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Supply Chain Risk Mitigation Analysis Using the House of Risk (HOR) and Interpretive Structural Modeling (ISM) Methods Approach

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Abstract—Supply chain disruptions have become increasingly complex due to uncertainty in global markets, operational inefficiencies, and external environmental factors. Effective risk mitigation strategies are therefore essential to ensure supply chain resilience and sustainability. This study aims to analyze and prioritize supply chain risk mitigation strategies using an integrated approach of House of Risk (HOR) and Interpretive Structural Modeling (ISM). The HOR method was employed to identify risk events and risk agents, evaluate their aggregate risk potential, and determine priority mitigation actions based on their effectiveness-to-difficulty ratio. Subsequently, ISM was applied to analyze the interrelationships among selected mitigation strategies and to establish a hierarchical structural model for implementation. The results indicate that several dominant risk agents significantly influence supply chain performance, including supplier delivery delays, inaccurate demand forecasting, and inadequate information sharing. The HOR analysis identified the most critical preventive actions, while the ISM results revealed the driving and dependent factors among mitigation strategies, enabling a systematic implementation sequence. The integration of HOR and ISM provides a comprehensive framework for both quantitative risk prioritization and structural strategic planning. This study contributes to supply chain risk management literature by offering a practical decision-support model for organizations seeking to enhance supply chain resilience through structured and prioritized mitigation planning.

Keywords— House Of Risk, Interpretive Structural Modeling, Risk Mitigation, Supply Chain Resilience, Supply Chain Risk Management.

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I. INTRODUCTION

According to data from the Central Statistics Agency (BPS) in 2023, the development of the number of food and beverage companies has fluctuated which tends to increase every year. These fluctuations directly have an impact on increasing the company's needs in terms of the fulfillment of raw materials to the product distribution process. Product packaging is important not only as a container for product packaging but also as a promotional tool and attracting the attention of buyers [1]. Supply chain refers to a series of activities or activities that are interrelated in delivering products, ranging from the acquisition of raw materials and parts, manufacturing and assembly processes, warehousing activities and inventory monitoring, order management and tracking of incoming orders, distribution through all channels, to delivery and management of information systems needed to monitor all of these activities [2]. The more complex a system is, the more risk of harm that can be posed to the system [3]. Therefore, good supply chain system flow management through risk management is needed by the company, among others, for customer satisfaction, increasing revenue, lowering costs, making the company stronger, and company activities can run effectively and efficiently [4].

The House of Risk method is a new method resulting from the integration of two research models, namely Failure Mode and Effect Analysis (FMEA) and House of Quality (HOQ) for the risk level analysis process by calculating the Risk Potential Number (RPN) and designing mitigation strategies as identified risk mitigation measures [5]. Supply Chain Operation References (SCOR) is a model designed to improve supply chain performance by providing a framework for the analysis, planning, and management of supply chain processes [6]. Meanwhile, The Interpretive Structural Modeling (ISM) is a method based on the use of experienced experts with practical knowledge to decompose a complex system into several subsystems and construct a hierarchical model. This hierarchical structure provides a clearer understanding of the components within a complex situation, making it easier to formulate appropriate strategies for problem-solving. Furthermore, ISM facilitates the understanding of relationships between factors and connects complex ideas and issues, thereby supporting more effective and efficient decision-making [7].

II. RELATED WORKS

A. Supply Chain Concept

Supply chain is an organizational system that performs various tasks and functions that involve information, funds, and other resources that are interrelated in the movement of goods or services from suppliers to consumers or customers [8]. These main roles include suppliers, manufacturers, distributors, retail outlets, and customers [9].

B. Supply Chain Management

Supply chain management practices focus on the integrated management of inventory, logistics, suppliers, production, and distribution to improve efficiency, quality, and customer satisfaction, as well as reduce operational costs and risks in the supply chain [10].. SCM processes include planning, procurement, production, warehouse management, product delivery to customers, and order returns [11]

C. Risk

Risk is the possibility of events or events that are detrimental to the Company or business, where these events cannot be predicted in the form of small losses that are meaningless, to large losses that have a big impact both material and non-material non-materil [12]. Forms of risk can include losses on wealth, individual suffering, legal liability, and losses due to changes in market conditions [13]

D. Supply Chain Risk Management

Supply Chain Risk Management (SCRM) is an approach used to monitor risks that may occur in the supply chain network [14]. The purpose of risk management is to assist the Company in understanding and overcoming the influence of the chain when a small or large risk occurs in the supply chain network and to ensure that when the risk occurs, the supply chain actors have the ability to return to normal conditions [15].

E. *Supply Chain Operations Reference* (SCOR)

The supply chain performance measurement model is SCOR (Supply Chain Operation Reference) which was developed by a professional institution, the Supply Chain Council (SCC) in 1996 [16]. The SCOR model enables complex supply chain management processes to be visualized and decomposed into manageable elements. It also supports the evaluation of an organization's supply chain performance and helps identify areas with potential for improvement [17]. In addition, SCOR divides supply chain processes into 5 core processes, namely plan, source, make, deliver, and return [18]. The SCOR model also models each supply chain process into three levels of hierarchy [19].

F. Interpretive Structural Modelling (ISM)

ISM is an analytical tool as a decision support that facilitates a thorough understanding of complex situations by relating and organizing ideas in a visual map. ISM is a planning methodology used to identify and infer the relationship of factors in a problem [20]. The Interpretive Structural Modeling (ISM) technique maps relationships among factors by analyzing their driving and dependence power, and then categorizes them into four clusters through MICMAC analysis. This approach provides a clearer visualization of influence compared to methods such as Delphi method or Analytic Hierarchy Process (AHP), which do not explicitly capture these relational dynamics [21].

G. House of Risk (HOR)

The House of Risk method is a method used to identify the risks that occur and find appropriate preventive measures [22]. House of Risk 1 is a stage to identify risk factors within the factory's supply chain, followed by estimating the impact of various risk events, determining the source of risk, and assessing the correlation between risk events and risk agents that will later be used in the calculation of Aggregate Risk Potential (ARP) for risk agents. The second step is the House of Risk analysis 2 which is used to select priority actions by considering the extent to which they are effective compared to other actions, as well as their resource factors and difficulties [23].

III. METHOD

PT XYZ is a manufacturing company engaged in the production of single-use plastic packaging for the needs of the food and beverage industry. In the last six months, the company has had obstacles in meeting market demand. This increase in demand from customers is not balanced by increasing production capacity, storage and resource optimization, both in terms of machinery, and effective supply chain management. In addition, the most dominant and consistent type of complaint that appears every month in the company is about the quality and quantity of products delivered. This is because the company only relies on one supplier without evaluating supplier performance and the weak Quality Control (QC) process. Based on these problems, PT XYZ needs to realize the importance of implementing supply chain risk management through risk analysis on supply chain activities to identify the source of the problem, as well as develop the right mitigation strategy

A. Data Collection Methods

Data collection in this study was carried out through interviews, observations, and questionnaires to 5 respondents related to the supply chain process, namely Plant Manager, Production Supervisor, PPIC Supervisor, Finished Good Warehouse Supervisor, and Semi-finished Good Warehouse Supervisor.

B. Data Processing Methods

The House of Risk (HOR) model is one of the analyses that is often used in supply chain management. HOR is a framework developed by the FMEA (Failure Mode and Effect Analysis) method and QFD (Quality Function Deployment) method [24]. This method is divided into two stages, namely House of Risk (HOR) phase 1 and House of Risk (HOR) phase 2. In phase 1, it begins with mapping supply chain activities using the Supply Chain Operations Reference Model (SCOR) method which consists of Plan, Source, Make, Delivery, and Return. Then continued to identify risks and determine priority risks to be handled based on a pareto diagram. In the 2nd stage, the priority risk sources will be re-analyzed with preventive action and the final result is obtained the priority order of risk mitigation as the output of the house of risk [25]. The Interpretive Structural Modeling (ISM) method is a planning methodology used to identify and conclude the relationship between factors in a problem [20]. The ISM method is used to map the relationship of factors in priority risk agents determined in the House of Risk (HOR) phase 1.

IV. RESULT AND DISCUSSION

A. Identify the Company's Supply Chain Activities Using the SCOR (Plan, Source, Make, Delivery, Return) Model

The first step in this study is to map business processes using the SCOR approach starting from the planning stage to the product to the customer.

Table 1. Company Business Process Supply Chain Based on SCOR

Major Process	Sub Process	Detail Activity
Plan	Preparation *Weekly Sales Report*	Compiling order summaries and sales forecasts by the marketing team
	Raw material procurement planning	Determine the required quantity of raw materials
	Production planning	Determine the weekly production volume based on Weekly Sales Report
Source	Procurement of raw materials	Place an order for raw materials
	Control process	Receiving and inspecting incoming raw materials
	Raw material storage	Storing raw materials in the semi-finished goods warehouse
Make	Production process	The production process is cariied out based on work orders issued by PPIC
	Quality control	Conduct quality checks on the finished products
	Product packaging	Packaging the finished product according to the box label
	Product storage	Move finished products to the finished goods warehouse
Delivery	Product delivery	Ship product to customers
Return	Return of new products to the customer	Return of new product to the customer

B. House of Risk I

At this stage, an assessment of the severity level was conducted for 26 potential risk impacts arising from the company's supply chain business processes, based on the results of the questionnaire survey thad had been conducted. The assessment was conducted using a 1-10 likert scale scale, where 10 indicates the most severe level of impact.

Table 2. Severity of Risk Event Impact

Ei	Risk Event	Severity
E1	Inaccurate demand forecast	5
E2	Mismatch between the amount of physical raw materials and the Erasoft system	5
E3	Miscalculation of raw material requirements	4
E4	The production plan exceeds the machine's effective capacity	7
E5	Mismatch between the physical inventory of FG in the warehouse and the Erasoft system	6
E6	Sudden changes to the production plan	6
E7	Delays in the delivery of raw materials	4
E8	The raw materials from the supplier do not meet the standards	7
E9	The quantity of raw materials received does not match the order	5
E10	The raw materials were damaged because they were stored outside the warehouse	7
E11	Incorrect type, quantity, and spesifications of the transferred materials	5
E12	Machine failure	8
E13	High overtime hours	7
E14	Unmet production targets	6
E15	Product quality and form do not meet standards	7

Ei	Risk Event	Severity
E16	Errors in box labeling	7
E17	The products were mixed up and the quantity does not match the BSTB	4
E18	Insufficient warehouse capacity	7
E19	Accumulation of product buffer stock in the warehouse	7
E20	Product contaminated with foreign objects	7
E21	Length of loading process	5
E22	Incompatibility of the product loaded with the Delivery Order (DO)	4
E23	The number of products shipped does not match	4
E24	Product delivery delays	6
E25	Product damage during delivery	4
E26	Customer complaints	7

The results of the questionnaire distribution were then also used in assessing the level of occurrence of risk causes against 32 risk agents that had been identified based on risk events. This assessment is carried out using a likert scale of 1-10, where the number 10 indicates the level of risk cause that appears most often.

Table 3. Rate of Occurrence of Risk Causes

Ai	Risk agent	Occurrence
A1	Incorrect demand forecast methods	7
A2	Absence of regular stock in the warehouse on a regular basis	5
A3	Inaccuracy in the calculation of raw materials	6
A4	Production needs exceed the effective capacity of machines	6
A5	Data mismatch between warehouse records and warehouse physical stock	5
A6	Reschedule delivery by customer	7
A7	Sudden order requests	7
A8	Miscommunication between purchasing and supplier	7
A9	Bad weather (rain)	5
A10	Lack of evaluation of raw material suppliers	6
A11	The availability of raw materials from suppliers is insufficient	6
A12	Inadequate storage capacity and facilities	7
A13	No re-checking before transfer	6
A14	Storage processes that don't match layouts	7
A15	Preventive maintenance machine not running	8
A16	Production scheduling doesn't go as planned	5
A17	Breakdown of machines that stop production for up to 2 days	7
A18	Changeover management & setup time is not optimal	7
A19	Not running SOP and IK production process and QC optimally	6
A20	Errors in the machine setting process	7
A21	Employee negligence	5
A22	Accumulation of buffer stock and customer deposit items	5
A23	Production is carried out before there is actual demand to maintain the productivity of machinery and labor	6
A24	The implementation of hygiene, PPE, and environmental control is not optimal	4
A25	Manual product search process	5
A26	Lack of resources (forklifts, operators) to load goods onto vehicles	6
A27	Incompatibility of the packaging label with the contents of the product	5
A28	Miscalculation of the number of products during packaging	5
A29	Number of unfulfilled requests	5
A30	Vehicle capacity does not meet	5
A31	The loading process and the standard of securing goods when shipping is not carried out according to the procedure	6
A32	The product does not meet specifications	6

Next, the assessment is conducted by calculating the Aggregate Risk Potential (ARP) based on the results of the assessment of the severity of risk impacts, the likelihood of risk agents occurring, and the correlation between risk events and risk agents. This calculation aims to determine the priority order of risk agents that must be addressed immediately.

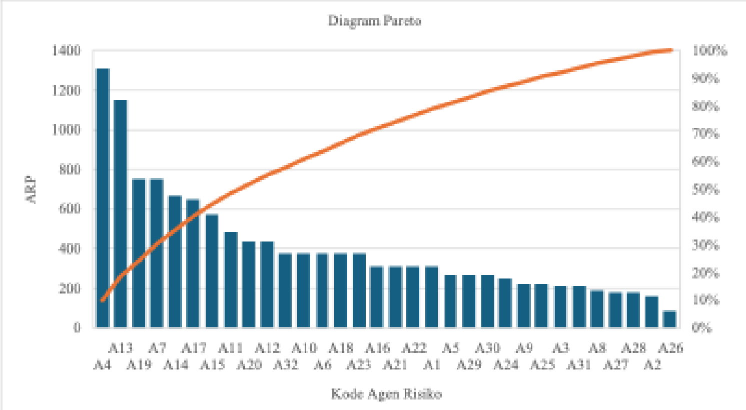

Figure 1. Pareto Diagram

The prioritization of risk agents is conducted using the 80:20 Pareto principle. This Pareto principle states that 80% of total risk is assumed to be caused by 20% of the dominant risk agents [26]. Therefore, based on this Pareto concept, the prioritized risk agents are those that cumulatively contribute up to 80% of the total ARP, namely 19 risk agents

Table 4. Causes of Priority Risk

Rank	Ai	Risk Agent	ARP	%ARP	%Cumulative
1	A4	Production needs exceed the effective capacity of machines	1314	10,32%	10,32%
2	A13	No re-checking before transfer	864	6,79%	17,11%
3	A7	Sudden order requests	756	5,94%	23,05%
4	A19	Not running SOP and IK production process and QC optimally	756	5,94%	28,99%
5	A14	Storage processes that don't match layouts	672	5,28%	34,27%
6	A15	Preventive maintenance machine not running	576	4,53%	38,79%
7	A17	Breakdown of machines that stop production for up to 2 days	525	4,12%	42,92%
8	A11	The availability of raw materials from suppliers is insufficient	486	3,82%	46,74%
9	A12	Inadequate storage capacity and facilities	441	3,46%	50,20%
10	A20	Errors in the machine setting process	441	3,46%	53,66%
11	A6	Reschedule delivery by customer	378	2,97%	56,63%
12	A10	Lack of evaluation of raw material suppliers	378	2,97%	59,60%
13	A18	Changeover management & setup time is not optimal	378	2,97%	62,57%
14	A23	Production is carried out before there is actual demand to maintain the productivity of machinery and labor	378	2,97%	65,54%
15	A32	The product does not meet specifications	378	2,97%	68,51%
16	A1	Incorrect demand forecast methods	315	2,47%	70,99%
17	A16	Production scheduling doesn't go as planned	315	2,47%	73,46%
18	A21	Employee negligence	315	2,47%	75,94%
19	A22	Accumulation of buffer stock and customer deposit items	315	2,47%	78,41%

C. Interpretive Structural Modeling (ISM)

At this stage, risk evaluation is carried out using the Interpretive Structural Modeling (ISM) method to see the relationship between priority risk agents. In the initial stage of this method, the priority risk agent will be given an element code to facilitate the work in the next stage.

Table 5. Priority Risk Agent Element Code

	Risk Agent Priorities	Element Code
A4	Production needs exceed the effective capacity of machines	A
A13	No re-checking before transfer	B
A7	Sudden order requests	C
A19	Not running SOP and IK production process and QC optimally	D
A14	Storage processes that don't match layouts	E
A17	Breakdown of machines that stop production for up to 2 days	F
A15	Preventive maintenance machine not running	G
A11	The availability of raw materials from suppliers is insufficient	H
A12	Inadequate storage capacity and facilities	I
A20	Errors in the machine setting process	J
A6	Reschedule delivery by customer	K
A10	Lack of evaluation of raw material suppliers	L
A18	Changeover management & setup time is not optimal	M
A23	Production is carried out before there is actual demand to maintain the productivity of machinery and labor	N
A32	The product does not meet specifications	O
A1	Incorrect demand forecast methods	P
A16	Production scheduling doesn't go as planned	Q
A21	Employee negligence	R
A22	Accumulation of buffer stock and customer deposit items	S

Furthermore, each priority risk agent element code is analyzed for its relationship between all elements using the symbols V, A, X, O where V means row-i affects the j-column but not the other way around, A means that the j-column affects the i-row but not the other way around, X means that the i-row and the j-column affect each other, and O means that the i-row and the j-column have no relationship.

Table 6. *Structural Self Interaction Matrix* (SSIM)

Element	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A		O	V	O	A	O	O	O	O	V	O	O	O	A	O	A	V	O	O	O
B			O	X	O	O	O	O	O	O	O	O	V	O	O	O	O	A	O	O
C				O	V	O	V	O	O	A	O	O	O	O	O	O	A	O	O	O
D					O	O	O	A	O	O	O	O	O	O	O	O	O	O	A	O
E						V	O	O	O	O	O	O	O	O	O	O	O	O	O	O
F							O	O	O	O	O	O	O	O	O	O	V	O	O	O
G								O	O	O	A	O	O	O	O	O	O	O	O	O
H									O	O	O	O	O	O	O	O	O	O	V	O
I										O	O	O	V	O	V	O	O	O	O	O
J											O	O	O	O	O	O	V	V	O	O
K												O	O	O	V	O	O	O	O	O
L													O	O	O	O	V	O	O	O
M														O	V	O	O	O	O	O
N															O	O	O	O	V	O
O																O	O	O	O	O
P																	O	O	V	O
Q																		O	O	O
R																			O	O
S																				V
T																				

The results of the SSIM matrix in the form of symbols V, A, X, O are then converted into binary numbers 1 and 0 with $V_{ij} = 1$, $V_{ji} = 0$, $A_{ij} = 0$, $A_{ji} = 1$, $X_{ij} = 1$, $X_{ji} = 1$, $O_{ij} = 0$, and Oji = 0. The conversion results in an initial reachability matrix, which is then tested for consistency in the transitivity relationship between elements by applying transitivity rules to rows and columns that have a value of 0. The results of the test are then used as the final reachability matrix.

Table 7. Final Reachability Matrix

Elemen	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	*Driving Power*
A	1	0	1*	0	0	1*	1*	0	0	0	0	0	0	0	0	0	1	0	0	5
B	0	1	0	1	0	0	0	0	0	1*	0	0	0	0	1	0	0	1*	0	5
C	1	0	1	0	0	1	1*	0	0	0	0	0	0	0	0	0	1*	0	0	5
D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
E	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
F	1	0	1*	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	5
G	1*	0	1*	0	0	1*	1	0	0	0	0	0	0	0	0	0	1	0	0	5
H	1*	0	1*	0	0	1*	1*	1	0	0	0	1	0	0	0	0	1	0	0	7
I	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
J	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1*	0	4
K	1	0	1	0	1*	1*	1*	0	1	0	1	0	0	0	0	0	1	0	1	9
L	1*	0	1*	0	0	1*	1*	1	0	0	0	1	0	0	0	0	1*	0	0	7
M	1*	0	1*	0	0	1*	1*	0	0	0	0	0	1	0	0	0	1	0	0	6
N	1	0	1*	0	1*	1*	1*	0	1	0	0	0	0	1	0	0	1*	0	1	9
O	0	0	0	1*	0	0	0	0	0	1*	0	0	0	0	1	0	0	1	0	4
P	1	0	1	0	1*	1*	1*	0	1*	0	0	0	0	0	0	1	1*	0	1	9
Q	1*	0	1	0	0	1*	1*	0	0	0	0	0	0	0	0	0	1	0	0	5
R	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1*	0	0	1	0	4
S	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3
Dependence Power	11	1	11	5	6	11	11	2	5	4	1	2	1	1	4	1	11	4	4	

Level separation is done to group each element into reachability sets, antecedent sets, and intersection sets. In performing level separation, the factors with elements in the reachability set and the intersection set are the same set of elements that become level 1 in iteration 1 [27]. Once Iteration 1 is known, then it must be separated from the other elements. The level separation stages in the next element can be done again with the same process.

Table 8. *Structural Self Interaction Matrix* (SSIM)

Element	Reachability Set	Antecedent Set	Intersection Set	Level
A	A, C, F, G, Q	A, C, F, G, H, K, L, M, N, P, Q	A, C, F, G, Q	1
B	B, D, J, O, R	B	B	3
C	A, C, F, G, Q	A, C, F, G, H, K, L, M, N, P, Q	A, C, F, G, Q	1
D	D	B, D, J, O, R	D	1
E	E	E, I, K, N, P, S	E	1
F	A, C, F, G, Q	A, C, F, G, H, K, L, M, N, P, Q	A, C, F, G, Q	1
G	A, C, F, G, Q	A, C, F, G, H, K, L, M, N, P, Q	A, C, F, G, Q	1
H	A, C, F, G, H, L, Q	H, L	H, L	2
I	E, I	I, K, N, P, S	I	2
J	D, J, O, R	B, J, O, R	J, O, R	2
K	A, C, E, F, G, I, K, Q, S	K	K	4
L	A, C, F, G, H, L, Q	H, L	H, L	2
M	A, C, F, G, M, Q	M	M	2
N	A, C, E, F, G, I, N, Q, S	N	N	4
O	D, J, O, R	B, J, O, R	J, O, R	2
P	A, C, E, F, G, I, P, Q, S	P	P	4
Q	A, C, F, G, Q	A, C, F, G, H, K, L, M, N, P, Q	A, C, F, G, Q	1
R	D, J, O, R	B, J, O, R	J, O, R	2
S	E, I, S	K, N, P, S	S	3

Furthermore, Interpretive Structural Modeling (ISM) was carried out to describe the relationship between the elements. This ISM model is arranged in hierarchical order of levels from highest to lowest level.

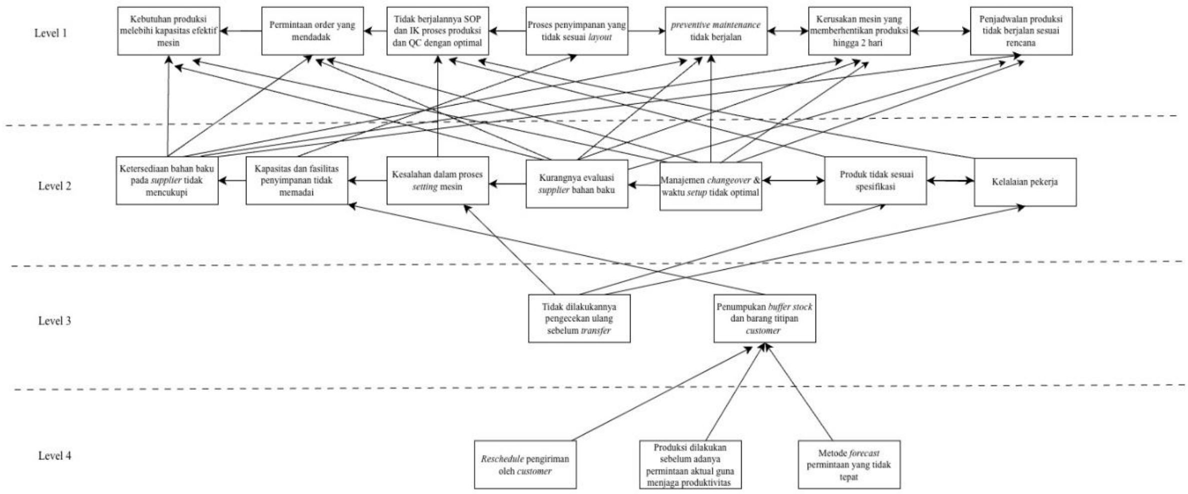

Figure 2. ISM Diagram

The MICMAC analysis at this stage is used to identify elements based on the driven power and dependence power obtained at the reachability matrix stage. Through MICMAC analysis, the analyzed elements were then mapped into four quadrants based on driving power and dependence power values. Quadrant I (autonomous variables) contains elements that have low driving power and dependence power. Quadrant II (dependent variables) consists of elements with low driving power but high dependence power. Quadrant III (linkage variables) includes elements that have equally high driving power and dependence power. Meanwhile, Quadrant IV (independent variables) contains elements with high driving power but low dependence power [28].

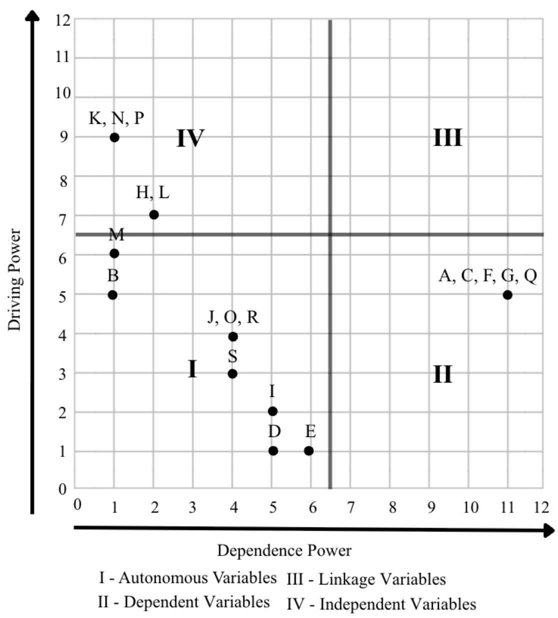

Figure 3. MICMAC

Identification of risk mitigation is the initial stage in stage 2 of the House of Risk (HOR) method. This mitigation is prepared based on the priority risk agents that have been obtained in the House of Risk (HOR) phase 1.

D. House of Risk II

Table 9. Risk Mitigation in Each Priority Risk Agent

Ai	Risk Agent	PAi	Risk Mitigation
A4	Production needs exceed the effective capacity of machines	PA1	Production needs exceed the effective capacity of machines
A13	No re-checking before transfer	PA2	Implementation of the goods transfer monitoring and verification system
		PA3	Conduct training to employees on the specifications of each product variation
A7	Sudden order requests	PA4	Create a deadline policy for customers to place an order
A19	Not running SOP and IK production process and QC optimally	PA5	Application of SP witnesses for disciplinary action
		PA6	Implementation of internal audits and periodic evaluations
A14	Storage processes that don't match layouts	PA7	Increase the number of pallets and tighten the use of pallets according to the type of goods
		PA8	Implementation of a barcode scanning system for each item in inbound and outbound activities
A15	Preventive maintenance not running	PA9	Tightening supervision of preventive maintenance schedules
A17	Breakdown of machines that stop production for up to 2 days	PA10	Conduct training on techniques related to temporary repairs
		PA11	Spare parts backup storage
A11	The availability of raw materials from suppliers is insufficient	PA12	Finding and adding alternative supplier networks
A12	Inadequate storage capacity and facilities	PA13	Product classification using FSN analysis based on Turn Over Ratio (TOR)
A20	Errors in the machine setting process	PA14	Conduct regular training to operators and create detailed guidelines for specific machine settings per product variation
A6	Reschedule delivery by customer	PA15	Implementing a google form digital communication system for order updates
A10	Lack of evaluation of raw material suppliers	PA16	Conducting KPI-based supplier evaluations
A18	Changeover management & setup time is not optimal	PA17	Perform production grouping by size (Oz) to reduce setup time
A23	Production is carried out before there is actual demand to maintain the productivity of machinery and labor	PA13	Product classification using FSN analysis based on Turn Over Ratio (TOR)
A32	Inconsistent product quality	PA18	Standardization of raw material specifications to suppliers
		PA19	Develop stricter supplier selection criteria
A1	Incorrect demand forecast methods	PA20	Perform forecasting accuracy every month and separate fast moving vs slow moving product forecasts

Ai	Risk Agent	PAi	Risk Mitigation
		PA21	Implement a forecast system with a reference of 5-week before and 13-week before
A16	Production scheduling doesn't go as planned	PA1	Optimizing machines through preventive scheduling and predictive maintenance
A21	Employee negligence	PA2	Implementation of the goods transfer monitoring and verification system
A22	Accumulation of buffer stock and customer deposit items	PA13	Product classification using FSN analysis based on Turn Over Ratio (TOR)
		PA22	Make a deal for a deposit item only for a certain period of time

The risk mitigation rating is determined using the Effectiveness to Difficulty of Ratio (ETDk) value by dividing the total risk mitigation effectiveness (TEk) by the risk mitigation difficulty (Dk).

Table 10. Risk Mitigation Rating

PAi	Risk Mitigation	TEk	DK	ETDk	Rank
PA1	Optimizing machines through preventive scheduling and predictive maintenance	14661	4	3665	1
PA2	Implementation of the goods transfer monitoring and verification system	10611	3	3537	2
PA13	Product classification using FSN analysis based on Turn Over Ratio (TOR)	10206	3	3402	3
PA3	Conduct training to employees on the specifications of each product variation	7776	3	2592	4
PA5	Application of SP witnesses for disciplinary action	6804	3	2268	5
PA6	Implementation of internal audits and periodic evaluations	6804	3	2268	6
PA4	Create a deadline policy for customers to place an order	6804	4	1701	7
PA7	Increase the number of pallets and tighten the use of pallets according to the type of goods	6048	4	1512	8
PA8	Implementation of a barcode scanning system for each item in inbound and outbound activities	6048	4	1512	9
PA9	Tightening supervision of preventive maintenance schedules	5184	4	1296	10
PA15	Implementing a google form digital communication system for order updates	3402	3	1134	11
PA16	Conducting KPI-based supplier evaluations	3402	3	1134	12
PA14	Conduct regular training to operators and create detailed guidelines for specific machine settings per product variation	3969	4	992	13
PA20	Perform forecasting accuracy every month and separate fast moving vs slow moving product forecasts	2835	3	945	14
PA21	Implement a forecast system with a reference of 5-week before and 13-week before	2835	3	945	15
PA17	Perform production grouping by size (Oz) to reduce setup time	3402	4	851	16
PA18	Standardization of raw material specifications to suppliers	3402	4	851	17
PA22	Make a deal for a deposit item only for a certain period of time	2835	4	709	18
PA11	Spare parts backup storage	1575	3	525	19
PA12	Finding and adding alternative supplier networks	1458	3	486	20
PA19	Develop stricter supplier selection criteria	1134	3	378	21
PA10	Conduct training on techniques related to temporary repairs	1575	5	315	22

V. CONCLUSION

Based on the results of the data analysis conducted in this study, it can be concluded that the House of Risk (HOR) Phase 1 method identified 19 priority risk agents out of 32 risk agents in the supply chain of PT XYZ, specifically A4, with an Aggregate Risk

Potential (ARP) value of 1314. Furthermore, the priority risk agents were analyzed using the Interpretive Structural Modeling (ISM) method; based on the MICMAC analysis results, it was shown that there are risk agents with high driving power as root causes, namely element K (rescheduling of shipments by the customer), element N (production carried out before actual demand to maintain machine and labor productivity), and element P (inaccurate demand forecasting method). In the House of Risk (HOR) Phase 2, 22 risk mitigation strategies were identified, focused on addressing the priority risk agents with the highest ARP values. The five mitigation strategies with the highest scores following the assessment include optimizing machinery through the planning and scheduling of preventive and predictive maintenance (PA1), implementing a system for monitoring and verifying goods transfers (PA2), classifying products using FSN analysis based on the Turn Over Ratio (TOR) (PA13), training employees on the specifications of each product variant (PA3), and the implementation of disciplinary sanctions (PA5). Thus, the mitigation measure that can be implemented at PT XYZ is PA1 (planning and scheduling of preventive and predictive maintenance) because it has the highest TEDk value of 3665.

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