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THE IMPLEMENTATION OF HOUSE OF RISK AND INTERPRETIVE STRUCTURAL MODELING APPROACH TO RISK MITIGATION OF SUPPLY CHAIN PROBLEMS IN THE FERTILIZER INDUSTRY

Muhamad Mukhtarul Haqi[1], Farida Pulansari[2], Sinta Dewi[3]

[1] Industrial Engineering, UPN "Veteran" Jawa Timur, Jl.Raya Rungkut Madya, Gunung Anyar, Surabaya, Indonesia, muhamadhaqi705@gmail.com

[2] Industrial Engineering, UPN "Veteran" Jawa Timur, Jl.Raya Rungkut Madya, Gunung Anyar, Surabaya, Indonesia, farida.ti@upnjatim.ac.id

[3] Industrial Engineering, UPN "Veteran" Jawa Timur, Jl.Raya Rungkut Madya, Gunung Anyar, Surabaya, Indonesia, sinta.dewi.ti@upnjatim.ac.id

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Abstract

PT. Petrokimia is seeing escalating difficulties in their supply chain system. Supply Chain Risk Management evaluations can be conducted using many methodologies. Supply Chain Risk Management (SCRM) is a process that involves identifying, evaluating, and reducing risks that have the potential to disrupt the smooth operation of the supply chain, which includes the movement of goods and services. This research combines prior studies by employing a hybrid approach known as House of Risk (HoR) and Interpretive Structural Modeling (ISM). The House of Risk (HoR) method is employed to identify registered risk agents by assessing the importance of preventative measures and selecting priority actions. The ISM methodology is utilized in this study to construct a structural framework for examining the contextual associations among risk elements in the company's supply chain. The organization experienced many hazards, with a total of 20 risk events generated by 30 risk agents across the Plan, Source, Make, Delivery, and Return stages. According to the Pareto diagram concept, there are 11 risk agents that require prioritized mitigation. Out of the 10 risks identified, 1 risk is categorized as dependent while the remaining risks fall within the autonomous sector. Among the 11 primary risk factors, the one with the highest ARP value is anticipated to serve as a benchmark for addressing several hazards that have arisen in the company's supply chain. The research has studied and generated mitigation measures to avoid production losses, time losses, and quality reduction resulting from hazards that may hinder the achievement of company objectives.

Keywords: House of Risk, Interpretive Structural Modelling, Relationship, Risk Management, Risk Mitigation

INTRODUCTION

The supply chain, which is a network of businesses and facilities linked to fulfill consumer requests through the exchange of goods, information, and funds.[1]. The current

[1] Yadav, A. K., & Samuel, C. (2022). Modeling resilient factors of the supply chain. Journal of Modelling in Management, 17(2), 456–485. <https://doi.org/10.1108/JM2-07-2020-0196>.

supply chain of adverse risks or disruptions[3,4,5]. Businesses deal with a growing number of issues in their supply chain systems, which are typified by a market environment that is becoming more unpredictable and volatile[6,7,8]. With manufacturers, suppliers, transportation, warehouses, retailers, and even customers themselves involved in today's competitive climate, supply chain management is critical to a company's survival[9,10,11]. In order to get a stronger position in the global market, industrial managers are concentrating on investigating critical supply chain management performance-enhancing features[12, 13]. For efficient management, a Supply Chain Risk Management (SCRM) framework is required.

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[13] Chowdhury, N. A., Ali, S. M., Paul, S. K., Mahtab, Z., & Kabir, G. (2020a). A hierarchical model for critical success factors in apparel supply chain. Business Process Management Journal, 26(7), 1761–1788 <https://doi.org/10.1108/BPMJ-08-2019-0323>.

A framework is essential for the efficient management of diverse SCR kinds[14]. Implementing risk mitigation techniques is crucial for effectively managing uncertainties and vulnerabilities that have the potential to affect the economic, social, and environmental performance indicators of supply chains[15,16,17]. Consequently, there has been a significant focus from both academics and industry professionals on effectively implementing the SCRM concept in recent years[18].

PT. Petrokimia Gresik is a company that within the scope of the Department of Industry and Trade of the Republic of Indonesia takes shelter under the Pupuk Indoneisa Holding Company (PIHC) which occupies an area of more than 450 hectares. PT. Petrokimia Gresik is the largest and most comprehensive fertilizer producer in Indonesia with total production reaching 9 million tons per year and has 8931 employees consisting of 3168 permanent employees and 5763 non-organic workers (assisted workers) who work on a contract system. In producing urea fertilizer, PT. Supplier owned by PT. Petrokimia Gresik in meeting the need for urea fertilizer comes from several countries in Asia, including China, India, Myanmar, Pakistan and Bangladesh. The greatest intensity of purchasing raw materials is made from suppliers from China because the prices are cheap. Based on the explanation from the procurement manager of PT. Petrokimia Gresik was obtained by a supplier from China who had failed to fulfill PT. Petrokimia Gresik orders. PT. Petrokimia Gresik, as many as 12 out of 168 complete orders throughout 2023. Then, there are problems related to product delivery schedules that are uncertain and can be delayed by up to one week, which results in backlogs of goods and increased workload for PT employees. Then there are problems related to production, namely defects in the finished fertilizer which causes the need for a rework process which takes quite a long time. And finally, PT. Petrokimia Gresik also has problems with storage warehouses which are often full, from which it can be concluded that this overcapacity is caused by supply chain problems. Based on the problem description above, PT. Petrokimia Gresik needs to realize the importance of implementing supply chain risk management to survive in a risky environment.

Supply Chain Risk (SCR) has characteristics of uncertainty and interdependence

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which must be included in the risk assessment stage of the Supply Chain Risk Management (SCRM) framework[19]. There are multiple approaches available for conducting a risk assessment of the SCR management framework. One of these methods is the House of Risk (Hor) technique. The House of Risk (HoR) method is utilized to identify registered risk agents by prioritizing preventative actions and selecting useful corrective actions that require a suitable allocation of financial and resource commitments[20]. The House of Risk (HoR) model is a commonly employed strategy or analytical tool for conducting risk mitigation analysis of a company's supply chain[21]. The House of Risk (HoR) model is a framework created by Pujawan and Geraldin (2009) through the integration of the FMEA (Failure Mode and Effect Analysis) and QFD (Quality Function Deployment) methodologies. Failure Mode and Effect Analysis (FMEA) is a highly effective technique for managing reliability[22,23,24]. It systematically identifies the key causes of system failure and takes measures to reduce their associated risks. Quality Function Deployment (QFD) is a method used to prioritize risk agents and select the most effective actions to mitigate potential risks. It is currently strongly recommended to implement QFD in the supply chain process[25,26,27].

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Prior study employing the HoR method in supply chain risk management has revealed that firms solely focus on identifying individual hazards and implementing mitigation strategies to address the root causes of each risk, without considering the interconnections between different risks[29]. In this newest iteration of the research, scholars employed a hybrid methodology known as House of Risk (HoR) and Interpretive Structural Modeling (ISM). The benefits of employing this hybrid methodology are as follows: By utilizing ISM, one may determine the correlation between crucial risk factors by assessing their driving force and dependency. MICMAC analysis can then classify these risk factors into four distinct categories: autonomous, dependent, linkage, and independent[28]. Strategies to mitigate risk, reduce risk causes, and handle risk in the supply chain. This hybrid method aims to enhance the resilience of Sustainable Supply Chain Management (SSCM) by including supply chain risk management. Risk mitigation measures play a crucial role in managing uncertainty and vulnerabilities that might affect the economic, social, and environmental performance indicators of the supply chain in SSCM[29].

RESEARCH METHODS

The purpose of this study is to identify the risk mitigation steps involved in PT. Petrokimia urea fertilizer manufacturing process. The House of Risk (HOR) method is used to analyze the plan, source, make, delivery, and return processes, and the Interpretive structural modeling (ISM) method is used to examine the relationships between risks. HoR 1 includes assessing or measuring the level of impact (severity) of identified risk events, assessing the level of occurrence of risk events from risk agents and assessing the level of correlation between risk events and risk agents. At this stage the Aggregate Risk Potential (ARP) value will also be calculated. while the ISM stage is an interactive relationship between determining factors; developing the Structural Self Interaction Matrix (SSIM); Determining the final affordability matrix; level division; and establish a hierarchical structure based on level division. House of Risk (HOR) phase 2 is also called the recommendation stage in the form of designing treatment or mitigation strategies to overcome previously identified risk agents. The company's core business processes, including the supply chain, were the subject of brainstorming sessions and interviews that produced data that was subsequently disseminated via surveys. The company conducted brainstorming sessions to identify potential events and causes of risk in its supply chain.

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Meanwhile, a questionnaire was utilized to collect data, assessing supply chain risk and the inter-agent relationships between risk agents. Relevant respondents were given a list of questions to complete. Three questionnaires were employed in this study: the HOR 1 questionnaire, the HOR 2 questionnaire, and the association between risk agents questionnaire. Seven employees, including the vice president of the goods/services planning department, the assistant vice president for technical identification and evaluation, the two expert staff members for data administration and reporting, the two junior assistant vice presidents for production II A, electrical, instrument, production, and general expert staff, were given the questionnaire. These employees have five years of work experience at PT. Petrokimia**.**

RESULT AND DISCUSSION

Risk House Stages 1

The initial phase of the House of Risk approach, known as House of Risk (HoR) Stage 1, focuses on locating and evaluating supply chain risks. Prioritizing some risks for additional attention after gaining an understanding of their origins and potential impact on supply chain operations is the aim.

Supply Chain Activity Mapping

The supply chain activity mapping process at PT Petrokimia Gresik utilizes the Supply Chain Operations (SCOR) process technique to identify indications. These indicators are categorized into plan, source, make, delivery, and return. The purpose of mapping supply chain activities in this manner is to identify and categorize each action inside every member of the supply chain. Additional information can be observed in Table 1.

Table 1. Mapping table of Supply Chain activities from the company PT. Petrokimia Gresik based on SCOR

Level 1	Level 2	Level 3
Major Process	***Sub Process***	***Detail Activity***
Plan	financial planning	Aligning the supply chain with the company's financial planning
	production planning	Planning the urea fertilizer production process
Source	Raw material procurement process	Scheduling and delivery of raw materials
		Checking the quality of raw materials sent by suppliers before entering the factory
		Receiving and weighing raw materials
		Storing in the raw material/emplacement warehouse
	supplier	supplier evaluation
Make	Urea fertilizer production process	Involves a chemical reaction between ammonia and carbon dioxide

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Level 1	Level 2	Level 3
Make	finished product	Checking product quality from the results of the production process
		product packaging
		Product storage in the finished product warehouse
Delivery	delivery process	Checking product availability updates
		Check the vehicle to be used
		Product Delivery
Return	Product returns reject	Returns and handling of products returned from consumers

Source : Primary Data

Risk Agent Identification

After identifying risks and knowing the risks that arise in the company's supply chain activities, at this stage a list of risk causes is determined which is the basis for risk events. The following is a list of risk causes:

Table 2. Risk Agent

Ai	Penyebab Risiko (*Risk Agent*)
A1	Reference prices for raw materials are less accurate
A2	Decrease in sales prices on the market
A3	Machine breakdown occurs
A4	Consumers want the goods they have ordered to be produced earlier
A5	Disruption during the delivery process
A6	Lack of evaluation of raw material suppliers
A7	Raw material receipt inspections are less thorough
A8	The availability of raw materials from suppliers is not sufficient
A9	There was miscommunication with the supplier
A10	There is no routine checking SOP from the company
A11	Inadequate storage facilities
A12	Product storage for too long
A13	Determine suppliers based on low price criteria, not quality
A14	Lack of discipline among employees in using complete PPE
A15	Lack of socialization of the importance of HSE
A16	Preventive maintenance is not optimal
A17	Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor
A18	Raw materials damaged during the storage process in the warehouse
A19	There is mixing of foreign materials during product manufacture
A20	The sack sewing process was not done correctly
A21	*human error*
A22	The arrangement and storage in the warehouse is not good
A23	Broken sacks cause damage to fertilizer
A24	Not being careful in the product transfer process
A25	Errors in recording and providing product identity
A26	vehicle servicing is carried out at low intensity

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Ai	Penyebab Risiko (*Risk Agent*)
A27	Old vehicle age
A28	Limited delivery means of transportation
A29	Returned products are not included in the defect category
A30	Inhibited communication between companies and consumers

Source: Primary Data

Risk Evaluation

After calculating the Aggregate Risk Potential (ARP), a risk evaluation will be carried out. In this risk evaluation stage, risk ranking will be carried out, namely selecting several risk agents that have the highest occurrence rate based on the concept of Pareto analysis. At this risk evaluation stage, the cumulative ARP value can be prioritized based on the Risk Agent ranking for input in creating a Pareto diagram. The following is a cumulative ARP table from risk agents:

Table 4. Dominant Risk Agent

Rank	Kode	Risk Agent	ARP
1	A13	Determine suppliers based on low price criteria, not quality	1080
2	A21	Human error	945
3	A3	Machine breakdown occurs	630
4	A16	Preventive maintenance is not optimal	609
5	A10	There is no routine checking SOP from the company	552
6	A7	Raw material receipt inspections are less thorough	432
7	A8	The availability of raw materials from suppliers is not sufficient	405
8	A4	Consumers want the goods they have ordered to be produced earlier	384
9	A17	Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor	312
10	A5	Disruption during the delivery process	306
11	A9	There was miscommunication with the supplier	243
12	A19	There is mixing of foreign materials during product manufacture	231
13	A11	Inadequate storage facilities	168
14	A24	Not being careful in the product transfer process	144
15	A28	Limited delivery means of transportation	132
16	A22	The arrangement and storage in the warehouse is not good	124
17	A12	Product storage for too long	93
18	A20	The sack sewing process was not done correctly	90
19	A25	Errors in recording and providing product identity	78
20	A6	Lack of evaluation of raw material suppliers	72
21	A14	Lack of discipline among employees in using complete PPE	72
22	A27	Old vehicle age	63
23	A30	Inhibited communication between companies and consumers	48
24	A2	Decrease in sales prices on the market	45
25	A26	vehicle servicing is carried out at low intensity	42

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Rank	Kode	Risk Agent	ARP
26	A1	Reference prices for raw materials are less accurate	30
27	A29	Returned products are not included in the defect category	27
28	A18	Raw materials damaged during the storage process in the warehouse	20
29	A23	Broken sacks cause damage to fertilizer	15
30	A15	Lack of socialization of the importance of HSE	12

Source : The results of the analysis from the primary data source

After calculating the Aggregate Risk Potential (ARP), the next step is to determine th e risk agent ranking. At the risk ranking stage, several risk agents will be priorities. Based on the Pareto diagram explained by Magdalena (2019), the priority problems to be addressed are problems that contribute up to 80% of the total problems identified[30]. By applying Pareto, focus will be given to risk agents who contribute the most to overall risk. This allows the most significant problems to be identified and resolved first, so that resources and time can be allocated efficiently to minimize the overall impact of the risk.

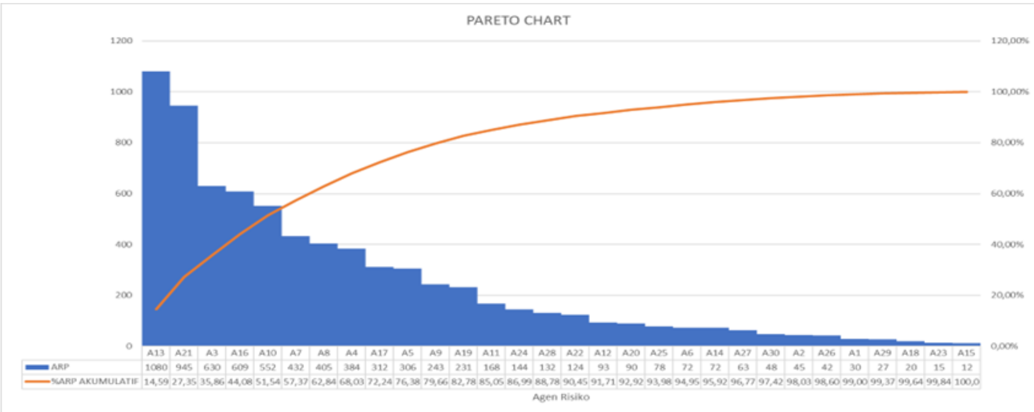

Figure 1. Diagram Pareto

Source : The results of the analysis from the primary data source

Table 5. Dominant risk agent

Rank	Kode	Risk Agent	ARP
1	A13	Determine suppliers based on low price criteria, not quality	1080
2	A21	Human error	945

[30] Magdalena, R., & Vannie, V. (2019). Analisis risiko supply chain dengan model house of risk (HOR) pada PT Tatalogam Lestari. J@ ti Undip: Jurnal Teknik Industri, 14(2), 53-62 <https://doi.org/10.14710/jati.14.2.%p>

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Rank	Kode	Risk Agent	ARP
3	A3	Machine breakdown occurs	630
4	A16	Preventive maintenance is not optimal	609
5	A10	There is no routine checking SOP from the company	552
6	A7	Raw material receipt inspections are less thorough	432
7	A8	The availability of raw materials from suppliers is not sufficient	405
8	A4	Consumers want the goods they have ordered to be produced earlier	384
9	A17	Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor	312
10	A5	Disruption during the delivery process	306
11	A9	There was miscommunication with the supplier	243

Source : The results of the analysis from the primary data source

Interpretive Structural Modeling (ISM)

The risk agents (elements) that have been obtained based on the HOR 1 calculation are 11 risk agents that have the largest ARP values which will be examined further using the ISM method. The ISM method in this research is to map the hierarchical structure of risk elements and assist in understanding how these elements influence each other. Based on the driver power (DP) in Table 6, a structural model diagram is obtained. A high driver power value for a risk agent explains that this risk agent influences many other risk agents. A low driver power value explains that the risk agent has no or little influence on other risk agents. The Structural Model Diagram can be seen in Figure 2.

Table 6. Final Reachability Matrix

Elemen Code	Elemen	Driver Power	Rank
A	Determine suppliers based on low price criteria, not quality (A13)	2	3
B	Human error (A21)	4	1
C	Machine breakdown occurs (A3)	2	3
D	Preventive maintenance is not optimal (A16)	3	2
E	There is no routine checking SOP from the company (A10)	4	1
F	Raw material receipt inspections are less thorough (A7)	2	3
G	The availability of raw materials from suppliers is not sufficient (A8)	1	4
H	Consumers want the goods they have ordered to be produced earlier (A4)	2	3
I	Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor (A17)	1	4
J	Disruption during the delivery process (A5)	2	3
K	There was miscommunication with the supplier (A9)	2	3

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Source : Data Processing SmartISM

Based on driver power, these factors are classified into four categories, namely autonomous, linkage, dependent and independent. Elements Determine suppliers based on low price criteria, not quality (A13) with element code A, Element Consumers want the goods they have ordered to be produced earlier (A4) with element code H, Element Disruption during the delivery process (A5) with element code J, Element There was miscommunication with the supplier (A9) with element code K; Elements human error (A21) with element code B; Element There is no routine checking SOP from the company (A10) with element code E; Preventive maintenance is not optimal (A16) with element code D; Element Machine breakdown occurs (A3) with element code C; Element The availability of raw materials from suppliers is not sufficient (A8) with element code G categorized as autonomous. Elements categorized in the autonomous sector have low driving power and low dependency power. Elements in the autonomous sector usually have little or no relationship to other risk elements in the supply chain system.

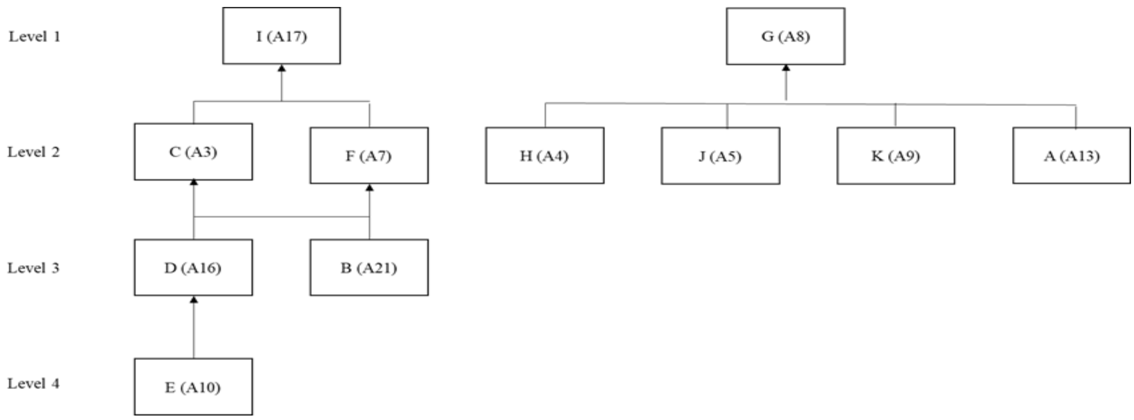

Figure 2. Diagram Model Struktural

Source : Data Processing SmartISM

Element Failure of the ammonia and carbon dioxide synthesis process control system in the reactor (A17) with element code I is categorized in the dependent sector. Element Failure of the ammonia and carbon dioxide synthesis process control system in the reactor (A17) because it does not affect any element and is influenced by several elements or risk agents, namely Machine breakdown occurs (A3) with element code C and the raw material acceptance inspection is less thorough (A7) with element code F. This means that the elements in this sector are elements that are not independent and do not have a strong relationship in the supply chain system.

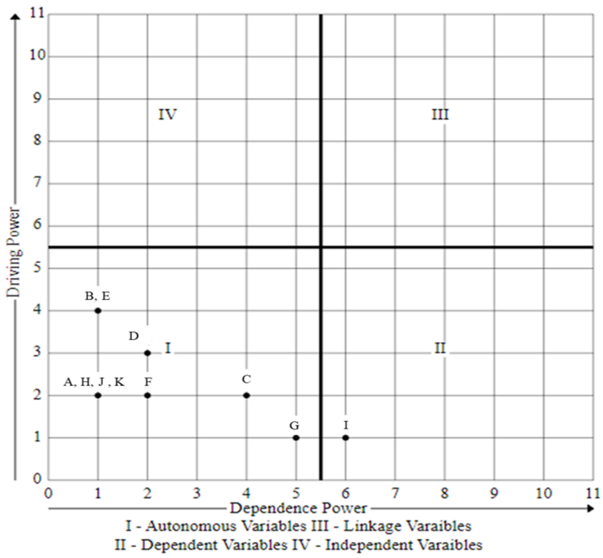

Figure 3. Matriks Driver Power-Dependence

Source : Data Processing SmartISM

House of Risk Stages 2

At this stage, a relevant risk mitigation action plan will be carried out based on the dominant risk causes. In each agent the risk can be prevented by one or more mitigation actions. To determine the design of a risk mitigation strategy, brainstorming is carried out with the company, this aims to validate risk agents regarding mitigation actions. At this stage, a relevant risk mitigation action plan will be carried out based on the dominant risk causes. In each agent the risk can be prevented by one or more mitigation actions. To determine the design of a risk mitigation strategy, brainstorming is carried out with the company, this aims to validate risk agents regarding mitigation actions.

Table 7. Risk Mitigation Strategy Design

Risk Agent		**Strategi Aksi Mitigasi**	
A13	Determine suppliers based on low price criteria, not quality	PA01	Improvement of Supplier Selection Criteria
		PA02	Clear Use of Contracts
A21	human error	PA03	Ergonomic and User-Friendly Design
		PA04	Use of Automation Technology
A3	Machine breakdown occurs	PA05	Preventive Maintenance Plan
		PA06	Backlog of Spare Equipment
A16	Preventive maintenance is not optimal	PA07	Maintenance Process Optimization
		PA06	Backlog of Spare Equipment
A10	There is no routine checking SOP from the company	PA08	Development of Routine Checking SOPs
A7	Raw material receipt inspections are less thorough	PA04	Use of Automation Technology
A8	The availability of raw materials from	PA09	Use of Long-Term Contracts

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Risk Agent		**Strategi Aksi Mitigasi**	
	suppliers is not sufficient	PA02	Clear Use of Contracts
		PA01	Improvement of Supplier Selection Criteria
A4	Consumers want the goods they have ordered to be produced earlier	PA10	Flexible Production Scheduling
A17	Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor	PA11	Use of Advanced Process Control
A5	Disruption during the delivery process	PA12	Monitoring Trends and External Conditions
		PA10	Flexible Production Scheduling
		PA13	Implementation of Supply Chain Management System
A9	There was miscommunication with the supplier	PA13	Implementation of Supply Chain Management System
		PA10	Flexible Production Scheduling
		PA02	Clear Use of Contracts

Source : The results of the analysis from the primary data source

The HOR phase 2 framework can be used to identify and prioritize proactive actions to maximize the effectiveness of efforts based on resource and financial commitments. HOR2 which presents 11 risk agents with 13 proposed actions is depicted in Table 7. In table 8 the priority of each action is obtained based on the value of the ratio of effectiveness and action difficulty k (ETD)k. The higher the ratio, the better the proposed action. Use of Automation Technology (PA4) corrective action is the most priority action because it has the highest ETD value with score 2450.

Table 8. Mitigation Strategy Ranking

	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	PA13	ARP
A13	1	3												1080
A21			3	9										945
A3					3	1								630
A16						1	3							609
A10								1						552
A7				3										432
A8	3	3							1					405
A4										3				384
A17											9			312
A5										1		3	9	306
A9		3								3			3	243
TEK	2295	5184	2835	9801	1890	1239	1827	552	405	2187	2808	918	3483	
Dk	3	3	3	4	4	4	3	3	4	3	5	3	3	
ETD	765	1728	945	2450	473	310	609	184	101	729	562	306	1161	
RANK	5	2	4	1	9	10	7	12	13	6	8	11	3	

Source : The results of the analysis from the primary data source

CONCLUSION

From the results of risk identification with SCOR, it was found that there were 20 risk events that occurred in the company, which were caused by 30 risk agents (causes) from the Plan, Source, make, delivery and return processes. Based on the Pareto diagram concept, there are 11 priority risk agents that need to be mitigated, namely determining suppliers using the criteria of low price, not quality (A13), human error (A21), machine breakdown occurs (A3), Preventive maintenance is not optimal (A16).), Absence of routine checking SOPs from the company (A10), Inspection of receipt of raw materials is less thorough (A7), The availability of raw materials from suppliers is not sufficient (A8), Consumers want goods that have been ordered to be produced earlier (A4), Failure of the control system for the ammonia and carbon dioxide synthesis process in the reactor (A17), Disruption during the delivery process (A5), Miscommunication with the supplier (A9).

Of the 11 priority risk agents, whether they are interrelated or stand alone using the Interpretive Structural Modeling method, of the 10 risks included are categorized into the autonomous sector, namely determining suppliers using the criteria of low price, not quality (A13), the consumer element wants goods that have been ordered to be produced earlier (A4), Element of disruption during the delivery process (A5), Element of miscommunication with the supplier (A9); Element of human error (A21), Element of the absence of routine checking SOPs from the company (A10); Preventive maintenance is less than optimal (A16); Elements of Machine breakdown occurs (A3), The availability of raw materials from suppliers is not sufficient (A8) are categorized in the autonomous sector. Elements categorized in the autonomous sector have low driving power and dependability and the risk of failure of the ammonia and carbon dioxide synthesis process control system in the reactor (A17) is categorized in the dependent sector, which indicates that the risk is not independent and does not have a strong relationship between the risks that arise in PT's supply chain system. PT. Petrokimia Gresik is expected to implement mitigation actions that have been analyzed and produced in this research to minimize production losses, time losses, quality reduction due to risks that arise in order to achieve company goals. After implementing the various mitigation actions, further research needs to be carried out to determine the results of implementing the existing mitigation actions. It is advisable that forthcoming investigations incorporate focus group discussions (FGDs) involving supply chain stakeholders, given the interdependence of risk agents' actions. In actuality, these dependencies are possible; therefore, the ANP method is recommended for their reduction.

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