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ANALISIS RISIKO RANTAI PASOK PADA PERUSAHAAN EKSPORTIR ROTAN ANYAMAN MENGGUNAKAN HOUSE OF RISK DAN ANALYTIC NETWORK PROCESS

SUPPLY CHAIN RISK ANALYSIS IN RATTAN WOVEN EXPORTING COMPANY USING HOUSE OF RISK AND ANALYTIC NETWORK PROCESS

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Abstrak— Sebuah perusahaan manufaktur dan eksportir furnitur anyaman rotan menghadapi tantangan dalam rantai pasoknya, terutama terkait kelangkaan bahan baku yang menghambat proses produksi. Penelitian ini bertujuan untuk mengidentifikasi risiko-risiko yang mempengaruhi rantai pasok produk dan ekspor rotan dengan menggunakan indikator dari model SCOR. Selain itu, penelitian ini juga bertujuan untuk merancang dan menentukan prioritas strategi mitigasi risiko rantai pasok, dengan mengintegrasikan metode House of Risk (HOR) dan Analytic Network Process (ANP). Model SCOR digunakan untuk mengidentifikasi risiko dengan mengelompokkan aktivitas berdasarkan lima proses utama rantai pasok: plan, source, make, deliver, dan return. Setelah itu, dilakukan penilaian terhadap setiap kejadian risiko, penyebab risiko, dan risiko prioritas yang memiliki dampak besar terhadap rantai pasok, menggunakan metode HOR Fase 1. Selanjutnya, dilakukan perancangan aksi mitigasi risiko menggunakan metode HOR Fase 2, dan penentuan aksi mitigasi risiko prioritas berdasarkan kriteria perusahaan, dengan menggunakan metode ANP. Hasil identifikasi risiko menunjukkan adanya 29 kejadian risiko dan 30 penyebab risiko. Sebagai solusi, dirancang 6 aksi mitigasi risiko untuk mengatasi masalah rantai pasok tersebut. Dari hasil penelitian, aksi mitigasi risiko prioritas yang direkomendasikan untuk diimplementasikan terlebih dahulu oleh perusahaan adalah melaksanakan perencanaan dan pengendalian ketersediaan bahan baku.

Kata kunci— ANP, HOR, Manajemen Risiko, Rantai Pasok, SCOR

Abstract— A manufacturing and exporter of rattan woven furniture company is facing challenges in its supply chain, particularly related to the scarcity of raw materials that affects the production process. This research aims to identify the risks affecting the supply chain of the rattan products and exports by utilizing indicators from the SCOR model. Additionally, the research also aims to design and prioritize supply chain risk mitigation strategies by integrating the House of Risk (HOR) and Analytic Network Process (ANP) methods. The SCOR model is employed to identify risks by grouping activities based on the five main processes of the supply chain: plan, source, make, deliver, and return. Subsequently, an assessment is conducted for each risk event, risk causes, and priority risks that have a significant impact on the supply chain, using the HOR Phase 1 method. Furthermore, the design of risk mitigation actions is carried out using the HOR Phase 2 method, and the determination of priority risk mitigation actions based on company criteria is done using the ANP method. The results of risk identification indicate the presence of 29 risk events and 30 risk causes. As a solution, 6 risk mitigation actions are designed to address the supply chain issues. From the research findings, the recommended priority risk mitigation action for the company to implement first is to execute planning and control of raw material availability.

Keywords— ANP, HOR, Risk Management, Supply Chain, SCOR

I. INTRODUCTION

Rattan is one of Indonesia's natural resources that plays a significant role in economic growth, as the country supplies approximately 80% of the global demand for rattan [1]. This high level of supply has led to the establishment of numerous rattan processing industries across Indonesia [2]. The abundance of raw rattan also positions rattan-based products and furniture as one of Indonesia's key export commodities [3]. According to research conducted by Anwar et al. [4], Indonesia's rattan furniture exports experienced a significant decline in the international market during 2015–2016. In line with this, a study by Dewi & Isharina [5] found that from 2017 to 2021, Indonesia's competitiveness in the global rattan furniture export market showed considerable fluctuation. Moreover, according to the 2023 report from the Ministry of Industry of the Republic of Indonesia, the export value of woven rattan, bamboo, and similar products decreased by 34.09% from February 2022 to February 2023.

Supply Chain Risk Management (SCRM) involves a range of strategies aimed at identifying, assessing, mitigating, and monitoring unforeseen events or conditions that may negatively affect any part of the supply chain [7]. Fan & Stevenson [8] argue that companies must implement supply chain risk management to handle potential disruptions caused by risks within the supply chain. As such, supply chain risk management is essential for ensuring profitability, business continuity, and long-term growth potential [8].

PT XYZ is a rattan woven furniture manufacturer and exporter based in Tangerang, Indonesia. The company exports its rattan crafts to the USA, Europe, Japan, Australia, and New Zealand. Based on an interview with the company owner conducted in early 2023, PT XYZ operates using a subcontracting production system, collaborating with external rattan weavers. The interview also revealed that PT XYZ had previously experienced a decline in export activity, indicated by a decrease in both the volume and value of exported rattan furniture, which in turn affected production volume. This decline also led to a reduction in the number of subcontracted weaving workers. Other issues encountered in PT XYZ's supply chain included suppliers failing to meet company orders, shortages of raw materials, and limited company resources unable to fulfill buyer demand. Additionally, PT XYZ has faced uncertainties such as high demand fluctuations, cultural communication differences, and complex changes in export trade regulations.

As a global company, PT XYZ operates a supply chain that is more complex than those of domestic firms. Given the uncertainties and risks associated with global supply chains, it is essential for PT XYZ to implement supply chain risk management practices to identify, assess, and mitigate risks along the supply chain. Proper mitigation increases the likelihood that customers will receive products as expected, thereby improving customer satisfaction [9]. Through the adoption of supply chain risk management, PT XYZ is expected to remain competitive and resilient in the international market despite the risks of declining furniture exports from Indonesia.

Several previous studies are relevant to the current research. For instance, Sartono et al. [10] analyzed and developed risk mitigation strategies for a knitted apparel company using the Supply Chain Operations Reference (SCOR) model and the House of Risk (HOR) framework. Their study identified 36 risk events and 35 risk agents, resulting in seven formulated mitigation strategies. Another study by Sukwadi & Caesar [11] employed the SCOR model, the HOR model, and the Analytical Hierarchy Process (AHP) to determine the most appropriate mitigation strategies for prioritized risks in the supply chain of polyvinyl chloride (PVC) compound production. Their results identified 10 prioritized risks and 10 corresponding mitigation strategies using the AHP method. Additionally, Tanjung et al. [12] conducted a study using Failure Mode Effect Criticality Analysis (FMECA) and the Analytical Network Process (ANP) to analyze supply chain risk management in the wooden toy industry. FMECA was used to identify, assess, and prioritize risks, while ANP was employed to determine the priority of risk mitigation strategies. Furthermore, Pujawan & Geraldin [13] also recommended the use of ANP for prioritizing risks.

In supply chain risk management, several sequential processes must be followed, including identifying the supply chain processes, the risk events, and their causes. Afterward, risks are assessed and prioritized to determine the most effective mitigation strategies. In this study, the SCOR model is used to identify risks by categorizing them into the five core supply chain processes: plan, source, make, deliver, and return [10]. Each risk event, its cause, and its level of priority are then assessed using Phase 1 of the HOR method. Subsequently, Phase 2 of the HOR model, integrated with the ANP method, is employed to design and prioritize the most suitable risk mitigation actions based on the company's criteria. Through such risk analysis, it is expected that the company will be able to map out operational supply chain risks and select the most critical mitigation actions to implement.

II. LITERATURE REVIEW

A. House of Risk (HOR)

The House of Risk (HOR) is a supply chain risk management method developed by I Nyoman Pujawan and Laudine H. Geraldin in 2009 [13]. This method builds upon the Failure Mode and Effect Analysis (FMEA) framework by integrating it with the House of Quality (HOQ) approach to prioritize risk agents [14]. The primary objective of the HOR method is to rank potential risks based on quantitative assessments, enabling the prioritization of mitigation strategies according to the Effectiveness-to-Difficulty Ratio [11]. According to [14], HOR supports a preventive approach to risk management by aiming to reduce the likelihood of risk occurrence. In assessing and evaluating risk severity, the HOR method utilizes the Risk Priority Number (RPN) from FMEA, which considers three factors: the likelihood of occurrence, the severity of impact, and the detectability of the risk. Once risk agents are identified and assessed, they are ranked based on their Aggregate Risk Potential (ARP) values. This prioritization ensures that organizations address the most critical risk agents first, especially when resources are limited. The HOR method comprises two main phases to determine the most suitable mitigation strategies: HOR Phase 1 and HOR Phase 2.

1) HOR Phase 1

HOR Phase 1 focuses on identifying risk agents and determining their priority level as a basis for mitigation actions [14]. The steps involved in this phase are as follows:

a) Identifying supply chain activities using the Supply Chain Operations Reference (SCOR) model, which includes five core processes: Plan, Source, Make, Deliver, and Return. The purpose of using the SCOR model is to categorize risks according to specific stages in the supply chain, facilitating traceability.
b) Identifying potential risk events (E_i) that may occur throughout the supply chain activities, categorized according to the SCOR model.
c) Assessing the severity of each risk event's impact. The severity rating criteria are tailored to the context of the company under study. Severity scores are incorporated into the HOR Phase 1 assessment table, as shown in Table 1.

Table-1. HOR Phase 1

Bussiness Process	***Risk Event*** ***(E_i)***	***Risk Agent (A_j)***			***Severity of Risk Event i (S_i)***
		A1	**A2**	**A3**	
Plan	E_1	R_{11}	R_{12}	R_{13}	S_1
Source	E_2	R_{21}	…	…	S_2
Make	E_3	…	…	…	S_3
Deliver	E_4	…	…	…	S_4
Return	E_5	...	…	…	S_5
Occurance of Agent j		O_1	O_2	O_3	
Aggregate Risk Potential (ARPj)		ARP_1	ARP_2	ARP_3	
Priority Rank of Agent j					

d) Identifying the causes of each risk event, also known as risk agents (Aj), and assessing the likelihood of occurrence (Oj) for each agent. Occurrence rating criteria are also adapted to the specific context of the company.
e) Assessing the correlation (Rij) between each risk event and its corresponding risk agent. The correlation is rated on a scale of 0, 1, 3, or 9: 0 indicates no correlation, 1 indicates low correlation, 3 indicates moderate correlation, and 9 indicates high correlation. These values are recorded in the HOR Phase 1 assessment table (Table 1).
f) Calculating the Aggregate Risk Potential (ARP) using severity and occurrence values to rank risk agents. The formula used is:

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

Where:
ARP: Aggregate Risk Potential of agent j
S_j : Severity of risk event i
O_j : Occurrence of agent j
R_{ij} : Correlation between risk event i and agent j

g) Ranking risk agents based on their ARP values from highest to lowest.
h) The prioritized ARP values from HOR Phase 1 are then used as input for further analysis in HOR Phase 2.

2) HOR Phase 2

HOR Phase 2 is aimed at designing risk mitigation strategies (Masri, 2016). The steps involved in this phase are as follows (Arasati, 2020):

a) The top-priority risk agents, as identified in HOR Phase 1, are further analyzed. These are selected using a Pareto diagram (Nadhira et al., 2019) and recorded in the Aggregate Risk Potential (ARPj) column of the HOR Phase 2 table (Table 2).
b) Identifying mitigation strategies (Preventive Actions, PAk) for each risk agent and

documenting them in the corresponding column of Table 2.

c) Determining the correlation (Ejk) between each risk agent and the proposed mitigation actions, using the same 0–1–3–9 scale as in HOR Phase 1.
d) Calculating the Total Effectiveness (TEk) of each mitigation strategy using the following formula:

$$TE_k = \sum ARP_j E_{jk} \quad (2)$$

Where:
TE_k : Total Effectiveness of mitigation strategy k
ARP_j : Aggregate Risk Potential of agent j
Ejk : Correlation between agent j and action k

Table-2. HOR Phase 2

To be Treated Risk Agent (A_j)	*Preventive Action* (PA_k)		*Aggregate Risk Potentials* (ARP_j)
	PA_1	**PA_2**	
A_1	E_{11}	E_{12}	ARP_1
A2	E_{21}	E_{22}	ARP_2
Total Effectiveness of Action k	TE_1	TE_2	
Degree of Difficulty Performing Action k	D_1	…	
Effectiveness to Difficulty Performing	ETD_1	…	
Rank of Prioroty	R_1	…	

e) Assessing the Difficulty (Dk) of implementing each mitigation action using a Likert scale from 1 to 5, based on the required resources and implementation complexity.
f) Calculating the Effectiveness-to-Difficulty Ratio (ETDk) using the formula

$$ETD_k = \frac{TE_k}{D_k} \quad (3)$$

Where:
ETD_k : Effectiveness-to-Difficulty Ratio for action k
TE_k : Total of effectiveness
D_k : Degree of Difficulty in implementing action k

The resulting ETD values are used to determine the priority order of mitigation strategies, with higher ETD values indicating more favorable options.

B. *Analytical Network Process (ANP)*

The Analytical Network Process (ANP) is a Multi-Criteria Decision-Making (MCDM) method developed as an extension of the Analytical Hierarchy Process (AHP) [15]. While the AHP method simplifies decision-making by focusing solely on hierarchical dependencies between elements, the ANP method offers a more comprehensive approach by accommodating interrelated elements within a system and allowing feedback among them [16]. According to Tanjung et al. [12], ANP serves as a tool to evaluate strategies and determine which strategies should be recommended or prioritized for risk mitigation. The ANP calculation process consists of the following steps [17]:

1) Clearly define the decision-making problem.
2) Establish the decision goal, select the relevant criteria, and determine potential alternatives with input from decision-makers.
3) Pairwise comparison matrices are constructed to assess the relative importance of one element over another. These comparisons are made among the criteria and subsequently between each criterion and its corresponding alternatives. The results are organized into an $n \times n$ matrix. Table 3 illustrates an example of a pairwise comparison matrix for Criterion A.

Table-3. Example of Pairwise Comparison Matrix

A	**a_1**	**a_2**	**…**	**a_n**
a_1	a_{11}	a_{12}	…	**a_{1n}**
a_2	a_{21}	a_{22}	…	**a_{2n}**
…	…	…	…	…
a_n	a_{n2}	a_{n1}	…	**a_{nn}**

Note:
B1 : B11, B12, etc.
B2 : B21, B22, etc.

Each value a_{ij} epresents the relative importance of element a_i (column) compared to a_j (row) with respect to Criterion A. The importance values are assigned using a scale from 1 to 9, where 1 indicates equal importance and 9 indicates absolute importance. If there are multiple decision-makers, the *Geometric Mean* is calculated to determine a consolidated score for each comparison, using the following formula:

$$Geometric\ Mean = (a_{ij1} \times a_{ij2} \times \ldots a_{ijn})^{1/n} \quad (4)$$

Where:
a_n : Evaluation result from the nth respondent
n : Number of respondents

4) The eigenvector is derived using the following formula:

$$X = \frac{\sum\left(\frac{Wij}{\sum Wj}\right)}{n} \tag{5}$$

Where:
X : Eigenvector
W_{ij} : Product of values in a row of the matrix
$\sum W_j$: Total of column values
n : Number of comparisons

5) Consistency Ratio (CR) analysis. The consistency ratio ensures that the geometric mean scores provided by decision-makers are reliable and usable for further calculation. A consistency ratio (CR) of 10% or lower is considered acceptable[12]. If the CR exceeds 10%, it suggests inconsistency in the pairwise judgments, and the comparison process must be repeated. The following formulas are used to determine the consistency index (CI) and consistency ratio (CR):

$$CI = (\lambda max - n)/(n - 1) \tag{6}$$

Where:
CI : Consistency Index
λ_{max} : Maximum eigenvalue
n : Number of criteria

$$CR = CI/RI \tag{7}$$

Note:
CR : Consistency Ratio
CI : Consistency Index
RI : Ratio Index

6) Since ANP considers interdependencies among elements, the supermatrix captures the complex relationships between them. There are three types of supermatrices in ANP:
   a) *Unweighted Supermatrix*
      This matrix is formed by placing all the eigenvectors derived from the pairwise comparisons between elements.
   b) *Weighted Supermatrix*
      The weighted supermatrix is produced by weighting each block of priority vectors according to the results of pairwise comparisons between clusters.
   c) *Limiting Supermatrix*
      The limiting supermatrix is obtained by raising the weighted supermatrix to powers repeatedly until the values in each column converge and become uniform across each row. This is achieved by exponentiating the weighted supermatrix by k, where $k = 1, 2, ..., n$.

7) Finally, the normalized values of each alternative are compared to determine which alternative should be selected as the final decision.

III. RESEARCH METHOD

This study employs the SCOR, HOR, and ANP methodologies. Data collection was conducted through respondents who are experts and key personnel involved in the supply chain management of PT XYZ, namely the Chief Executive Officer and the Operations Manager. Both primary and secondary data were gathered to gain a comprehensive understanding of PT XYZ's supply chain procedures. Primary data were obtained directly through observations, interviews, and questionnaires with the CEO and Operations Manager of PT XYZ. Secondary data consisted of supporting information, such as company reports, literature, and other indirect sources that complemented the primary data. The research methodology employed in this study is illustrated in the diagram in Figure 1.

The methodological steps began with defining the objectives, followed by mapping the supply chain activities, identifying risks and their causes within the supply chain, and assessing these risks using HOR Phase 1. Subsequently, a Pareto-based evaluation was conducted to prioritize risk agents. Risk mitigation strategies were then designed using HOR Phase 2. This was followed by the development of an ANP network model and the assessment of the importance scale for each mitigation strategy, based on the criteria established by the company. Finally, risk mitigation priorities were determined by integrating the results of HOR Phase 2 with the ANP values. The strategy with the highest value was selected as the top-priority mitigation action to be implemented by the company.

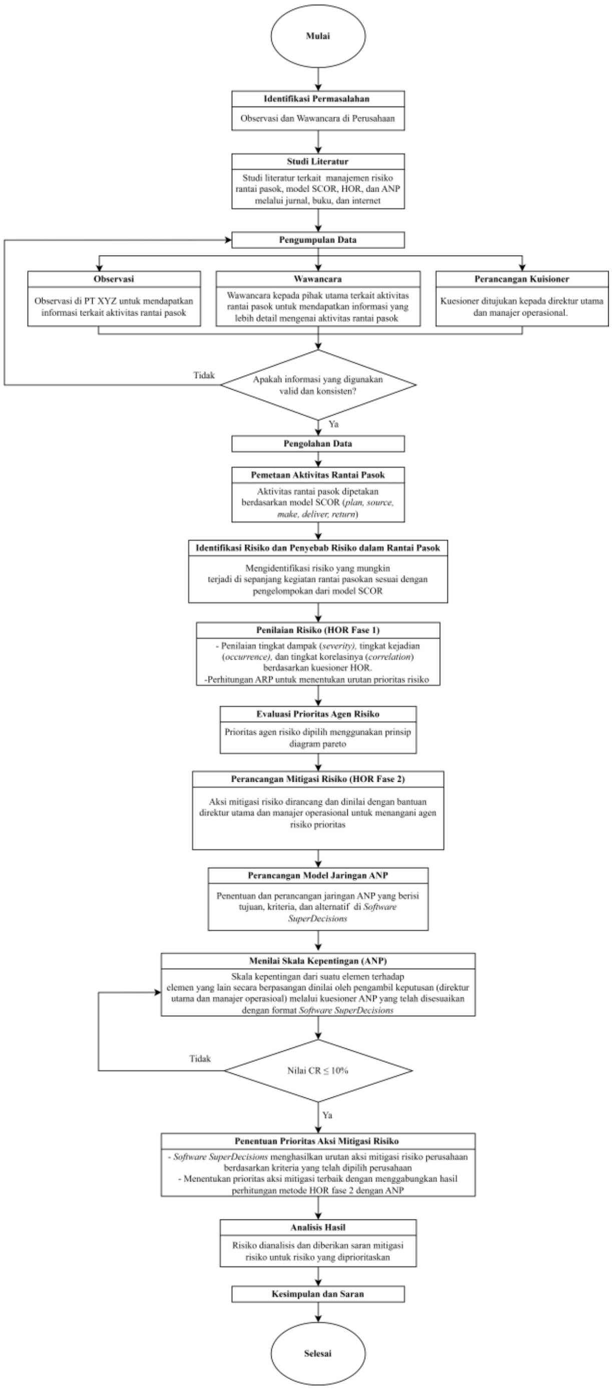


Figure-1. Research Methodology

IV. RESULT AND DISCUSSION

This study focuses on the operational activities within the supply chain and rattan export processes of PT XYZ. The objectives of this research are to identify supply chain risks, assess the likelihood of risk occurrences, analyze their causes, determine prioritized risks, and formulate mitigation strategies that should be prioritized for implementation by the company. The findings indicate the existence of potential risk events and the underlying causes (risk agents) that contribute to those risks.

A. *Supply Chain Activity Mapping*

In this stage, the supply chain activities of PT XYZ were mapped using the Supply Chain Operations Reference (SCOR) model. The SCOR model is used to categorize supply chain activities into five main processes: Plan, Source, Make, Deliver, and Return. The mapped activities are presented in Table 4.

Table-4. Supply Chain Activities

SCOR Process	Supply Chain Activities	Activity Code
Plan	Planning for fulfilling buyer orders	C1
	Planning for raw material procurement	C2
	Planning for weaving capacity	C3
	Planning and scheduling production	C4
	Planning for order delivery	C5
Source	Purchasing raw materials	C6
	Receiving raw materials	C7
	Storing raw materials	C8
Make	Conducting production activities	C9
	Final product quality control	C10
	Storing finished products	C11
Deliver	Preparing shipping instructions	C12
	Informing delivery schedules	C13
	Booking shipping containers	C14
	Checking shipping requirement completeness	C15
	Delivering orders to buyers	C16
Return	Returning raw materials not meeting agreements	C17

Returning finished products to weavers for rework if not up to specification	C18
Handling product claims by buyers requiring compensation or replacement	C19

A. *Risk Assessment*

1) *Severity Assessment*

The severity criteria were established based on discussions with the President Director and Operations Manager. Table 5 below presents the average severity scores obtained from the questionnaire responses completed by both the President Director and the Operations Manager.

Table 5. Severity Scores of Risk Events

SCOR Process	*Risk Event* Code	Risk Event Description	Severity
Plan	E1	Order quantity exceeds company capacity	6
	E2	Company unable to meet buyer's complex design requirements	5
	E3	Miscommunication between company and buyer	5,5
	E4	Difficulty in sourcing appropriate raw materials	5,5
	E5	Unavailability of required raw materials	7,5
	E6	Miscommunication between company and supplier	4,5
	E7	Shortage of weaving labor	7
	E8	Order changes from the buyer	4
	E9	Inaccurate production scheduling	5
	E10	Uncertainty in customer's choice of shipping method	2
Source	E11	Fluctuations in raw material prices	2
	E12	Delays in raw material arrival	4,5
	E13	Inconsistent quality of raw materials	3,5
	E14	Quantity of raw materials received does not match agreement	5
	E15	Damage to raw materials during storage	6
Make	E16	Production delays	6
	E17	Equipment/machine breakdown	6,5
	E18	Product specifications do not meet standards	7
	E19	Inaccurate measurements	3,5
	E20	Errors in finished product quantity	6,5
	E21	Damage to finished products during storage	7
Deliver	E22	Errors in shipping instruction data entry	5
	E23	Inconsistent shipping schedules	4
	E24		6

		Unavailability of containers on time	
	E25	Issues with export licensing	6,5
	E26	Delays in order delivery to buyer	6,5
	E27	Delays in replacement raw material delivery	7,5
Return	E28	Delayed return of reworked products by weavers	6,5
	E29	Product claims from buyers requiring refund or replacement	5,5

2) *Occurrence Assessment*

The occurrence ratings were also based on discussions with the President Director and Operations Manager. Table 6 below presents the average occurrence scores derived from the questionnaire responses completed by both respondents.

Table-6. Occurrence Scores of Risk Agents

Risk Agent Code	Risk Agent Description	Occurrence
A1	Company unable to accept orders due to overload	5
A2	Company resources insufficient to meet buyer demand	4
A3	Lack of communication between the company and other parties	5
A4	Supplier unable to provide required raw materials	7,5
A5	Shortage of skilled and competent labor	4,5
A6	Sudden changes in buyer demand	3,5
A7	Adverse weather conditions (rain)	6
A8	Power outages	4
A9	Limited workforce availability	5
A10	Exchange rate fluctuations	4
A11	Lack of supplier performance evaluations	3,5
A12	Damage to raw materials during transportation	6,5
A13	Natural disasters	7
A14	Poor packaging	3,5
A15	No pre-shipment product inspection	6
A16	Unsanitary and damp storage conditions	5,5
A17	Shortage of raw materials	8,5
A18	Worker negligence	5,5
A19	Lack of maintenance on production equipment	4,5
A20	Inaccurate quality control	6,5
A21	Inefficient facility layout	4
A22	Inadequate warehouse management procedures	5
A23	Incomplete export licensing requirements	4
A24	Logistics providers failing to meet contract agreements	6
A25	Reworking non-compliant products takes excessive time	5
A26	Products not tested before shipment	4,5

A27	Products stuck at the port	7
A28	Product contamination	8
A29	Decline in buyer confidence toward the company	9,5
A30	Inadequate work supervision	6

3) Correlation Assessment

The correlation assessment criteria are adapted from those proposed by Pujawan & Geraldin (2009). The average scores of the correlations between risk events and risk agents, obtained through questionnaires completed by the President Director and the Operations Manager, were used as input for the Aggregate Risk Potential (ARP) calculation.

4) Aggregate Risk Potential (ARP)

Once the severity, occurrence, and correlation values between risk events and risk agents were obtained from the questionnaire responses of the President Director and the Operations Manager, the ARP could be calculated. The ARP calculation serves to identify and rank the risk agents that have the most significant influence on the occurrence of risk events. By determining the order of influence of the risk agents, the most critical risk causes can be prioritized for mitigation. The results of the ARP calculation are presented in Tables 7a and 7b.

5) Evaluation of Risk Agent Prioritization

Risk agent prioritization was conducted using the Pareto diagram principle, which suggests that 80% of problems are caused by 20% of the possible causes. By mitigating the top 20% of risk agents, it is expected that 80% of the impacts can be addressed. The prioritized risk agents for mitigation are shown in Table 8.

Table-8. Risk Agent Prioritization

Code (Aj)	Risk Agent	ARP	%	Cummulative
A4	Supplier's inability to provide required raw materials	4601,3	10,2%	10,2%
A17	Shortage of raw materials	4033,3	9,0%	19,2%
A18	Worker negligence	2899,9	6,4%	25,6%

6) Risk Mitigation Design

The design of risk mitigation actions (preventive actions) aims to address the three prioritized risk agents identified through the Pareto principle. The mitigation strategies were developed through discussions with the President Director and the Operations Manager, supported by a literature review. After mitigation recommendations were finalized, Phase 2 of the House of Risk (HOR) was conducted by mapping each preventive action to its corresponding risk agent. The mitigation actions for prioritized risk agents are presented in Table 9, and the results of the HOR Phase 2 calculations are shown in Table 10.

7) Determining Mitigation Priorities Using ANP

In this study, HOR Phase 2 is not the final stage for determining mitigation priorities. This is because HOR Phase 2 does not incorporate the specific criteria required by the company when selecting mitigation strategies. The decision-making in HOR Phase 2 is based solely on the ease of implementation and the strength of the relationship between preventive actions and risk agents. Therefore, the final prioritization of mitigation actions is determined by multiplying the ETDk values from HOR Phase 2 with the ANP (Analytic Network Process) weights. The mitigation action with the highest product of ETDk and ANP weight will be prioritized for implementation by the company.

Table-7a. ARP Calculation Results

Bussiness Process	***Risk Event (Ei)***	***Risk Agent* (Aj)**															***Severity of Risk Event i* (Si)**
		A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**	**A13**	**A14**	**A15**	
Plan	**E1**	9	9	3	3	9	9	0	0	9	0	0,5	2	0	0	0	6
	E2	2	9	3	9	9	0	0	0	3	0	0	0	0	0	0	5
	E3	0	0,5	6	0	0	1,5	0,5	0,5	0	0	0	1,5	0,5	0	1,5	5,5
	E4	0	1,5	4,5	9	0	4,5	0	0	0	9	0	0	0	0	0	5,5
	E5	0	4,5	2	9	1,5	6	9	1,5	4,5	4,5	0	9	3	0,5	0,5	7,5
	E6	0	4,5	9	6	1,5	1,5	0,5	0,5	0,5	1,5	0	1,5	0,5	0,5	1,5	4,5
	E7	0	9	4,5	0	9	9	0,5	0	9	1,5	0	1,5	1,5	0	0	7
	E8	9	6	3	6	1,5	6	0	0	0	1,5	0	0	0,5	0	0	4
	E9	0	1,5	3	3	0,5	1,5	1,5	0,5	0,5	1,5	0	0,5	0,5	0,5	1,5	5
	E10	0	0	5	0	0,5	1,5	0,5	0,5	0,5	0,5	0	0	0,5	0	0,5	2
Source	**E11**	3	1,5	1,5	4,5	0,5	0,5	0	0	0	9	0	0	1,5	1,5	0	2
	E12	0	4,5	1,5	3	0,5	0,5	2	0,5	1,5	0	9	0,5	2	0,5	0	4,5
	E13	0	1,5	3	6	0,5	1,5	3	1,5	1,5	1,5	9	6	1,5	1,5	6	3,5
	E14	0	4,5	3	9	1,5	0,5	1,5	1,5	1,5	1,5	9	1,5	1,5	0	6	5
	E15	0	1,5	1,5	1,5	0,5	0	4,5	0	1,5	0	0	0	1,5	4,5	1,5	6
Make	**E16**	0	4,5	1,5	9	4,5	4,5	6	6	4,5	1,5	0	9	3	1,5	1,5	6
	E17	0	4,5	1,5	4,5	4,5	0,5	1,5	4,5	1,5	0	0	0	3	0,5	0	6,5
	E18	0	4,5	1,5	4,5	4,5	4,5	4,5	4,5	4,5	1,5	0	0,5	1,5	1,5	4,5	7
	E19	0	1,5	1,5	0	3	0	0	0	0,5	0	0	0	0	0	0	3,5
	E20	0	1,5	5	4,5	1,5	1,5	0	0	0	0	0	0	4,5	0	6	6,5
	E21	0	4,5	0	0	0,5	0,5	4,5	0,5	0,5	0	0	0	4,5	4,5	0,5	7
Deliver	**E22**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
	E23	0	0	0	0	0	0	3	0	0	0	0	0	4,5	0	0	4
	E24	0	1,5	3	0	0	4,5	2	0,5	0	0	0	0	6	0	0	6
	E25	0	1,5	3	0	0,5	0,5	0	0,5	0,5	0,5	0	0	0,5	0	0	6,5
	E26	0	0	3	4,5	4,5	4,5	9	1	3	0	0	4,5	9	0	0	6,5
Return	**E27**	0	4,5	1,5	9	0,5	1,5	6	1,5	4,5	0,5	9	4,5	6	0	0	7,5
	E28	0	4,5	0,5	4,5	2	4,5	6	1,5	4,5	0	0	4,5	6	0	1,5	6,5
	E29	0	0	3	0	0	0	0	0	0	0	0	0	0	9	9	5,5
Occurance of Agent j		5	4	5	7,5	4,5	3,5	6	4	5	4	3,5	6,5	7	3,5	6	
Aggregate Risk Potential (ARPj)		530	2138	2070	4601,3	1645,9	1477,9	2482,5	675	1796,3	689	656,25	1872	2700,3	524,13	1377	
Priority Rank of Agent j		27	6	7	1	13	14	5	21	11	20	24	8	4	28	15	

Table-7b. ARP Calculation Results (continued)

***Bussiness* Process**	***Risk Event (Ei)***	***Risk Agent* (Aj)**															***Severity of Risk* Event *i* (Si)**
		A16	**A17**	**A18**	**A19**	**A20**	**A21**	**A22**	**A23**	**A24**	**A25**	**A26**	**A27**	**A28**	**A29**	**A30**	
Plan	**E1**	0	9	0,5	0	0	0	0,5	0	0	0	0	0	0	0	0	6
	E2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5
	E3	0	1,5	6	0	1,5	0	3	0	1,5	1,5	1,5	3	0	3	0	5,5
	E4	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	5,5
	E5	0	6	1,5	0	1,5	0	6	0	1,5	1,5	0,5	0	0	0	1,5	7,5
	E6	0	0	6	0	1,5	0	3	0	3	0,5	0,5	0	0	0	1,5	4,5
	E7	0	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	E8	0	1,5	1,5	0	0	0	0	0	0	1,5	1,5	0	0	9	0,5	4
	E9	0,5	6	5	0	0,5	0	1,5	0,5	0,5	0	0	0	0	0	1,5	5
	E10	0	0	0,5	0	0	0	0,5	0	5	0,5	0	0	0	0	0	2
Source	**E11**	0	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	E12	4,5	0,5	0,5	0,5	0	0	0	1,5	6	0	0	0	0	0	0,5	4,5
	E13	1,5	1,5	1,5	1,5	4,5	0,5	0,5	0	0	1,5	0,5	0	0	0	1,5	3,5
	E14	0	4,5	4,5	1,5	1,5	0	0,5	0	1,5	0,5	0,5	0	0	0	0,5	5
	E15	9	0	4,5	1,5	4,5	6	6	0	1,5	0	0,5	0	0	0	4,5	6
Make	**E16**	0,5	9	1,5	2	1,5	0	1,5	0	1,5	1,5	0	0	0	0	6	6
	E17	2	0,5	4,5	9	1,5	1,5	0,5	0	0	1,5	0	0	0	0	1,5	6,5
	E18	6	1,5	9	4,5	9	1,5	1,5	0	0	1,5	4,5	0	3	0	6	7
	E19	0	0	6	4,5	1,5	0	0,5	0	0	0,5	0	0	0	0	5	3,5
	E20	0	9	4,5	1,5	4,5	0	1,5	0	0	0	0	0	0	0	6	6,5
	E21	9	0	4,5	0,5	1,5	9	5	0	0	1,5	2	0	9	0	1,5	7
Delive r	**E22**	0	0	9	0	0	0	0	3	0	0	0	0	0	0	0	5
	E23	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	4
	E24	0	0	0	0	0	0	0,5	4,5	9	0	0	0	0	0	0	6
	E25	0	0	0,5	0	0	0	0,5	9	4,5	0	0	3	0	0	0	6,5
	E26	0	6	9	1,5	0	0	1,5	3	9	4,5	0	9	0	0	3	6,5
Return	**E27**	0	4,5	1,5	4,5	1,5	0	1,5	4,5	4,5	1,5	0	0	0	0	1,5	7,5
	E28	0	4,5	9	0,5	0	0	0	0	0	6	1,5	0	0	0	1,5	6,5
	E29	0	0	9	0	9	0	0	0	0	0	0	0	0	3	9	5,5
Occurance of Agent j		5,5	8,5	5,5	4,5	6,5	4	5	4	6	5	4,5	7	8	9,5	6	
Aggregate Risk Potential (ARPj)		1116,5	4033,3	2899,9	907,88	1732,3	484	1116,3	592	1857	787,5	372,38	661,5	672	655,5	1855,5	
Priority Rank of Agent j		16	2	3	18	12	29	17	26	9	19	30	23	22	25	10	

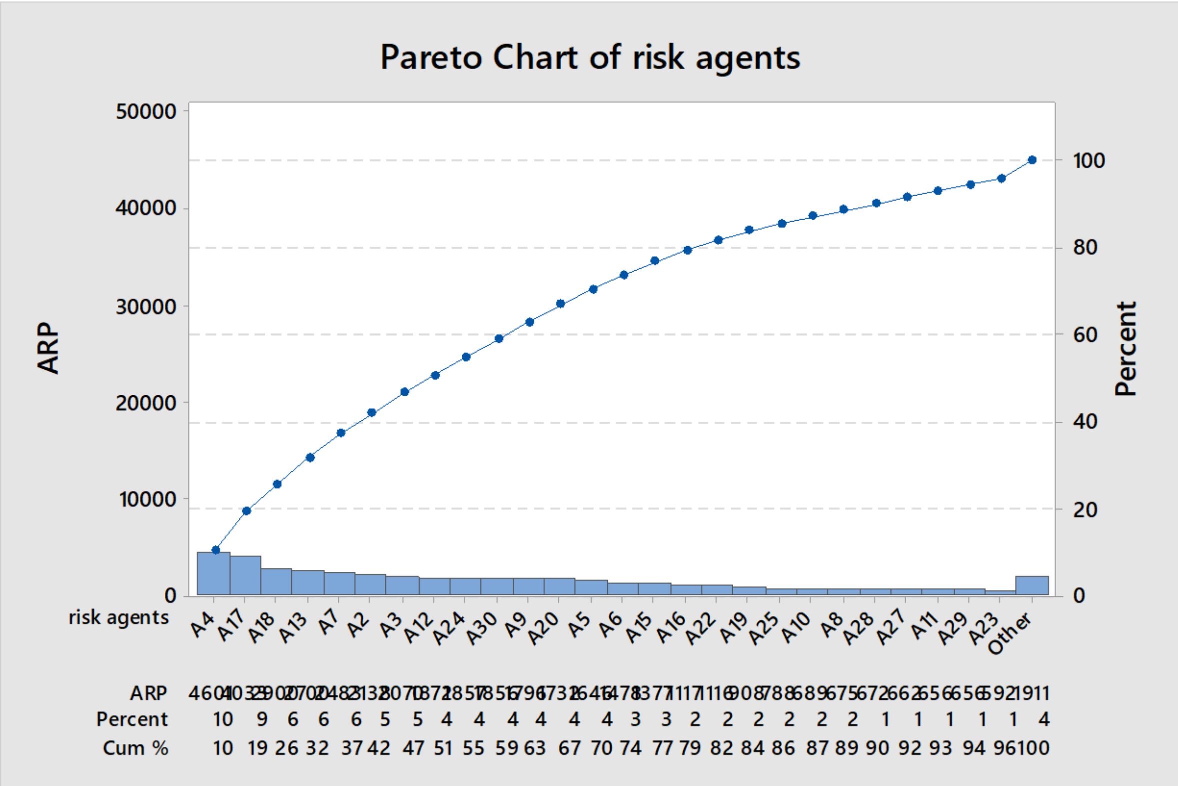


Figure 2. Pareto Diagram of ARPj

Table-8. Mitigation Actions for Prioritized Risk Agents

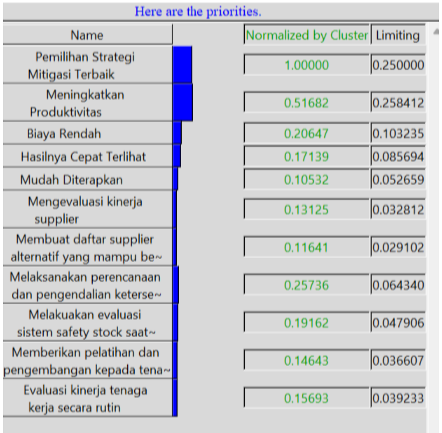
Risk Agent Code	Risk Agent Description	ARP	%	Cummulative	Preventive Action	Mitigation Code (PAk)
A4	Supplier's inability to provide required raw materials	4601,25	10,23%	10,23%	Evaluate supplier performance	PA1
					Create a list of alternative suppliers with efficient collaboration potential	PA2
A17	Shortage of raw materials	4033,25	8,97%	19,20%	Implement planning and control for raw material availability	PA3
					Evaluate the current safety stock system	PA4
A18	Worker negligence	6,45%	6,45%	25,64%	Provide training and development for workers	PA5
					Conduct regular performance evaluations of workers	PA6

Table-9. HOR Phase 2 Calculation

To be Treated Risk Agent (Aj)	Correlation with Preventive Actions (PAk)						Aggregate Risk Potentials (ARPj)
	PA1	PA2	PA3	PA4	PA5	PA6	
A4	9	9	3	0	0	0	4601,25
A17	0	9	9	9	0	0	4033,25
A18	0	0	0	0	9	9	2899,875
Total Effectiveness of Action k	41411,3	77710,5	50103	36299,3	26098,9	26098,9	
Degree of Difficulty Performing Action k	2,5	3,5	2,5	2,5	4	2	
Effectiveness to Difficulty Performing	16564,5	22203	20041,2	14519,7	6524,72	13049,4	
Rank of Priority	3	1	2	4	6	5	

8) *Analytical Network Process (ANP)*

The selection of criteria was determined by the President Director and Operations Manager of PT XYZ. Four criteria were chosen by PT XYZ, namely: the ability to increase productivity, low cost, rapid results, and ease of implementation. As the objective of applying the ANP method is to determine the most effective mitigation action, the alternatives used are the mitigation actions developed in HOR Phase 2. Data processing using the ANP method was carried out with SuperDecisions Software Version 3.2. The computational results from the software are illustrated in Figure 3.



Here are the priorities.

Name	Normalized by Cluster	Limiting
Pemilihan Strategi Mitigasi Terbaik	1.00000	0.250000
Meningkatkan Produktivitas	0.51682	0.258412
Biaya Rendah	0.20647	0.103235
Hasilnya Cepat Terlihat	0.17139	0.085694
Mudah Diterapkan	0.10532	0.052659
Mengevaluasi kinerja supplier	0.13125	0.032812
Membuat daftar supplier alternatif yang mampu be~	0.11641	0.029102
Melaksanakan perencanaan dan pengendalian keterse~	0.25736	0.064340
Melakuakan evaluasi sistem safety stock saat~	0.19162	0.047906
Memberikan pelatihan dan pengembangan kepada tena~	0.14643	0.036607
Evaluasi kinerja tenaga kerja secara rutin	0.15693	0.039233

Figure 3. ANP Calculation Results

In Figure 3, the ANP calculation results are presented in the "Normalized by Cluster" column.

It can be observed that the most influential criterion in selecting the best mitigation strategy is "Increasing Productivity," with a weight of 0.5168. The best alternative mitigation action is "Implementing Planning and Control for Raw Material Availability," with a weight of 0.25736. In this study, the prioritization of the best mitigation strategy or action is determined by integrating the results of the HOR Phase 2 calculation with the ANP values. The structure of the combined calculation table is similar to the HOR Phase 2 calculation table presented in Table 9. However, in the integrated table, an additional row is included below the "Effectiveness to Difficulty Performing" (ETDk) row, namely "Effective for the Company." The purpose of calculating the "Effective for the Company" value is to incorporate the company's selected decision-making criteria for identifying the optimal mitigation strategy. This value is obtained by multiplying the ETDk value by the corresponding ANP weight. The results of this integrated calculation for determining the best risk mitigation action priority are shown in Table 10.

Table-10. Revised HOR Phase 2 Calculation with ANP Integration

To be Treated Risk Agent (Aj)	Preventive Action						Aggregate Risk Potentials (ARPj)
	PA1	PA2	PA3	PA4	PA5	PA6	
A4	9	9	3	0	0	0	4601,25
A17	0	9	9	9	0	0	4033,25
A18	0	0	0	0	9	9	2899,875
Total Effectiveness of Action k	41411,3	77710,5	50103	36299,3	26098,9	26098,9	
Degree of Difficulty Performing Action k	2,5	3,5	2,5	2,5	4	2	
Effectiveness to Difficulty Performing	16564,5	22203	20041,2	14519,7	6524,72	13049,4	
Effective for The Company	2174,09	2584,65	5157,8	2782,26	955,415	2047,85	

Rank of Priority	4	3	1	2	6	5

The ranking of PT XYZ's risk mitigation actions based on the combined ETDk value from HOR Phase 2 and the ANP score is presented in Table 11 below.

Table-11. Proposed Mitigation Actions

Code	Alternative Mitigation Strategy	Effective for the Company Score
PA3	Implement planning and control for raw material availability	5157,80
PA4	Evaluate the current safety stock system	2782,26
PA2	Create a list of alternative suppliers capable of efficient collaboration	2584,65
PA1	Evaluate supplier performance	2174,09
PA6	Conduct regular performance evaluations of workers	2047,85
PA5	Provide training and development for workers	955,41

Based on the integration of the ETDk value from HOR Phase 2 and the ANP weight, the top-priority risk mitigation action is *"Implementing planning and control for raw material availability."* This action is recommended to be implemented first by the company. It is selected as the priority mitigation strategy because of its efficient impact on the continuity of PT XYZ's supply chain. By implementing planning and control for raw material availability, the company can ensure consistent raw material supply.

V. Conclusion

The identification of supply chain risks at PT XYZ, based on the SCOR model, revealed 29 risk events and 29 corresponding risk agents. In the HOR method, risk events and risk agents were analyzed using calculations of severity of impact, frequency of occurrence, and the correlation between risk events and risk agents, resulting in the Aggregate Risk Potential (ARP) values. These ARP values were further analyzed using the 80/20 principle of the Pareto diagram to determine the priority risk agents for mitigation. The analysis identified three priority risk agents: the supplier's inability to provide the required raw materials, raw material shortages, and human error.

Based on a literature review and discussions with the President Director and the Operations Manager, six mitigation actions were developed to address the identified priority risk agents. These include: evaluating supplier performance (PA1), compiling a list of alternative suppliers capable of efficient collaboration (PA2), implementing planning and control of raw material availability (PA3), evaluating the current safety stock system (PA4), providing training and development for employees (PA5), and conducting regular employee performance evaluations (PA6). The prioritization of these risk mitigation actions for implementation at PT XYZ was determined using the "Effective for the Company" value—calculated by multiplying the Effectiveness to Difficulty Performing (ETDk) value from HOR Phase 2 with the corresponding ANP weight. The mitigation action with the highest "Effective for the Company" score is designated as the top priority. The recommended prioritization of mitigation actions, from highest to lowest, is as follows: implementing planning and control of raw material availability (PA3), evaluating the current safety stock system (PA4), compiling a list of alternative suppliers capable of efficient collaboration (PA2), evaluating supplier performance (PA1), conducting regular employee performance evaluations (PA6), and providing training and development for employees (PA5). Through this risk analysis approach, the company is expected to effectively map the risks present within its supply chain operations and select the most critical mitigation actions for implementation.

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