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Supply Chain Risk Mitigation Analysis on Coffee Comodities Using the Integration of FMEA and HOR Methods

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Abstrak

Kopi telah menjadi komoditas global sejak awal penemuannya, sehingga tidak mengherankan jika terdapat variasi budidaya kopi yang beragam di berbagai wilayah. Secara ekonomi, kopi memiliki peran yang penting bagi negara-negara penghasil kopi, dimana kopi dibudidayakan dan di produksi, termasuk di Indonesia. Perusahaan ini merupakan salah satu perusahaan yang bergerak di bidang manufaktur produksi kopi bubuk. Dalam usahanya untuk memenuhi target pasar, perusahaan ini mengalami kendala. Oleh karena itu dilakukan analisis rantai pasok pada proses produksi kopi untuk mengidentifikasi risiko yang terjadi. Penyenyelesaian masalahan dalam penelitian ini menggunakan integrasi metode FMEA dan HOR. Penerapan integrasi metode tersebut dalam kaitannya dengan analisis mitigasi risiko rantai pasok juga sudah banyak dilkembangkan. Berdasarkan hasil identifikasi risiko pada HOR tahap I, terdapat 17 kejadian risiko yang disebabkan oleh 25 penyebab risiko. Dari 25 penyebab risiko, bedasarkan perhitungan ARP diperoleh 11 penyebab risiko dominan. Kemudian pada HOR tahap II dirancang 17 langkah mitigasi untuk mencegah ataupun meminimalisir 11 risiko dominan yang diperoleh dari hasil perhitungan HOR fase I. Setelah dilakukan perhitungan total efektifitas serta derajat resulitan, diperoleh hasil perangkingan efektivitas mitigasi berdasarkan rasio kesulitan (ETDk) dengan nilai tertinggi melakukan pemeliharaan preventif rutin pada peralatan penggilingan untuk mencegah kerusakan dan ketidakstabilan proses (PA 7) sebesar 16143.21, dan ranking terakhir mempersiapkan cadangan mesin kopi atau komponen penting untuk mengurangi downtime produksi (PA 16) sebesar 1406.16.

Kata Kunci: FMEA, HOR, manajemen risiko, rantai pasok

Abstract

Coffee has been a global commodity since its discovery, so it's not surprising that there are various coffee cultivation variations in different regions. Economically, coffee plays a significant role in coffee-producing countries, including Indonesia, where it is cultivated and produced. The company is one of the companies engaged in the manufacturing of powdered coffee production. In its efforts to meet market targets, the company faces challenges. Therefore, a supply chain analysis is conducted on the coffee production process to identify occurring risks. The resolution of issues in this research utilizes the integration of FMEA and HOR methods. The application of these integrated methods about supply chain risk mitigation analysis has also been widely developed. Based on the risk identification results in HOR stage I, there are 17 risk events caused by 25 risk causes. Out of 25 risk causes, 11 dominant risk causes are obtained based on ARP calculations. Then, in HOR stage II, 17 mitigation steps are designed to prevent or minimize the 11 dominant risks obtained from the HOR phase I calculations. After calculating the total effectiveness and degree of difficulty, the results of the mitigation effectiveness ranking based on the difficulty ratio (ETDk) with the highest value carried out routine preventive maintenance on milling equipment to prevent damage and process instability (PA 7) of 16143.21, and the last rank prepared a backup of coffee machines or critical components to reduce production downtime (PA 16) of 1406.16.

Keywords: *FMEA, HOR, risk management, supply chain*

INTRODUCTION

Coffee is one of the most common consumed beverages around the world due to its stimulative effect and desirable bitter taste (Gokcen & Sanlier, 2019). With increasing interest in the role of coffee in health, general knowledge of population consumption patterns and within the context of the full diet is important for both research and public health. Overall, coffee and tea contributed to less than 10% of the energy intake (Cornelis, 2019). Roasted coffee is a complex mixture of thousands of bioactive compounds, and some of them have numerous potential health-promoting properties that have been extensively studied in the cardiovascular and central nervous systems, with relatively much less attention given to other body systems, such as the gastrointestinal tract and its particular connection with the brain, known as the brain–gut axis (Dehond *et al.,* 2021). Coffee has recently begun to be loved by all circle communities, it is indicated by the proliferation of some coffee shops with various types and types of modern presentations (Maspul, 2022). Coffee sector is highly dependent on international prices and affected by the structure and workings of the world coffee market. Notwithstanding the severe price shocks that have been shacking its value chain, coffee remains a fundamental component of economy and export (Degaga, 2020).

The development of Indonesia's economy is inseparable from the contribution of the agricultural sector as a source of foreign exchange and job provider contributed by the plantation sub-sector (Rasoki & Nurmalia, 2021). According to the 2023 Indonesian Statistical Report from the Central Statistics Agency, Indonesia's coffee production reached 794.8 thousand tons in 2022, an increase of about 1.1% compared to the previous year (Badan Pusat Statistik, 2023). Coffee contributes 33.67% of the total export of Indonesian plantation commodities (International Coffee Organization, 2019). The role of coffee commodities for the Indonesian economy is quite significant, both as a source of income for coffee farmers, foreign exchange earners, raw material producers for industry, and job providers through processing, marketing, and trade activities (exports and imports) (Ditjen Perkebunan, 2015). Therefore, it can be said that coffee is an Indonesian export flagship commodity and plays an important role in the Indonesian economy.

Tabanan regency is one of the most coffee-producing regions in Bali. Companies in this research is one of the largest manufacturing companies in Tabanan regency engaged in coffee production. In meeting the company's targets, The company often experiences obstacles so that the realization of coffee powder production can only meet a few percent of the desired production target. Once identified, the difference between realization and production target is influenced by many factors, including market price fluctuations, delays in the arrival of raw materials, and raw materials that are not in accordance with specifications. One form of response from the company to the issues is conducting risk mitigation analysis to identify, evaluate, and reduce risks that may affect production activities. The main objective of risk mitigation analysis is to minimize the negative impacts of these risks and enhance company productivity. Risk assessment plays a vital role in reducing project risks and achieving sustainable development. The risk evaluation can provide suitable decisions when we face choices among different actions (Ouyang *et al.,* 2021).

In this study, risk mitigation analysis is conducted by integrating the Failure Mode and Effect Analysis (FMEA) and House of Risk (HOR) methods. The FMEA method is a suitable method for assessing the risks of organizing a running event and determining safety measures. Its advantage is a detailed assessment of risks in individual processes, activities of the organization with a connection to the entire management system. The use of the method will ensure detailed preparation for the event in terms of prevention in the planning process (Kardos et al., 2021). FMEA is an analysis technique that combines technology and experience to identify production process failures and plan to prevent their recurrence (Atin and Lubis, 2020). Usually, FMEA is ranked by experts on the basis of process under analysis; RPN is the product ranked on three values, from 1 to 10: Severity (S), Occurrence (O), and Detection (D), the final value of the RPN ranks the critical potential failure modes (PFMs) in the process analyzed, helping to take decisions based on possible risks. Next, based on the previous established range of the RPN value, contingency plans must be applied to avoid the risk of possible failure in the process under analysis (Aguirre *et al.,* 2021).

The purpose of FMEA is to prevent unacceptable failures and assist management in allocating resources more efficiently (Mustaniroh *et al.,* 2020). HOR is a modification of Failure Modes and Effect of Analysis (FMEA) and House of Quality (HOQ) to prioritize which risk sources are first selected for the most effective action to reduce the potential risks from these sources (Tanjung *et al.,* 2019). This method is generally often used to identify the problem (risk) in the supply chain (supply chain). The advantages of this method lies in the framework for the planning of proactive strategies to mitigate risks that arise and create a healthy supply chain. In the HOR method a risk agent (risk agent) is chosen that has the highest probability of occurrence and a severe risk event. Then mitigation measures are arranged that can reduce risk agents with the highest priority (Wibowo & Ahyudanari, 2020). HOR 1 is used to determine the ranking of each risk agent based on its aggregate risk potential. Meanwhile, HOR 2 is intended to prioritize proactive actions that the company should take to maximize the cost-effectiveness of efforts in dealing with the selected risk agents in HOR 1 (Ahmad *et al.,* 2020).

The application of Failure Mode and Effect Analysis (FMEA) and House of Risk (HOR) in relation to supply chain risk mitigation analysis has also been extensively developed. In 2017, in a study by Helmi (2017) on Risk Mapping and Mitigation of Small and Medium Enterprise Clothing Product Using SCRM, with indicators such as price fluctuation, shipping, forecasting, and warehouse condition. This study discusses risk mitigation design for SME clothing products using FMEA and HOR methods. In this study, the proposed preventive actions were still general and did not provide solutions for potential risk events. In the following year, Ummi (2018) conducted a study on Integration HOR and ANP for Supply Chain Risk Mitigation of Cassava Opak Chips Industry, with indicators such as shipping, price fluctuation, coordination, environment, product quality, and automation. This study discusses risk mitigation analysis in the cassava chips industry supply chain using the integration of HOR and ANP. However, this study did not explain the data collection techniques and parameters used in selecting respondents to fill out the severity and occurrence scales, thus the data obtained may be less reliable. In this study, I also conducted a risk identification of the supply chain from upstream to downstream, starting from product planning activities, procurement, transformation of raw materials into finished products, shipping and distribution, to the product return stage. In this study, I also used validity and reliability tests to determine whether the measurement instruments I used are consistent and reliable, thus producing effective and accurate research results.

RESEARCH METHOD

Research Location

Tabanan Regency is one of the largest coffee-producing regions in Bali besides Kintamani. According to data from the Tabanan Regency Department of Agriculture, the area of coffee plantations reaches 9,585.87 hectares (Dinas Pertanian Kabupaten Tabanan, 2022). The research location is conducted at the company located at Jl. Yeh Gangga I, Gubug Delodan. Companies in this research is one of the companies engaged in manufacturing to produce powdered coffee. The company has been established since 2009 with its main operational activity being the production of robusta and arabica powdered coffee.

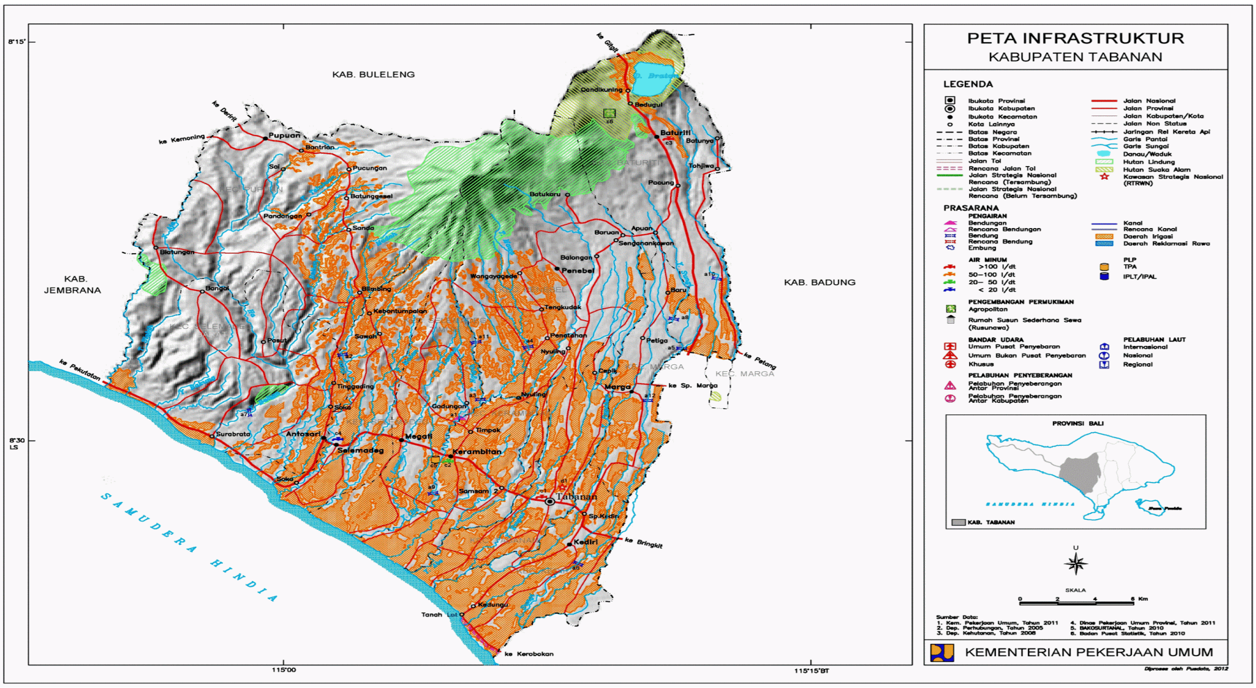

Figure 1. Research's Location

Data Collection Method

Data collection was conducted at the company, a manufacturing company involved in the production of coffee commodities. The data collected in this study included interviews and brainstorming results based on risk mapping activities in the company's supply chain from upstream to downstream, followed by the preparation and distribution of questionnaires. The data required in this research are product demand data, production schedule data, production quantity data, defective product quantity data, warehouse capacity data, delivery schedule data, and quantity of returned goods data. Brainstorming was used to identify potential risk events and their causes, while questionnaires were used to determine the severity level of risk events, the occurrence probability of risk causes, and the correlation between risk events and their causes. Interviews and questionnaire completion were carried out by personnel involved in the supply chain activities with high competence in the field. In this study research samples were including managers and staff members from the supply chain and logistics department.

Analysis Method

After distributing the questionnaire to 6 respondents, based on the FMEA concept an assessment will be carried out on the severity of the risk and the probability of risk occurring based on the scale below:

Table 1. Severity and Occurrence Scale of Risk Analysis

Rank	Severity	Occurrence
1	None	Almost certain
2	Very minor	Very high
3	Minor	High
4	Low	Moderately high
5	Moderate	Moderate
6	Significant	Low
7	Major	Very low
8	Extreme	Remote
9	Seriously	Very remote
10	Dangerous	Absolutely remote

Source : Suryani et.al, 2023

Then validity and reliability tests were carried out using SPSS 23 software. Validity test is a test that functions to see whether a measuring instrument is valid or invalid. The measuring instruments referred to here are the questions in the questionnaire. A questionnaire is said to be valid if the questions in the questionnaire can reveal something that is measured by the questionnaire (Miftahul Janna & Herianto, 2019). Questionnaire data validity testing aims to ensure that the questionnaire used in research measures what it should measure in a correct and reliable way. Validity testing helps ensure that the questionnaire produces accurate and reliable data. Based on the concept of validity testing, the comparison of r_{count} and r_{table} values is:

1. If the value $r_{count} > r_{table}$ = valid.
2. If the value $r_{count} < r_{table}$ = invalid.

Reliability is a test to measure the extent to which an instrument provides stable and consistent results. This test is important because it refers to the consistency of the entire instrument (Nur Amalia et al., 2022). The decision-making criteria in reliability testing are as follows:

1. If Cronbach's Alpha value > 0.60, then the questionnaire's items can be considered reliable.
2. If Cronbach's Alpha value < 0.60, then the questionnaire's items cannot be considered reliable.

If the data is valid and reliable then proceed to the HOR analysis stage 1 which focuses on finding dominant risk events that must be carried out mitigation actions first. The dominant risk agent is obtained from the results of the ARP calculation and then mapped using a pareto chart using the concept 80% : 20%, meaning that the priority problems that must be resolved are problems with a percentage of up to 80%. The Aggregate Risk Potential (ARP) value is obtained using the formula:

$$ARPj = Oj \sum Si \, Rij \quad \text{..................................} \quad (1)$$

Where :

ARP = Aggregate Risk Potential

O_j = Occurrence

S_i = Severity

R_{ij} = Relationship

After obtaining the dominant risk agent, the analysis continues to HOR stage 2 where mitigation strategies will be designed to prevent or minimize risk agents that appear in the company's supply chain process. In HOR phase 2, the Total Effectiveness of Action (TEk) is calculated. The TEk value is obtained from the value between the Aggregate Risk Potential (ARP) of each risk agent which is correlated with each other and then multiplied by the correlation value. The TEk calculation is obtained using the formula:

$$TEk = \sum ARPjEjk \text{..................... (2)}$$

Where:

TE_k = Total Effectiveness of Action

ARP = Aggregate Risk Potential

Ej_k = Correlation between risk agent and mitigation action

After getting the TEk value and knowing the value of each mitigation action, the next step is to calculate the ETDk. The ETDk value is obtained from the TEk value divided by the Dk value. The following is an example of calculations and ETDk results for mitigation strategies:

$$ETDk = TEk/Dk \text{........................ (3)}$$

Where:

ETD_k = Effectiveness to difficulty ratio of action

TE_k = Total effectiveness of action

D_k = Degree of difficulty

RESULT AND DISCUSSION

As one of the largest coffee producers in the Tabanan region, the company strives to increase production to meet market demand. In its efforts to meet market targets, the company often encounters obstacles, that is differences between planned and actual coffee production. The difference between planned and actual coffee production is influenced by several factors, such as market price fluctuations, with a 25% increase over the past 6 months, material arrival delays of 1-3 days, and raw materials that do not meet desired specifications, including factors such as size, color, brittleness level, and coffee aroma. Based on the factors affecting production activities, they have a significant impact on production operational activities and the quality of the final product. The coffee powder defect standard set by the company is 10%, but in reality, it often exceeds this figure. This event has a crucial impact on the company. In Table 1, the difference between planned production and actual coffee production in the July-December 2023 production period is as follows:

Table 2. Recap of Production Targets and Realization

Month	Production Target (Kg)	Production Realization (Kg)
July	1,400	1,120
August	1,400	1,180
September	1,400	1,300
October	1,400	1,220
November	1,400	1,200
December	1,400	1,050

Based on the data in Table 1, it can be observed that there is a difference between planned and actual production over the past 6 months. In July 2023, The company could only achieve 80% of the coffee production target. This fluctuated in the following months. In December 2023, the company again experienced a decrease in coffee production, where they could only fulfill 75% of the planned production. This phenomenon resulted in the company failing to meet the desired production target. Identification of this risk event was obtained from the results of interviews and brainstorming with the supply chain and logistics department. Interviews and brainstorming were conducted with the manager and 5 supply chain and logistics staff who understand the company's conditions with a minimum working period of 5 years. The risks that have been identified are risks that hinder the achievement of the company's objectives. The risk events and risk agents that have been identified are as follows:

Table 3. Results of Identification of Risk Events and Risk Agents

Code	Risk Events	Code	Risk Agent
E1	The raw materials received are not inspected by the quality control department/consignee	**A1**	Inspectors who are not thorough
		A2	Lack of equipment or technology to carry out inspections effectively
E2	Damage to production machines	**A3**	There is a delay in preventive maintenance on production machines
E3	Maintenance takes a long time	**A4**	Limited skilled workforce
E4	Production costs exceeded the budgeted target	**A5**	There is an increase in energy and operational costs in the production process
		A6	Lack of proper planning in production budget
E5	Price fluctuations from suppliers	**A7**	Changes in price policies from suppliers due to scarcity of raw material commodities
E6	Dependence on a single supplier	**A8**	Quality risk from a single source
E7	Increase in storage costs	**A9**	*Overstock capacity*
E8	Production schedule delays	**A10**	Unexpected machine failure
		A11	The quality of raw materials is not good
E9	Decreased quality during the production process	**A12**	Raw materials does not meet the established standards
		A13	Worker error (human error)
		A14	Inappropriate working methods
		A15	Unsupportive work environment
E10	Incomplete grinding process	**A16**	Instability of the grinding process
E11	There was a work accident	**A17**	Lack of K3 training
E12	Packaging damaged	**A18**	Lack of protection during the shipping process
E13	Production targets not met	**A19**	Errors in production planning
		A20	Errors in production scheduling
E14	Product damage in transit	**A21**	Improper packaging and shock during transportation
		A22	Driver's non-compliance with traffic rules
E15	Delay in product delivery to consumers	**A23**	Errors in planning delivery routes
E16	The number of defective products exceeds the standard	**A24**	Lack of quality control of the raw materials used
E17	Delay in handling returned products	**A25**	Lack of an effective returns management system

Source: Company Data

Risk Event Validity Test

The instrument used in this research has 17 statements for assessing the severity of risk events with 6 respondents consisting of managers and 5 supply chain and logistics staff. The results of the risk event validity test using SPSS 23 software are as follows:

Table 4. Risk Event Validity Test Results

Code	Risk Events	r_{count}	r_{table}	Decision
E1	The raw materials received are not inspected by the quality control department/consignee	0.859	0.811	Valid
E2	Damage to production machines	0.837	0.811	Valid
E3	Maintenance takes a long time	0.898	0.811	Valid
E4	Production costs exceeded the budgeted target	0.966	0.811	Valid
E5	Price fluctuations from suppliers	0.904	0.811	Valid
E6	Dependence on a single supplier	0.966	0.811	Valid
E7	*Overstock capacity*	0.852	0.811	Valid
E8	Production schedule delays	0.845	0.811	Valid
E9	Decreased quality during the production process	0.824	0.811	Valid
E10	Incomplete grinding process	0.837	0.811	Valid
E11	There was a work accident	0.884	0.811	Valid

Code	Risk Events	r_{count}	r_{table}	Decision
E12	Packaging damaged	0.905	0.811	Valid
E13	Production targets not met	0.958	0.811	Valid
E14	Product damage in transit	0.854	0.811	Valid
E15	Delay in product delivery to consumers	0.884	0.811	Valid
E16	The number of defective products exceeds the standard	0.854	0.811	Valid
E17	Delay in handling returned products	0.847	0.811	Valid

Based on the results of the validity test with 6 respondents, the results obtained were $r_{count} > r_{table}$, meaning that the 17 statement items in the questionnaire were valid.

Risk Agent Validity Test

The instrument used in this research has 25 statements to assess the level of risk occurrence with 6 respondents consisting of managers and 5 supply chain and logistics staff. The results of the risk agent validity test using SPSS 23 software are as follows:

Table 5. Validity Test Results Risk Agent

Code	Risk Agent	r_{count}	r_{table}	Decision
A1	Inspectors who are not thorough	0.906	0.811	Valid
A2	Lack of equipment or technology to carry out inspections effectively	0.819	0.811	Valid
A3	There is a delay in preventive maintenance on production machines	0.864	0.811	Valid
A4	Limited skilled workforce	0.829	0.811	Valid
A5	There is an increase in energy and operational costs in the production process	0.876	0.811	Valid
A6	Lack of proper planning in production budget	0.819	0.811	Valid
A7	Changes in price policies from suppliers due to scarcity of raw material commodities	0.820	0.811	Valid
A8	Quality risk from a single source	0.849	0.811	Valid
A9	Increase in storage costs	0.876	0.811	Valid
A10	Unexpected machine failure	0.853	0.811	Valid
A11	The quality of raw materials is not good	0.827	0.811	Valid
A12	Raw material sdoes not meet the established standards	0.850	0.811	Valid
A13	Worker error (human error)	0.876	0.811	Valid
A14	Inappropriate working methods	0.819	0.811	Valid
A15	Unsupportive work environment	0.877	0.811	Valid
A16	Instability of the grinding process	0.838	0.811	Valid
A17	Lack of K3 training	0.805	0.811	Valid
A18	Lack of protection during the shipping process	0.954	0.811	Valid
A19	Errors in production planning	0.838	0.811	Valid
A20	Errors in production scheduling	0.853	0.811	Valid
A21	Improper packaging and shock during transportation	0.820	0.811	Valid
A22	Driver's non-compliance with traffic rules	0.886	0.811	Valid
A23	Errors in planning delivery routes	0.889	0.811	Valid
A24	Lack of quality control of the raw materials used	0.864	0.811	Valid
A25	Lack of an effective returns management system	0.926	0.811	Valid

Reliability Test

Reliability testing is a process for measuring the extent to which a measurement instrument, such as a questionnaire or test, produces consistent and reliable results in measuring the intended concept or variable. In this research, the reliability test uses SPSS 23 software. Based on the reliability test concept, if the Cronbach alpha value is > 0.6, then the questionnaire can be said to be reliable.

Risk Event Reliability Test

The instrument used in this research has 17 statements for assessing the severity of risk with 6 respondents consisting of managers and 5 supply chain and logistics staff. The results of the risk event reliability test using SPSS 23 software are as follows:

Case Processing Summary

		N	%
Cases	Valid	6	100.0
	Excluded[a]	0	.0
	Total	6	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.968	17

Figure 2. Risk Event Reliability Test Results

Based on the results of the reliability test for 17 statement items with a total of 6 respondents, a cronbach alpha value of 0.968 was obtained, because 0.968 > 0.6, the questionnaire can be said to be reliable.

Risk Agent Reliability Test

The instrument used in this research has 25 statements to assess the level of risk occurrence with 6 respondents consisting of managers and 5 supply chain and logistics staff. The results of the risk agent reliability test using SPSS 23 software are as follows:

Case Processing Summary

		N	%
Cases	Valid	6	100.0
	Excluded[a]	0	.0
	Total	6	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.978	25

Figure 3. Reliability Test Results Risk Agent

Based on the results of the reliability test for 25 statement items with a total of 6 respondents, a cronbach alpha value of 0.978 was obtained, because 0.978 > 0.6, the questionnaire can be said to be reliable.

House of Risk Analysis Phase I

Determining the level of impact of each risk event and risk agent is carried out by distributing questionnaires to departments and parties related to the company's supply chain and logistics activities. The following are the results of the summary of respondent data that has been distributed.

Table 6. Severity and Occurrence Scores

Code	Risk Events	Severity	Code	Risk Agent	Occurrence
E1	The raw materials received are not inspected by the quality control department/consignee	6.7	**A1**	Inspectors who are not thorough	3.3
			A2	Lack of equipment or technology to carry out inspections effectively	7.2
E2	Damage to production machines	7	**A3**	There is a delay in preventive maintenance on production machines	4
E3	Maintenance takes a long time	7.5	**A4**	Limited skilled workforce	2.6
E4	Production costs exceeded the budgeted target	6.7	**A5**	There is an increase in energy and operational costs in the production process	7.3
			A6	Lack of proper planning in production budget	3.2
E5	Price fluctuations from suppliers	6.8	**A7**	Changes in price policies from suppliers due to scarcity of raw material commodities	5.8
E6	Dependence on a single supplier	6.7	**A8**	Quality risk from a single source	3.8
E7	Increase in storage costs	6.7	**A9**	Overstock capacity	2.3

Code	Risk Events	Severity	Code	Risk Agent	Occurrence
E8	Production schedule delays	6.8	**A10**	Unexpected machine failure	2.8
			A11	The quality of raw materials is not good	6.3
E9	Decreased quality during the production process	6.8	**A12**	Raw materialsdoes not meet the established standards	3.2
			A13	Worker error (human error)	2.3
			A14	Inappropriate working methods	2.2
			A15	Unsupportive work environment	1.8
E10	Incomplete grinding process	8	**A16**	Instability of the grinding process	6.8
E11	There was a work accident	6.2	**A17**	Lack of K3 training	2.5
E12	Packaging damaged	7.2	**A18**	Lack of protection during the shipping process	2.8
E13	Production targets not met	6.5	**A19**	Errors in production planning	1.8
			A20	Errors in production scheduling	1.8
E14	Product damage in transit	6.3	**A21**	Improper packaging and shock during transportation	6.2
			A22	Driver's non-compliance with traffic rules	1.5
E15	Delay in product delivery to consumers	6.2	**A23**	Errors in planning delivery routes	1.7
E16	The number of defective products exceeds the standard	7.3	**A24**	Lack of quality control of the raw materials used	7
E17	Delay in handling returned products	6.5	**A25**	Lack of an effective returns management system	2.2

Source: Data Processing Results

Based on the results of identifying the correlation between risk events and risk agents, which aims to find out how much the risk agent can influence the risk event. The ARP value calculation is used to rank the causes of emerging risks to identify priority risk agents to carry out mitigation steps first. The results of the ARP calculation are as follows:

Table 7. ARP Calculation Results

Rank	Code	Risk Agent	ARP
1	A11	The quality of raw materials is not good	2118.69
2	A5	There is an increase in energy and operational costs in the production process	1961.51
3	A24	Lack of quality control of the raw materials used	1803.9
4	A16	Instability of the grinding process	1574.88
5	A3	There is a delay in preventive maintenance on production machines	1141.6
6	A2	Lack of equipment or technology to carry out inspections effectively	956.16
7	A7	Changes in price policies from suppliers due to scarcity of raw material commodities	896.1
8	A12	Raw materials does not meet the established standards	880.32
9	A21	Improper packaging and shock during transportation	753.3
10	A10	Unexpected machine failure	703.08
11	A1	Inspectors who are not thorough	659.34
12	A4	Limited skilled workforce	614.38
13	A13	Worker error (human error)	424.12
14	A8	Quality risk from a single source	413.82
15	A18	Lack of protection during the shipping process	340.2
16	A6	Lack of proper planning in production budget	320.64
17	A14	Inappropriate working methods	253.22
18	A19	Error in production panning	250.02
19	A20	Errors in production scheduling	227.52
20	A9	Overstock capacity	204.24
21	A22	Driver's non-compliance with traffic rules	179.55
22	A15	Unsupportive work environment	157.14
23	A17	Lack of K3 training	139.5
24	A25	Lack of an effective returns management system	128.7

Rank	Code	Risk Agent	ARP
25	A23	Errors in planning delivery routes	94.86

Source: Data Processing Results

After calculating the Aggregate Risk Potential (ARP), risk agent ranking will be carried out. In the risk ranking stage, several priority risk agents will be selected. According to Magdalena (2019), according to the pareto concept, 80%: 20%, the priority problems that must be resolved are problems with a percentage of up to 80%.

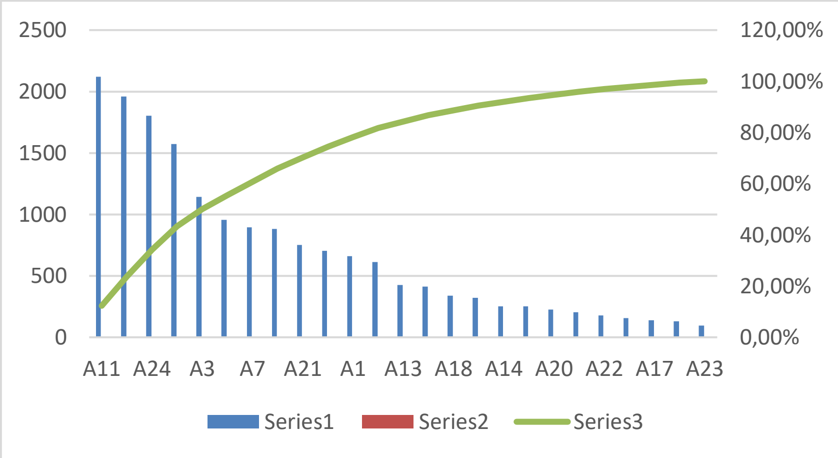

Figure 4. Pareto Chart

Based on the results of the pareto chart, there are 11 risk agents with problem priorities up to a percentage of 80%, the 11 risk agents are poor quality of raw materials (A11), increased energy and operational costs in the production process (A5), lack of quality control over raw materials used (A24), instability of the grinding process (A16), delays in preventive maintenance on production machines (A3), lack of equipment or technology to carry out inspections effectively (A2), changes in price policies from suppliers due to scarcity of raw material commodities (A7), raw materials that do not meet the specified standards (A12), inappropriate packaging and shocks during transportation (A21), unexpected machine damage (A10), and inspectors who are not careful (A1). The dominant risk agent will be calculated in the HOR analysis stage II to formulate appropriate and effective mitigation steps.

House of Risk Analysis Phase II

The mitigation strategy design is given to each risk agent who has the highest ARP value based on the Pareto concept. Within each agent the risk can be mitigated by one or more mitigation actions. To design the mitigation strategy, discussions or brainstorming are carried out with the Company, the aim is to confirm the risk agent regarding the mitigation strategy and to check the relevant mitigation strategy design for each risk agent.

Table 8. Mitigation Strategy Design

Code	Risk Agent	Code	Preventive Action
A11	The quality of raw materials is not good	**PA1**	Establish good relationships with suppliers to ensure consistency and quality of raw materials
		PA2	Conduct strict quality testing for each lot of raw materials received
A5	There is an increase in energy and operational costs in the production process	**PA3**	Conduct energy audits to identify areas where energy use can be optimized
		PA4	Re-evaluate the supply chain to identify potential cost reductions, such as using cheaper raw materials or optimizing production processes
A24	Lack of quality control of the raw materials used	**PA5**	Strengthen quality control processes by using appropriate measurement tools and testing methods

Code	Risk Agent	Code	Preventive Action
		PA6	Facilitate employee training to ensure a good understanding of quality standards and testing methods
A16	Instability of the grinding process	**PA7**	Perform routine preventive maintenance on grinding equipment to prevent damage and process instability
A3	There is a delay in preventive maintenance on production machines	**PA8**	Implement a strict and documented preventive maintenance schedule for each production machine
A2	Lack of equipment or technology to carry out inspections effectively	**PA9**	Invest in the equipment and technology needed to effectively carry out inspections, coffee sorting machines
A7	Changes in price policies from suppliers due to scarcity of raw material commodities	**PA10**	Build a diverse supplier network to reduce the risk of dependence on one supplier
		PA11	Plan raw material reserves to anticipate price fluctuations
A12	*Raw materials*does not meet the established standards	**PA12**	Draw up clear contracts with suppliers regarding the quality standards that must be met
		PA13	Conduct regular audits of incoming raw materials to ensure that they meet established quality standards
A21	Improper packaging and shock during transportation	**PA14**	Use packaging that is sturdy and resistant to shock
A10	Unexpected machine failure	**PA15**	Establish a reserve fund for sudden repairs or machine replacement
		PA16	Prepare backup coffee machines or important components to reduce production downtime
A1	Inspectors who are not thorough	**PA17**	Conduct regular internal audits to ensure inspection quality is maintained

Source: Data Processing Results

The step to mitigate risk agents whose ARP values dominate is by designing a mitigation strategy for each risk agent. So from the table above we get 17 relevant mitigation strategies. The next stage is to identify the correlation between dominant risk agents and mitigation measures. Identification of correlations in HOR stage II aims to find out how effectively the mitigation steps formulated can handle sources of risk, of course also considering the Company's resources and capabilities. After identifying correlations, the Total Effectiveness of Action (TEk) of 11 of each mitigation action was calculated. If the TEk value has been obtained, the next step is to weight the Difficulty of Performing Action (Dk) value. The weighting was carried out by 6 respondents consisting of managers and 5 supply chain and logistics staff. This Dk value states the level of difficulty in implementing each mitigation action. The weighting of the Dk values is carried out based on the following scale:

Table 9. Value scale Dk

Scale	Level	Explanation
3	Low	Easy to apply
4	Medium	Currently to be implemented
5	High	Difficult to implement

Source: Pujawan and Geraldine, 2009

The next step after getting the TEk and Dk values is to calculate the Effectiveness To Difficulty of Ratio (ETDk) value. This ETDk value states the ratio between the effectiveness value of the mitigation action and the level of difficulty of each mitigation action. The calculation results can be seen in the table below:

Table 10. ETDk Calculation Results

Code	Preventive Action	TE_k	D_k	ETD_k
PA1	Establish good relationships with suppliers to ensure consistency and quality of raw materials	49110.72	3.8	12923.87
PA2	Conduct strict quality testing for each lot of raw materials received	47165.72	3.3	14292.64
PA3	Conduct energy audits to identify areas where energy use can be optimized	17653.59	4	4413,398
PA4	Re-evaluate the supply chain to identify potential cost reductions, such as using cheaper raw materials or optimizing production processes	17653.59	3.7	4771.241
PA5	Strengthen quality control processes by using appropriate measurement tools and testing methods	34496.91	4.3	8022.537
PA6	Facilitate employee training to ensure a good understanding of quality standards and testing methods	35815.59	3.2	11192.37
PA7	Perform routine preventive maintenance on grinding equipment to prevent damage and process instability	48429.63	3	16143.21
PA8	Implement a strict and documented preventive maintenance schedule for each production machine	23288.27	3	7762.757
PA9	Invest in the equipment and technology needed to effectively carry out inspections, coffee sorting machines	57765.69	3.7	15612.35
PA10	Build a diverse supplier network to reduce the risk of dependence on one supplier	19910.37	3.2	6221.991
PA11	Plan raw material reserves to anticipate price fluctuations	8064.9	3.8	2122,342
PA12	Draw up clear contracts with suppliers regarding the quality standards that must be met	43226.19	3	14408.73
PA13	Conduct regular audits of incoming raw materials to ensure that they meet established quality standards	43226.19	4.2	10291.95
PA14	Use packaging that is sturdy and resistant to shock	6779.7	3	2259.9
PA15	Establish a reserve fund for sudden repairs or machine replacement	6327.72	3.5	1807.92
PA16	Prepare backup coffee machines or important components to reduce production downtime	6327.72	4.5	1406.16
PA17	Conduct regular internal audits to ensure inspection quality is maintained	20342.79	4.3	4730.881

Source: Data Processing Results

Effectiveness to Difficulty (ETDk) refers to the comparison between how effective an action or strategy is in achieving a particular goal compared to the level of difficulty required to implement or execute it. In this context, it pertains to evaluating how well a mitigation action or approach designed to address a specific problem works relative to how difficult or complex it is to implement. After calculating the total effectiveness and degree of difficulty, the results of the mitigation effectiveness ranking based on the difficulty ratio (ETDk) with the highest value carried out routine preventive maintenance on milling equipment to prevent damage and process instability (PA 7) of 16143.21, and the last rank prepared a backup of coffee machines or critical components to reduce production downtime (PA 16) of 1406.16. These calculations have considered many factors, one of the most important being the company's resource capability to implement these mitigation actions. After implementing various mitigation actions, further research is needed to understand the results of the implementation of these mitigation actions. The company is expected to continue to renew its risk management in the supply chain process from procurement processes, production processes, distribution, to the return acceptance of returned coffee products. This is done to make risk management in the supply chain more effective and efficient, and in line with the company's supply chain conditions.

CONCLUSIONS

In the House of Risk (HOR) stage 1, there are various kinds of risks that occur in the company, that is 17 risk events. From several risk events, 25 risk agents were obtained. So, of the 25 causes of risk agents, there are 11 most dominant risk agents based on the pareto chart from calculating the Aggregate Risk Potential (ARP) value. Then the House of Risk (HOR) stage 2 produces 17 mitigation actions which are ranked based on the value of the level of effectiveness of the mitigation action (TEk) and the ratio between the effectiveness value of the mitigation action and the level of difficulty of each mitigation action (ETDk). Several mitigation actions that have the greatest impact on the company's supply chain activities are:perform routine preventive maintenance on grinding equipment to prevent damage and process instability (PA7),invest in the equipment and technology needed to effectively carry out inspections, coffee sorting machines (PA9), and draw up clear contracts with suppliers regarding the quality standards that must be met (PA12).The suggestions that the author can propose regarding the research that has been carried out are, The company is expected to implement 4 mitigation actions with the largest ETDk values produced in this research. Recommended mitigation strategies for further review by the company include carrying out routine preventive maintenance on grinding equipment to prevent damage and process instability, investing in the equipment and technology needed to carry out effective inspections, such as coffee sorting machines, drawing up clear contracts with suppliers regarding quality standards that must be met, and carry out strict quality testing for each lot of raw materials received. After implementing the various mitigation actions, further research needs to be carried out to determine the results of implementing the existing mitigation actions. Apart from that, the company is expected to continue to carry out updates in risk management in the supply chain process from the procurement process, production process, distribution, to receiving returned coffee products. This is done so that risk management in the supply chain is more effective and efficient, and in accordance with the state of the company's supply chain.

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