the respondents. The data obtained will be obtained through several stages. then the highest WRPN value will be obtained for risk control

2.2.1 Analytical Network Process (ANP)

In data processing with the ANP method, after obtaining the results of the questionnaire for the assessment of pairs and then processed using Super decision Software, the eigenvector value in each criterion for each cluster can be determined. This eigenvector reflects the relative weight or priority of the elements in the matrix. After calculating the eigenvector of the paired comparison matrix, the values are normalized so that the total is 1. This produces what is called a normalized by cluster value, the following are the normalized by cluster results obtained from data processing using super decision software:

Table.1 Hasil Normalized by Cluster

cluster	Criteria	Normalized By Cluster
Actor	Fishermen	0,16537
	TPI	0,40244
	PT. XYZ	0,43220
Problem	Availability of fish raw materials	0,19752
	Price changes	0,08685
	Quality improvement	0,25161
	Increased productivity	0,08889
	Limited *cold storage* capacity	0,37540
Risk Factors	Quality	0,44885
	Storage	0,27224
	Supply	0,18812
	Transportation	0,09080

After obtaining the normalized by cluster result, the next step is to calculate the Inconsistency Ratio result, the value of the inconsistency ratio obtained in the paired matrix does not reach 0.1. This shows that the assessment given by the respondents has been consistent and reliable. The next step is the calculation of the super matrix, the super matrix is a large matrix that includes all the comparisons between the elements, including the cluster relationship. Cluster-based normalized values are used to determine local priorities in the super matrix. The super matrix is then used to calculate the overall priority, resulting in a limit matrix that is used as a weight for each criterion and sub criteria. The results of the limit matrix calculation can be seen in the following table:

Table 2. Limit Matrix Calculation Result

Kluster	Kode	Kriteria	Limitting Supermatrix	Total Limit
Actor	NLYN	Fisherman	0,055122	0,3333
	XYZ	PT. XYZ	0,144066	
	TPI	TPI	0,134145	
Problem	KB	Availability of fish raw materials	0,065841	0,3334
	PH	Price changes	0,028859	
	PK	Quality improvement	0,083870	
	PP	Increased productivity	0,029631	
	KC	Limited *cold storage* capacity	0,125133	
Risk Factors	KL	Quality	0,149617	0,3364
	PN	Storage	0,090745	
	PS	Supply	0,065841	
	TS	Transportation	0,030266	

From the results of the limiting matrix obtained, it can be concluded that the cluster that has the highest total weight is a risk factor cluster of 0.3364, then for the problem cluster with a total weight of 0.3334, then for the actor cluster with a total weight of 0.3333. From the weight value, the risk factor cluster showed the highest level of importance compared to other clusters. Therefore, the cluster with the highest priority will be prioritized for further processing.

2.2.2 Failure Mode and Effect Analysis (FMEA)

The FMEA method is used to determine the priority of risk factors based on the Risk Priority Number (RPN) value. Based on the results of the risk causes of the highest modes of failure obtained in the ANP method and the Severity (S), Occurrence (O) and Detection (D) assessments obtained in the questionnaire results, the following results can be known:

Table 3. Results of Risk Processing with the FMEA Method

Modes of Failure	Cause of Failure	S	O	D	RPN	Total RPN
Quality	Microbial Contamination	7	5	5	175	1.141
	Employee Negligence		5	6	210	
	Sewage pollution		4	6	168	
	Procedures not followed correctly		4	6	168	
	Temperature fluctuations are too high or low		5	6	210	
	The fish received was already in a less fresh condition		6	5	210	
Storage	Limited *cold storage* capacity	7	7	7	343	1.687
	Temperature is not suitable		5	7	245	
	Storage is too long		6	8	336	
	Power outage without *generator backup*		5	9	315	
	Cold storage *doors* are often opened and closed		8	8	448	
Supply	Diversity in supply quality	6	7	7	294	810
	Uncertainty of supply availability		6	5	180	
	Post-arrest handling		4	6	144	
	Seasons and weather are erratic		4	5	120	
	Supplier Loyalty		3	4	72	
Transportation	Long transport distance	6	3	4	72	390
	Uncertainty of transportation time		4	5	120	
	Travel insecurity		3	6	108	
	Shipping delays		3	5	90	

Based on the results of data processing, the highest priority is storage risk with a cumulative RPN of 1,687, followed by quality risk with a total RPN of 1,141, transportation risk with a total of RPN 390, and transportation risk with a total RPN of 144.

2.2.3 Weighted Failure Mode and Effect Analysis (WFMEA)
After data processing is carried out using the ANP and FMEA methods, the next stage is the integration of the two methods, namely the *Weighted Failure Mode and Effect* Analysis (WFMEA) method to obtain *the Weighted Risk Priority Number* (WRPN). The WRPN value was obtained from the results of the final weighting of data processing using the ANP method for risk factors as the cluster with the highest final weight as seen in the Table. 2, then multiplied by the cumulative RPN result for each failure mode as shown in the Table. 3. The following are the results of the processing of risk control priority determination based on the integration of the *Analytical Network Process* and *Failure Mode and Effect Analysis* (FMEA) methods, so that the Weighted Risk Priority Number (WRPN) value for each risk will be obtained, can be seen in the following table:

Tabel 4. Results of ANP and FMEA Integration Calculation

Cluster	Criteria	Weight Value	RPN	WRPN	Risk categories	Risk Control
Risk Factor	Quality	0,149617	1.141	170,713	High	Mitigation
	Storage	0,090745	1.687	153,087	High	Mitigation
	Supply	0,065841	810	53,3312	Low	Receive
	Transportation	0,030266	390	11,8037	Very Low	Receive

The results of method integration showed that the quality risk factor had the highest WRPN of 170.713 and required mitigation, followed by storage risk with a WRPN of 153.087 which also required mitigation. Supply risk factors with a WRPN of 53.3312 and transportation with a WRPN of 11.8037 are included in the low and very low risk categories, so they do not require risk control. Failure modes with higher WRPN are given higher priority for corrective actions. The results of this study are different from the previous research by [9], regarding the Risk Management Analysis of the Implementation of Cold Chain System for Processed Fish where the highest value was obtained in supply, while in this study the highest value was obtained in quality.

3. Results and Discussion

After processing the data and being given a mitigation strategy, the results and discussions can be known as follows:

The results of data processing using the ANP method using Super decision software show the construction of the cold chain system model. After creating a paired comparison matrix between clusters, the relative weight value is normalized to 1 (normalized by cluster). The consistency test showed that the inconsistency ratio value did not exceed 0.1, indicating that the respondents' assessment was consistent and reliable. The final weighting results showed that the risk factor cluster had the highest weight of 0.3364, followed by the problem cluster with a weight of 0.3334 and the actor cluster with a weight of 0.3333.

The next stage is to use the FMEA method to obtain the RPN value and determine the high risk priority of each failure. The priority cluster is a risk factor with a weight of 0.3364, so it is necessary to identify the Effect of Failure, Cause of Failure, and Current Control. The results show that storage risk has the highest priority with an RPN value of 1,687, followed by quality risk with an RPN value of 1,141, supply risk with an RPN value of 390, and transportation risk with an RPN value of 144.

The next stage is the integration between the ANP method and the FMEA Method by multiplying the final weight value produced in the ANP method with the cumulative RPN results obtained in the FMEA method so that the Weighted Risk Priority Number (WRPN) value of each risk is obtained. Based on the results of the integration of the two methods, it was obtained that the quality risk factor had the highest WRPN value of 170.713 which was classified as a high risk category so mitigation was needed, followed by a storage risk factor with a WRPN value of 153.087 including a high risk category that required mitigation, followed by a supply risk factor with a WRPN value of 53.3312 which was classified as a low risk category so that control was not needed risk and transportation at the final priority with a WRPN value of 11.8037 which is classified as a very low risk category so that risk control is not required.

After obtaining the WRPN value, it is known that quality and storage risk factors require mitigation strategies. Mitigation actions for quality risk factors are as in the table below:

Table 5. Mitigation Strategies on Quality Risk Factors

Risk Factor	Cause of Failure	Mitigation Strategies
Quality	Microbial Contamination	Separating microbe-contaminated fish. Identify tipping points in the cold chain and strengthen contamination prevention protocols.
	Employee Negligence	Increasing supervision and monitoring at every stage of fish handling. Prevent employee burnout with task rotation and supervisor checks.
	Sewage pollution	Performs microbiological and chemical tests to detect contaminants. Ensuring only fish that meet the standards are further processed.
	Procedures not followed correctly	Sanction employees who do not comply with procedures. Provide ongoing training on SOPs.
	Temperature fluctuations are too high or low	Perform periodic calibration and maintenance on cold storage. Pack the fish in a material that can insulate the temperature.
	The fish received was already in a less fresh condition	Establish strict criteria regarding the condition of the fish received.

Table 6. Mitigation Strategies on Quality Risk Factors

Risk Factor	Cause of Failure	Mitigation Strategies
Storage	Limited *cold storage* capacity	Manage fish supply by forecasting demand and setting production schedules. Communicate with suppliers and distribution partners for planned deliveries.
	Temperature is not suitable	Regular maintenance of cold storage. Restricting access to cold storage for trained and authorized personnel.

Storage	Storage is too long	Applying the FIFO method for stock management. Schedule on-demand production to avoid overproduction.
	Power outage without *generator backup*	Using temporary ice storage during blackouts. Manually monitor cold storage temperature.
	Cold storage *doors* are often opened and closed	Setting an alarm for a cold storage door that is open for too long. Supervising employee work habits related to the use of cold storage doors.

4. Conclusion

Based on the results of research at PT. XYZ concluded that quality and storage risk factors have the highest priority with WRPN values of 170.713 and 153.087 respectively, which are classified as high risk and require mitigation. Mitigation measures for quality risks include separation of contaminated fish, identification of critical points in the cold chain, increased monitoring, prevention of employee fatigue through job rotation, microbiological and chemical testing, ensuring only fish meet processing standards, sanctions for non-compliance, SOP-related training, calibration and maintenance of cold storage, packaging of fish in temperature insulation materials, return of non-fresh products to suppliers, and the establishment of strict criteria for fish admission. Meanwhile, storage risk mitigation includes forecasting demand and setting production schedules, routine maintenance and maintenance of cold storage, restricting access only to trained and authorized personnel.

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