ISSN (Print): 0974-6846
ISSN (Online): 0974-5645
Indian Journal of Science and Technology, *Vol 11(24), DOI: 10.17485/ijst/2018/v11i24/117978 , June 2018*

Risk Analysis and Mitigation Using SCOR-Fuzzy ANP

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Abstract

Objective: To identify the supply risk and determine the mitigation strategies that can be applied. **Methods:** The first method used to analyze risk is SCOR, then risk assessment with fuzzy-FMEA method. The method which can be used is to analyze the risk weight by using Fuzzy method, then selected 80% of the risk that has the highest weight. Furthermore, the data is used to formulate risk mitigation strategy using Fuzzy ANP method. **Results:** The results of the study showed 80% risk with the highest weight. The results of this research found that the highest risk in the cultivation department is the risk of procedural errors in the process of manufacturing, maintenance or cultivation. While the highest risk for the manufacturing department is the risk of experiencing delays in the supply of mushrooms. Alternative strategies for supply risk mitigation on the part of the cultivation department such as consistent Standard operate procedure OP implementation strategies, timely pickup, and optimization of transportation availability, improvement and improvement of nursery planning. Alternative strategies for supply risk mitigation on the part of manufacturing such as increased communications and inter-division coordination, improved raw material fulfillment, increasing SOP tuning frequency, improvements and optimization of machine. **Application:** It is concluded that fuzzy FMEA can be used to analysis risk supply accurately and fuzzy ANP can formulate the risk mitigation strategy to support supply performance of high quality and high value selling canned mushroom products.

Keyword: Fuzzy-ANP, Fuzzy-FMEA, Mitigation, Supply, Supply Chain Operator Reference (SCOR), Risk

1. Introduction

Companies are required to meet the dynamic market demand in order to survive. Companies that make strategic decisions and implement it quickly and innovatively are capable achieving strategic competitiveness in both domestic and global markets[1]. The emergence of high quality products is not merely determined from the production process but also the provision of raw materials from suppliers as well as on time delivery process; those are some of the most crucial aspects. Thus successful achievements require effort from related company's network. Companies' networks that work together to create and deliver products to the consumers' hands are called supply chain.

Supply management is needed to maintain a company's consistency in achieving efficiency and competitiveness. The competitiveness of a company cannot be separated from the conditions including business implementation and balancing the quality both in the form of goods and services[2].

The methods that can be used for supply risk measurement are Supply Chain Operator Reference (SCOR), Fuzzy- Failure Mode and Effect Analysis (FMEA) and Fuzzy- Analytical Network Process (ANP). SCOR is used to describe supply chain in detail, define and categorize processes needed in the supply chain performance measurement[3].

Failure Mode and Effect Analysis (FMEA) analysis is implemented to identify potential failure forms based on the focus or priority obtained. Evaluating risk factors such as occurrence (O), severity (S) and detection (D) required by FMEA method may not be realistic in actual application. Instead of conventional FMEA, fuzzy FMEA can be used to evaluate risk[4]. The linguistic variables are used to evaluate three factors of severity, occurrence and

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detection as interpretations of FME factor ranging from 1-10[5]. Determining priority using ANP requires a model that represents the interconnection between the criteria and its sub-criteria. Fuzzy ANP is a combination of fuzzy and ANP method[6]. ANP method allows dependencies between criteria, between alternatives, and between criteria and alternatives which do not exist in AHP method[7]. ANP is able to describe reality better than AHP[8]. This method aims to control the chance of failure risk and also to design the mitigation strategy that will occur in supply performance.

One of the businesses that currently has excellent prospect is mushroom. Mushroom demand continues to increase. One of the business actors is PT ABC which is specialized in processing and canning button mushroom (*Agaricus bisporus*) for export purpose. This research analyzes and mitigates the risk of failure on supply and has a good supply management system and produces high quality and high value selling canned mushroom products.

2. Materials and Methods

This study employed a case study at PT ABC. The limitation of this study was identification of supply performance activity conducted at a company as mushroom supplier. Identification was not carried out on the distributors and consumer as the supply members, the risk being analyzed was not included in the company's financial risk. This research employed three data analyses, SCOR method for risk identification, Fuzzy Failure Mode and Effect Analysis (FFMEA) for determining the weight of risk on supply risk and Fuzzy Analytic Network Process (FANP) method for determining the priority of appropriate alternative strategy to minimize losses due to the risks occurred. The expert respondents involved in this research consisted of 4 respondents which were from the cultivation department including the head of post-harvest section and the head of composting section, and the factory / manufacturing department including the production manager and production supervisor.

The procedures in this research were preliminary survey, literature study, problem identification, research problems and research objectives formulation, data setting and data collection methods, expert determination and questionnaire preparation, supply activity identification, supply risk identification using SCOR, supply risk assessment using Fuzzy-FMEA method, supply risk mitigation strategies using Fuzzy-ANP method, recommendations, as well as conclusions and suggestions. The data analysis was carried out in the Agro-industrial Management Laboratory, Brawijaya University, Malang, Indonesia.

The data analyses were performed using SCOR, fuzzy FMEA (FFMEA) and fuzzy ANP (FANP) methods. The steps of the methods were described as follows:

2.1 SCOR

SCOR was used to describe current business processes and define the desired process[9]. SCOR processes which became the priority were *plan, source, make, deliver,* and *return*. The stages of data processing performed were:

1. Identifying the company's supply chain
   The company's supply chain identification was done by observing the company's supply chain system and preparing the company's supply chain framework using SCOR model approach.
2. Classifying supply chain activity based on supply chain perspective
   Five supply chain perspectives such as *plan, source, make, deliver* and *return* were classified by the main activity of each company's supply chain. Risk occurrence questionnaires were for *plan, source, make, deliver* and *return* on supply chain.
3. Determining and validating risk occurrence
   Risk occurrences which were designed using SCOR approach were based on the main perspective of the supply chain as *plan, source, make, deliver* and *return*. Once the risk occurrence was determined, then validation of the risk occurrence was actually represented by the company's supply chain performance.

2.2 Fuzzy-FMEA

FMEA method was used as the combination of several quality assessment methods to eliminate potential risks and build trust in the system[10,11]. FMEA identified the risk of failure and effect as three factors: severity, occurrence and detection. Severity (S) implied the consequences or impacts of failure. Occurrence (O) reflected the probability or frequency of failure. While detection (D) was the probability of failure which was detected before the effects were realized[12]. Another disadvantage of FMEA method was that all three factors were assumed to have the same importance, while it had to be adjusted based on the study case[13]. The steps that could be done to overcome the weakness were employing fuzzy math approach.

Table 1. Pair-wise comparisons scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
2	Moderate importance	Experience and judgment moderately favor one element over another
3	Strong importance	Experience and judgment strongly favor one element over another, indicating domination in practice
4	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
5	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation

Source:[15]

Fuzzy theory could solve the problem with descriptive parameters which were subjective, vague and inappropriate[14]. Fuzzy logic had membership value only 0 and 1 but its value was between 0 to 1.

The steps of Fuzzy FMEA analysis were as follows[4]:

1. Determining values of O, S, and D based on the scale, calculating aggregate of each factor O, S, and D,
2. Calculating aggregate weight of the relative importance of factor O, S, and D,
3. Determining Fuzzy Risk Priority Number (FRPN) for each failure model, and
4. Ranking the risk based on FRPN value in which the largest FRPN value became the top rank that had to be prioritized first.

2.3 Fuzzy-ANP

Further risk measurement results were used to determine the risk mitigation strategy for product development using ANP fuzzy method. The steps of the Fuzzy ANP method were:

1. Identifying criteria and sub-criteria,
2. Creating hierarchy structure and network relationship of ANP model, and
3. Determining the weight of the criteria, sub-criteria and each alternative with each criterion by using a pair-wise comparison matrix.
   – Calculating priority vectors
   – Calculating Consistency Ratio (CR)
   - Developing pair-wise comparison matrix.
   - The pair-wise comparison matrix was needed to calculate its impact on the compared alternatives with the measurement ratio scale 1-9 as in Table 1.
   - Calculating the priority vector for the main criteria
   - Calculating Consistency Ratio (CR), it was consistent if CR ≤ 10%.
     CR value was categorized as good if it indicated ≤ 0.1. If the CR value was ≥ 0,1, the questionnaires needed to be redistributed.

     Consistency Ratio: $CR = \frac{CI}{RI}$

     Notes:
     CI : Consistency Index
     RI : Random Index
     The requirement of Random Index can be seen in Table 2.

Table 2. Random index

UM	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.34	1.41	1.45	1.49

Source:[15]

   - Determining fuzzy comparison matrix.
     Chang's extent analysis method[15-16] and used to evaluate fuzzy pair-wise comparison[17] and in details, It used Chang's extent analysis method[18].

3. Results and Discussion

Assessment of Risk Events: The assessment results of the risk occurrences impacts on the cultivation department and factory department of PT ABC are listed in Table 3. The occurrence, severity and detection values for each failure mode were assessed by the respondents. The respondents involved in each of the supply were two

Table 3. Aggregate value of O, S, D in cultivation and manufacturing department

No.	Identified Risk Cultivation Department	O	S	D
1	Risk of demand and fluctuative mushroom yields	7.5	8	5
2	Risk of procedural error in manufacturing, maintenance or cultivation process	8.375	8.3	6
3	Risk of damaged seeds or decreased quality which was not in accordance with the standard	9.25	8.83	5
4	Risk of inappropriate post-harvest handling which affected the amount of yields	7.5	8.33	4.167
5	Risk of machinery and equipment breakdown	5	8	4
6	Risk of lack of cleanliness or sanitation of workers and environment	7.125	7.5	5
7	Risk of damaged mushroom due to post-harvest process delay	8.375	8	4.167
8	Risk of delay in seeds, fertilizer and compost supply	5	6	4.5
9	Risk of delay in mushrooms supply until shipment to manufacturing	7.5	8	4.5
10	Risk of time constraints to meet the increasing and sudden demand based on grade from manufacturing	7.5	8	4.5
Factory / Manufacturing Department				
1	Risk of discrepancy in the number of mushrooms required	6.25	4	6
2	Risk of delay in mushrooms supply	6.25	4.5	6
3	Risk of mushroom quality that did not meet the standard or request	6.25	6	4.5
4	Risk of production delay and warehouse scheduling errors due to lack of coordination	5	4	5.5
5	Risk of machinery and equipment breakdown in the production process which reduced yield productivity	3.75	3.5	7,5
6	Risk of product damage during production process	3.75	4.5	7
7	Risk of discrepancy between production results and demand/plan	5	35	6,5
8	Risk of mismatched number of demanded products	3	3.5	6,83
9	Risk of delay in products supply due to changes in the number of requests	3.75	5	5,5
10	Risk of rejected mushroom products that did not meet the standard	3.75	6.5	6

persons. After the assessment of two respondents, aggregation was performed by using equation; eq. (1) to (3). Thus the researchers got the value of occurrence, severity and detection. Occurrence showed the level of possibility or chance of failure. Severity indicated how serious the impacts due to failure. Detection revealed the detection rate that could be done by the cause of failure controls[4]. The three parameters of Severity (S), Occurrence (O), and Detection (D) were assumed to have the same importance; this ignored the importance of the three parameters that might be different in its application[5]. Assessment of aggregation result of occurrence, severity and detection value for each risk is shown in Table 3.

As seen in Table 3 the aggregation value of cultivation department indicated that the highest occurrence value was found in the risk of damaged seeds or decreased quality which was not in accordance with the standard, its value was 9.3. The highest severity value was found in the risk of damaged seeds or decreased quality which not in accordance with the standard, its value was 8.8. While the highest detection value was found in the risk of procedural error in manufacturing, maintenance or cultivation process, its value was 6. At occurrence value with risk of damaged seeds or decreased quality which was not in accordance with the standard, it was commonly found at a company especially cultivation department which led to cause a significant impact. It could be explained that in the period 1-31 January 2017 the number of broken mushroom in Kalitejo area was 6.02%. The damage increased compared to the period 1-31 March 2017 which indicated 6.17%. Thus the risk of damaged seeds or decreased quality which was not in accordance with the standards could significantly affect the number of damaged mushroom yields.

Furthermore, the aggregate value of manufacturing department indicated that the highest occurrence value was found in 3 risks, it was the risk of mushroom supply delay, risk of mushroom quality which was not in

accordance with the standard or demand and the risk of discrepancy in the number of required mushrooms; the value for each risk was 6.25. The highest severity value was found in the risk of rejected mushroom products that were not in accordance with the established standard, the value was 6.5. While the highest detection value was at the risk of machinery and equipment breakdown in the production process which reduced the productivity, the value was 7.5. Occurrence (O) reflected the probability or frequency of failure occurred. While detection (D) was the probability of failure which was detected before the impact was realized[12].

3.1 Calculation of Importance Weight and Occurrence, Severity and Detection Factors Aggregate

The weight value, fuzzy number and the mean aggregate value of occurrence, severity and detection factor in the factory / manufacturing and the cultivation department are shown in Table 4. The weight aggregate value of fuzzy number and the mean aggregation of occurrence, severity and detection factor in the factory / manufacturing and cultivation department are shown in Table 5.

Table 4. Weights, fuzzy numbers and respondent's average in cultivation and manufacturing departments

Assessors		Weight Factor	Fuzzy Number	Aggregate
Cultivation Department				
Expert 1	O	H	(0.5; 0.75; 1)	0.75
	S	H	(0.5; 0.75; 1)	0.75
	D	H	(0.5; 0.75; 1)	0.75
Expert 2	O	H	(0.5; 0.75; 1)	0.75
	S	H	(0.5; 0.75; 1)	0.75
	D	VH	(0.75; 1; 1)	0.92
Factory / Manufacturing Department				
Expert 1	O	L	(0; 0.25; 0,5)	0.25
	S	L	(0; 0.25; 0,5)	0.25
	D	H	(0.5; 0.75; 1)	0.75
Expert 2	O	M	(0.25; 0.5; 0.75)	0.5
	S	H	(0.5; 0.75; 1)	0.75
	D	M	(0.25; 0.5; 0.75)	0.5

In calculating the aggregate value, the existing fuzzy number was multiplied by the weight of the respondent's importance. The aggregate value of importance weights was used as the rank value for each factor in the FRPN calculation. It was consistent with a statement which explained that Fuzzy FMEA indicates that each factor has its own weight; it is in contrast to conventional FMEA which assumes all factors have equal importance weight[4]. The conventional FMEA did not take into account the relative importance of risk factors and treated them in the same degree of importance.

Table 5. Aggregate values of weight, fuzzy number and averages in cultivation and manufacturing department

Factor	Aggregate	Square
Cultivation Department		
Occurrence	0.75	0.321
Severity	0.75	0.321
Detection	0.83	0.357
Factory / Manufacturing Department		
Occurrence	0.375	0.25
Severity	0.5	0.333
Detection	0.625	0.416

FRPN Value Calculation

FRPN value was calculated based on the previous equations. Then, FRPN value of each risk was sorted from the largest to the smallest, in which the largest value was the highest rank. The largest or first rank of FRPN values indicated that this risk needed attention. FRPN was calculated based on two departments namely cultivation department and factory / manufacturing department. The results of FRPN value from the cultivation department for each risk can be seen in Table 6.

Based on Table 6, those risks were based on 80% of the risks. It was done by calculating the total FRPN of all risks and then the highest FRPN value (1st rank) was divided by total FRPN and multiplied by 100%. Then, the second FRPN value was calculated until it indicated 80%. It could be seen that the highest risk on the fresh mushroom products supply of cultivation department was the risk of procedural errors in manufacturing, maintenance or cultivation process, its value was 7.423. The results of FRPN value from the manufacturing side for each risk can be seen in Table 6. It was known that the highest risk of mushroom products supply for the manufacturing side was the risk of delay in mushrooms supply with 5.507.

Table 6. FRPN values of cultivation and manufacturing department

No.	Statement	FRPN	Ranking
Cultivation Departments			
1	Risk of procedural error in manufacturing, maintenance or cultivation process	7.423	1
2	Risk of seeds damaged or decreased quality which was not in accordance with the standard	7.316	2
3	Risk of demand and fluctuative mushroom yields	6.625	3
4	Risk of damaged mushroom due to post-harvest process delay	6.431	4
5	Risk of lack of cleanliness or sanitation of workers and environment	6.383	5
6	Risk of delay in mushrooms supply until shipment to manufacturing	6.380	6
7	Risk of time constraints to meet the increasing and sudden demand based on grade from manufacturing	6.380	7
8	Risk of inappropriate post-harvest handling which affected the amount of yields	5.369	8
Factory / Manufacturing Department			
1	Risk of delay in mushrooms supply	5.507	1
2	Risk of rejected mushroom products that did not meet the standard	5.479	2
3	Risk of mushroom quality that did not meet the standard or request	5.377	3
4	Risk of discrepancy in the number of mushrooms required	5.295	4
5	Risk of product damage during production process	5.169	5
6	Risk of discrepancy between production results and demand/plan	4.952	6
7	Risk of machinery and equipment breakdown in the production process which reduced yield productivity	4.892	7
8	Risk of delay in products supply due to changes in the number of requests	4.842	8

Table 7. Criteria and alternative strategy of risk mitigation in cultivation and manufacturing department

Criteria	Alternative Strategy
Cultivation Department	
SOP Formulation and Implementation	Consistency of SOP implementation (A1)
	Control function improvement (A2)
	Determination of SOP standardization based on requirements to maintain quality (A3)
Quality Decrease	Improvement in maintaining seed stability (B1)
	Timely picking (B2)
	optimization of human resources performance to maintain quality (B3)
Mushroom Supply Delay	Optimization of transportation availability (C1)
	Standardization of harvesting speed (C2)
	Consistency of SOP implementation based on requirements to maintain quality (C3)
Harvest Instability	Communications and coordination betterment among divisions (D1)
	Seedling plan revision and improvement (D2)
	Briefing and socialization improvement for human resources to maintain quality (D3)

Criteria	Alternative Strategy
Factory / Manufacturing Department	
Mushroom Raw Materials Availability	Updating the schedule of mushroom raw material availability (A1)
	Communications and coordination betterment among divisions (A2)
	Improvement of mushroom supply control (A3)
Mushroom Quality	Factory performance maximization (B1)
	Product handling optimization based on quality standard (B2)
	Improvement of raw materials fulfillment (B3)
SOP	Consistency of SOP implementation (C1)
	Increasing the frequency of SOP assessment (C2)
	Regular SOP improvement (C3)
Equipment and Transportation	Optimization of transportation availability (D1)
	Preventive and corrective engine maintenance (D2)
	Improvement and optimization of machinery and equipment (D3)

3.3 Supply Risk Mitigation using Fuzzy ANP Method

Fuzzy FMEA method was employed in the formulation of risk mitigation strategies based on the risks that existed in each stage that have been analyzed previously. Based on that risk, four criteria were formed along with its alternative strategies that were used to minimize losses due to the risks. It was processed by using FANP method. The criteria and alternatives of supply risk mitigation strategies in the cultivation and factory department can be seen in Table 7.

3.4 Organizing Hierarchy Structure and ANP Network Relationship

The hierarchy structure of ANP model was based on inner and outer dependence relationships.

1. *Inner Dependence Relationship of Cultivation Department*

   The inner dependence relationship indicated an element relation in one criterion marked by a rotation line in the ANP hierarchy[19]. The inner dependence relationship employed in this study was as follows:

   1. Alternative strategy on SOP criteria, consistency of SOP implementation, improvement of control function; determination of SOP standardization based on requirements to maintain quality
   2. Alternative strategies on Quality Decrease criteria, improvement in maintaining seed stability; timely picking, optimization of human resources performance.
   3. Alternative strategy on mushroom supply delay criteria, optimization of transportation availability, standardization of harvesting speed, consistency of demand planning that should be based on the quality maintenance agreement.
   4. Alternative strategies on harvest instability criteria, communications and coordination betterment among divisions, seedling plan revision and improvement, briefing and socialization improvement for human resources to maintain quality.

2. *Outer Dependence Relationship of Cultivation Department*

   The relationship of outer dependence indicated that there was a relationship between the elements in criteria A and the elements criteria B[19]. The relationship of outer dependence employed in this study was as follows (Figure 1):

   1. Relationship between SOP criteria, and quality decrease and harvest instability criteria,
   2. Relationship between quality decrease criteria, and mushroom supply delay and harvest instability criteria,
   3. Relationship between mushrooms availability delay, and quality decrease and harvest instability criteria, and
   4. Relationship between harvest instability criteria, and quality decrease and mushroom supply delay criteria.

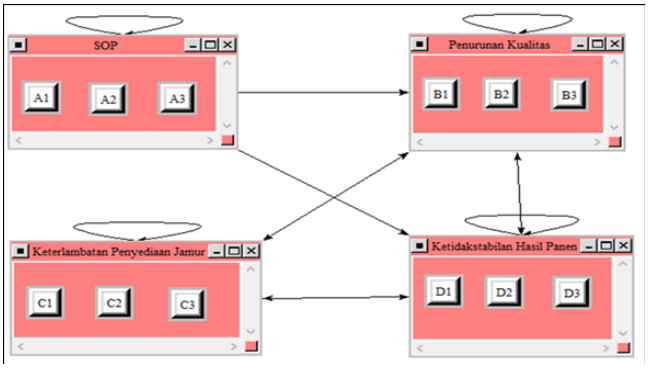

Figure 1. Relationship of supply risk mitigation strategy network in cultivation department.

Note: A ⟶ B : Influenced Relationship
A ⟷ B : Interaction Relationship
: Influenced between alternative in one criterion

3. *Manufacture Department Inner Dependence Relationship*

The inner dependence relationship used in this study was as follows:

1. Alternative strategy on the availability criteria of mushroom raw materials, Updated schedule of the availability of mushroom raw materials; Improved communication and coordination among divisions; Increased control of mushroom raw materials supply,
2. Alternative strategy on the quality criteria of mushroom, maximizing the factory performance; optimizing product handling according to quality standard; increased raw material fulfillment,
3. Alternative strategy on the SOP criteria, Consistency of SOP performance; Increasing SOP assessment frequency; Periodically SOP improvement, and
4. Alternative strategy on the equipment and transportation criteria, optimizing transportation availability; Preventive and Corrective Machine maintaining; machine and transportation optimization and restoration.

4. *Manufacture Department Outer Dependence Relationship*

The outer dependence relationship used in this study was as follows (Figure 2):

1. The relationship between the criteria of the availability of mushroom raw materials with the criteria of SOP and Equipment and Transportation,
2. The relationship between the criteria of the mushroom quality with the criteria of SOP and Equipment and Transportation,
3. The relationship between the criteria of the SOP with mushroom quality and mushroom raw materials availability, and
4. The relationship between the criteria of the equipment and transportation with the criteria of SOP and mushroom raw material availability.

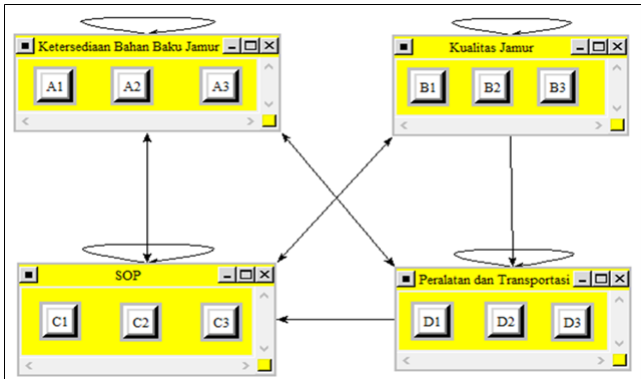

Figure 2. The relationship of supply risk mitigation network strategy of manufacturing department.

Note: A ⟶ B : Influenced Relationship
A ⟷ B : Interaction Relationship
: Influenced between alternative in one criterion

3.5 Criteria Weight Determination

These criteria weighting was done to know the criteria that would be the priority. Based on the FRPN measurement, it got highest risk in cultivation and factory department as seen on Table 8.

The result of fuzzy ANP calculation by two experts from the risk factor of the cultivation department can be seen in Table 8. Based on Table 8 it could be seen that the calculation result of normalization of vector weight of 4 risk factors was obtained from expert 1 which was 0.508; 0.253; 0.137; 0.102. Expert 2 resulted 0.043; 0.406; 0.144; 0.406. After obtained the result of normalization value of vector weight then aggregate calculation of risk factor was done. Table 9 shows the aggregate results among the risk factors. The aggregate results indicated the priority or ranking in determining the mitigation of mushroom product supply risks. The risk on Standard Operational Procedure (SOP) became the most dominant risk factor of 0.344.

Table 8. Recapitulation of result of calculation F ANP risk criteria factor for department of cultivation

Risk Factor	Expert	Criteria Weight Vector	FANP Weight Vector Normalization
Formulation and Implementation of SOP	Expert 1	1	0.508
Quality Decrease		0.499	0.253
Delay of Mushroom provision		0.269	0.137
Unstable Yield		0.201	0.102
SOP	Expert 2	0.106	0.043
Quality Decrease		1	0.406
Delay of Mushroom provision		0.354	0.144
Unstable Yield		1	0.406

Table 9. Results of aggregate risk factors of the department of aquaculture

Risk Factors	Result of Aggregate Risk	Ranking
Formulation and Implementation of SOP	0.344	1
Quality Decrease	0.291	2
Delay of Mushroom Provision	0.148	4
Unstable Yield	0.176	3

3.6 Calculation of Alternative Strategies

ANP fuzzy calculation was from two experts on four risk factors. After obtained the result of normalization value of vector weight, then aggregate calculation between alternative of strategy was performed. The result of aggregate between strategies was obtained from the average value of normalization of the vector weight which was the end of the calculation of the FANP value of each strategy that was rooted in accordance with the number of experts that is 2. The aggregate value between the strategies on the four criteria can be seen in Table 10.

Table 10. Strategy aggregate value for 4 risk factors

Risk Factors	Alternative Strategy	Strategy Aggregate Value	Ranking
Formulation and Implementation of SOP	Consistency in performing SOP	0.065	1
	Controlling function improvement Standard Setting	0	3
	SOP based on quality require-ment to keep the quality	0	2
Quality Decrease	Improvement in maintaining seed stability	0.098	2
	Timely picking	0.190	1
	Human resource performance optimization. Risk of maintaining quality	0	3
Delay of Mushroom Provision	Optimization of transportation availability	0.100	1
	Standardization of employee picking speed	0	3
	The consistency of demand planning must be appropriate as the agreement of maintaining quality	0.048	2
Unstable Yields	Improvement of communication and coordination between divisions	0	3
	Improvement and improve-ment of nursery planning	0.082	1
	Improvements in direction and socialization of human resources to maintain quality	0	2

Table 10 shows the aggregate weighting value of each strategy for minimizing the highest risks that occur on the cultivation department. Therefore, appropriate strategies were needed to minimize the risk.

3.7 Risk Mitigation Alternative Strategy of Cultivation Department

1. *Consistency of SOP implementation*
   SOP implementation consistency strategy got first priority of SOP criteria. This strategy had the highest value to reduce the risk of SOP, its value was 0.065. This strategy was carried out to maintain the consistency and continuous implementation of SOPs to keep all processes conducted in accordance with existing procedures in the company or in the area of cultivation. According to[20], SOP served as a guideline in the company to ensure the steps of each member has been running effectively and consistently.
2. *Timely Picking*
   A timely picking strategy got the first priority of quality degradation criteria. This strategy had the highest value to reduce the risk of quality decrease that was equal to 0.190. This strategy was done to reduce the occurrence of damage to the harvest of mushroom, because picking time delay led to various kinds of possibilities. One of them was damage the mushroom products itself resulting in a downgrade. It was consistent with[21] harvesting exceeding the prescribed time limit allows damage to the mushroom.
3. *Optimization of Transportation availability*
   Optimization Strategy of Availability Transportation got the first priority of delays in supplying the mushroom. This strategy had the highest value to reduce the risk of delay in providing mushroom that was equal to 0.1. This strategy was done to smooth the process of distributing fresh mushrooms during the journey from the cultivation area to the manufacturing so that the distribution / travel became efficient. According to[22] the importance of paying attention to the duration of travel on transportation options not only from the results of research, but considering the actual value of capital distribution in different corridors.
4. *Improvement and Increasing Seedling Planning*
   Strategy of improvement and increasing seedling planning got the first priority of the seeds failure criteria. This strategy had the highest value to reduce the risk of volatility of crops that was equal to 0.082. The improvement and increasing strategy of the nursery planning was done to overcome the problem in the unstable result of the harvest so that the need to improve the scheduling of planting or breeding in mushroom. According to[23] the success of controlling environmental conditions is crucial to the success of mushroom breeding.

3.8 Risk Mitigation Supply of Factory Department (Manufacturing)

On the factory department, the risks were taken to minimize the four risks. Among them the risk of the availability of mushroom raw materials, the quality of mushrooms, SOPs, equipment and transportation. Result of calculation of normalization of vector weight of 4 risk factor got result from expert 1 equal to 0,416; 0.196; 0.023; 0.364. Expert 2 had 0.175; 0.280; 0.175; 0.370. The result of normalization calculation of vector weight obtained from calculation of fuzzy synthetic extent taken minimum from the result can be seen in Table 11. Calculation of vector weight and normalization of vector weight have range of value from 0 to 1.

Table 11. Recapitulation of FAHP calculation result of risk factor of manufacturing

Risk Factors	Expert	Vector Weight Criteria	FANP Normalization Vector Weight
Mushroom raw Material Availability	Expert 1	1	0.416
Mushroom Quality		0.472	0.196
SOP		0.056	0.023
Equipment and Transportation		0.873	0.364
Mushroom raw Material Availability	Expert 2	0.471	0.175
Mushroom Quality		0.756	0.280
SOP		0.471	0.175
Equipment and Transportation		1	0.370

After the researchers got the result of vector weighted normalization value then the researchers did aggregate calculation of risk factor. The aggregate results among the risk factors were derived from the average value of weighted vector normalization that was the end of the calculation of the FANP value of each risk factor that was rooted in accordance with the number of experts which was 2. The aggregate value on the manufacturing risk factor can be seen in Table 12. Based on Table 12, it was obtained the results of aggregate among risk factors.

The aggregate results indicated the priority or ranking in determining the mitigation of mushroom product supply risks. The availability of mushroom raw material became the most dominant risk factor of 0.321.

Table 12. Results of aggregate risk factors by two experts

Risk Factors	Results of Aggregate Risk Factors	Ranking
Mushroom raw Material Availability	0.321	1
Mushroom Quality	0.269	2
SOP	0.147	4
Equipment and Transportation	0.244	3

3.9 Calculation of Alternative Strategies

ANP fuzzy calculation was from two experts on four risk factors. After obtained the result of normalization value of vector weight, then aggregate calculation between alternative of strategy was done. The aggregate results between the strategies were derived from the average value of normalization of the vector weight which was the end of the calculation of the FANP value of each strategy that was rooted in accordance with the number of experts that was 2. The aggregate value among the strategies in the five risk factors can be seen in Table 13.

3.10 Risk Mitigation Alternative Strategy of Factory Department

1. *Improved Communication and Coordination among Divisions*
   Improved communication and coordination among divisions strategy got the first priority on the availability of raw materials. This strategy had the highest value to reduce the risk of raw material availability of 0.218. The strategy to improve communication and coordination among divisions was done so that in distributing fresh mushrooms to the company did not experience problems and constraints. According to[24] the not-maximally use of information and communication technology in coordinating is not due to limited facilities and capabilities but because there is a need that cannot be met if coordination is done by maximizing the utilization of information and communication technology.
2. *Increasing the fulfillment of raw materials*
   The strategy of increasing the fulfillment of raw materials got the first priority of mushroom quality criteria. This strategy had the highest value to reduce the risk of the quality of mushrooms that was equal to 0.126. The strategy of increasing raw material fulfillment was aimed to not run out of mushroom supply and delays of fresh mushroom supply and cold minimize expense to material handling cost. According to[25] based on

Table 13. Aggregate value strategy for 5 risk factors

Risk Factors	Alternative Strategy	Strategy Aggregate Value	Ranking
Mushroom Raw Material Availability	Update scheduling availability of mushroom raw materials	0	3
	Improved communication and coordination among divisions	0.218	1
	Increased control of raw materials of mushrooms supply	0.054	2
Mushroom Quality	Maximize factory performance	0.084	2
	Optimization of product handling according to quality standard	0.054	3
	Increased raw material fulfillment	0.126	1
SOP	Consistency of SOP implementation	0.039	2
	Increase the frequency of SOP assessment	0.061	1
	SOP improvements periodically	0.039	3
Equipment and Transportation	Optimization of transportation availability	0	3
	Preventive and corrective machine maintenance	0.035	2
	Improvement and optimization of machine and equipment	0.147	1

planning and production schedules, material management must plan raw materials because effective planning can reduce inventory costs and production costs.

3. *Increasing Frequency of SOP Assessment*
   The strategy of increasing the frequency of SOP assessment got the first priority of SOP criteria. This strategy had the highest value to reduce the risk of SOP that was equal to 0.061. This strategy was done to increase the frequency of SOP assessment. Maintain consistent and continuous implementation of the SOP to keep all processes was conducted in accordance with existing procedures in the company or at work.
4. *Improvement and Optimization of Machine and Equipment*
   The improvement and optimization strategy of machine and equipment got the first priority for equipment and transportation. This strategy had the highest value to reduce equipment and transportation risk that was equal to 0.147. Improvement and optimization of machine and equipment was required so that machines and production equipment would not suffer any damage soon nor did it hamper the smooth production of mushroom products. According to[26] the need for maintenance measures periodically to keep the engine performance well. One of the appropriate strategies was the replacement of components with the determination of component replacement intervals so that it would be able to improve the reliability of the system and engine so that it could operate optimally.

4. Conclusion

1. The calculation result with FMEA fuzzy on the cultivation department took eight highest risk of FRPN; the risks were taken based on 80% of the risks. The highest risk on the supply of fresh mushroom products of the cultivation department was the risk of procedural errors in the process of manufacture, maintenance or cultivation by 7.423. The lowest risk of supply of mushroom products at PT ABC for the cultivation department was the risk of postharvest handling which was wrong or inappropriate to affect the amount of crops, its value was 5.369. The highest risk that occurred in the supply of mushroom products for the manufacturing sector was the risk of delay in mushrooms supply which indicated 5.507. The risk of delay in the supply of mushrooms was indeed a major problem faced by the factory department. The lowest risk of mushroom products supply at PT ABC for the manufacture was the risk of delay in products supply due to changes in the number of requests, the value was 4.842.
2. The alternative strategies for supply risk mitigation in cultivation department included the consistency of SOP implementation strategy, timely picking, and optimization of transportation availability, revision and improvement of seedling planning. The alternative strategies for supply risk mitigation in manufacturing department included improving communication and coordination among divisions, increasing raw materials provision, increasing the frequency of SOP assessment, and improvement and optimization of machine and equipment.

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