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Supply Chain Risk Management System for The Wooden Educational Toy Manufacturing Industry in Bekasi, West Java

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Abstract. *The wooden educational toy manufacturing industry plays an important role in supporting children's cognitive and motor development, while presenting its own challenges in operational and supply chain management. The complexity of managing raw material supply, meeting the requirements of product safety and delivery standards, and adjusting to fluctuations in market demand may pose interrelated risks. This problem will have an impact on the company's operational effectiveness. This research aims to identify the causes of the main risks, map the relationships between risks, and determine priority mitigation strategies. The methods used are House of Risk (HOR) for risk identification and mitigation strategies based on the Aggregate Risk Potential (ARP) value, and Analytical Hierarchy Process (AHP) to prioritize mitigation strategies based on Safety, Cost, Time, and Effectiveness criteria. Activity identification was conducted through the Supply Chain Operations Reference (SCOR) approach and visualized using a Network Diagram Model with K-Means Clustering. This research identified 12 main supply chain activities to obtain the main cause of 44 Risk Events based on 24 Risk Agents. The results showed that 8 mitigation strategies were designed with the highest priority being regular coordination between departement against the cause of lack of effective communication. Through this research, it was found that the implementation of the selected mitigation strategies can significantly reduce operational risk and improve supply chain efficiency.*

Keywords: *risk management, wooden toy manufacturing industry, house of risk, analytical hierarchy process*

I. Introduction

The development of the manufacturing industry encourages companies to continue transforming by reviewing processes and evaluating results to drive economic growth, innovation, and social progress (Shi & Su, 2023). One of the rapidly growing subsectors is the educational wooden toy industry, which relies heavily on innovation, efficiency and product quality to meet children's safety standards. Along with the development of the manufacturing industry and globalization, players in the wooden toy industry face risks related to product safety, regulatory compliance, and inventory and quality management. Risk is the possibility of a threat, adverse impact, or danger that can thwart or stop something that has been planned. Risks usually arise due to imperfections in the process, resulting in various obstacles in its implementation. (Wang et al., 2021). These risks can disrupt operations and be financially detrimental, so appropriate mitigation efforts are needed to maintain business continuity.

The wooden toy company is a manufacturer of children's educational toys that cooperates with the government in providing educational game tools made from wood. In meeting consumer needs, the company faces various risks in the supply chain that disrupt the smooth flow of goods and services. Supply chain disruptions are unexpected events that negatively impact the flow of goods or services, as a tangible form of risk that can hinder performance and cause losses if not managed effectively. (Berger et al., 2023; Saleheen & Habib, 2023). The issues identified include interrelated risks in planning, procurement, production, delivery and customer evaluation activities, which trigger process instability.

Various studies have shown the importance of supply chain risk management. The supply chain risk management process aims to keep risks minimal and under control by referring to established strategies, methods, and tools. (Gurtu

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& Johny, 2021). Risk prioritization should consider convenience, cost, and preventing further risks. In an effort to manage and prioritize risks in the company, identification is carried out through the House of Risk (HOR) method which is effective for identifying and mitigating risks in a structured manner (Rozudin & Mahbubah, 2021). Then the Analytical Hierarchy Process (AHP) method helps in prioritizing mitigation strategies based on the criteria desired by the company (Utami et al., 2022). However, research that integrates the two methods in the context of the educational wooden toy industry, especially Indonesian MSMEs, is still limited. This research offers scientific novelty through the application of the integration of the HOR and AHP methods with the Supply Chain Operations Reference (SCOR) scope approach in the company's supply chain risk management.

The problem of this research is the existence of interrelated risks in the supply chain at a Wooden Toy Manufacturing Industry company that hampers operational efficiency and reduces customer satisfaction, so a systematic and measurable mitigation strategy is needed. Based on these problems, this research aims to provide risk mitigation proposals in the distribution flow of the supply chain system in the Wooden Toy Manufacturing Industry company as a risk management strategy in the company's operational processes. This research identifies the process flow of interrelated activities in the supply chain using the Supply Chain Operations Reference (SCOR) approach to understand the interrelationships between processes that have the potential to cause operational disruptions. Furthermore, this research identifies potential risks and causal factors in each supply chain activity, and prioritizes the main risk causes using the House of Risk (HOR) method. Mapping the relationship between the main risk causes and the affected activities is done through a Network Diagram Model to illustrate the cause-and-effect relationship, making it easier to plan risk control. Then, an efficient and effective mitigation strategy is designed by integrating HOR for mitigation strategy formulation and using Analytical Hierarchy Process (AHP) in decision making to determine the right mitigation strategy based on the company's priorities and criteria.

II. RESEARCH METHOD

This research is a case study conducted with the main focus of the research is to analyze and mitigate operational risks that affect the smooth production process of wooden toys in the company's supply chain. Operational risks include potential disruptions to production, inventory management and distribution activities that can impact business efficiency and sustainability. In its vision "To become a leading company that supports government programs in the procurement of educational aids, helps educate the nation's children through educational toys, and develops products that are loved by all Indonesian children", the company strives to continuously improve its performance and business processes in order to realize this vision effectively and sustainably. A company is said to be optimal if it can produce high-quality products at the lowest possible cost and in an efficient time and pay attention to process safety (Praysi Nataly Rattu et al., 2022). Therefore, optimization of operational processes in the company needs to be done to achieve results in accordance with the plan effectively and efficiently.

The data sources in this study consist of primary data and secondary data obtained from January 2025 - June 2025. Primary data was obtained through direct observation of the production and operational processes, interviews, as well as Brainstorming and Focus Group Discussion (FGD) activities to support observations related to events, linkages, causes, and risk mitigation strategies with owners and employees. In addition, internal company documentation in the form of organizational structure, history of production problems, and operational process reports were used to complement information related to the risks studied. Secondary data were obtained from literature, journals, books, and company documents related to risk management standards. The variables studied in this research consist of risk events, risk agents, and mitigation

Figure 1. Risk Management Process SNI ISO 31000:2018

strategies. This research focuses on the internal stage of formulating improvement proposals as part of an effort to optimize risk management, which can be further developed in further research to achieve optimal results.

Based on SNI ISO 31000, the risk management process is the systematic application of policies, procedures and practices in various aspects, including communication, consultation, setting the context, as well as identifying, analyzing, evaluating, handling, monitoring and controlling risks (Sri Sarjana et al., 2022) which can be seen in Figure 1.

The approach used in this research is integrative, combining risk analysis and supply chain management methods. The methods used include Supply Chain Operations Reference (SCOR) for process mapping, House of Risk (HOR) for risk identification and evaluation, and Analytical Hierarchy Process (AHP) in mitigation strategy decision making. In addition, visualization of interrelationships between risks is

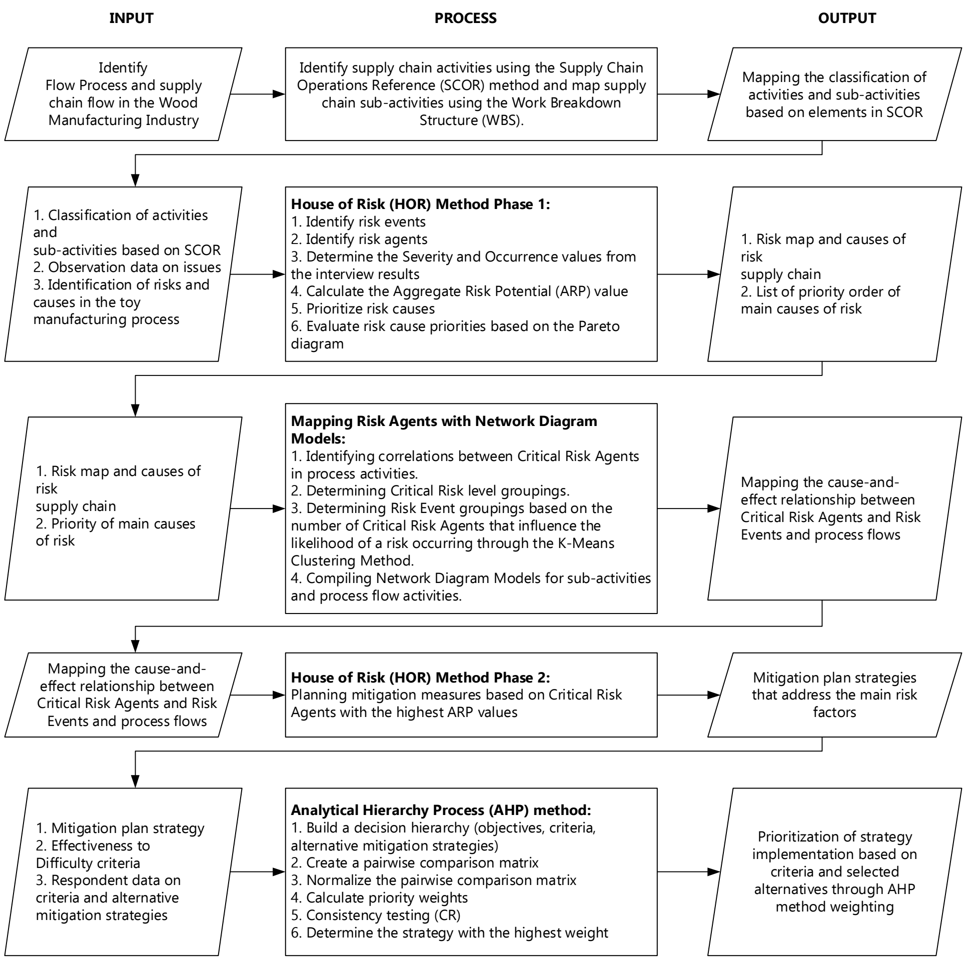

Figure 2. Flow of Risk Management Research Stages in the Wood Manufacturing Industry

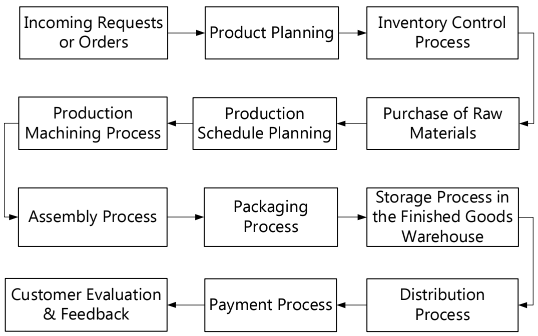

Figure 3. Operational Process Flow of the Wooden Educational Toy Manufacturing Industry

done through a Network Diagram Model that is categorized based on the results of clustering with the K-Means Clustering method. The risk management process combines the concepts of Supply Chain Management and Risk Management into Supply Chain Risk Management. The flow of the research stages is shown in Figure 2, where the risk management process is integrated with the final results that can be tailored to the company's needs.

III. RESULT AND DISCUSSION

In the initial stage of the research, observation and brainstorming activities were conducted together with the company to obtain the company's operational process flow, which would be further analyzed using the Supply Chain Operation References (SCOR) model. There are 12 main operational process flow stages shown in Figure 3.

Table 1. Supply Chain Activities in the Wooden Toys Manufacturing Industry

Code	Process	
	Activity	**Work Package**
	Planning	
C1	Incoming Request or Order	Order acceptance
		Order verification
		Making a Work Order (SPK)
C2	Production Planning	Product design as an example model
		Cost estimation analysis
		Part quantity specification analysis
		Production time analysis
		Work division analysis
C3	Inventory Control Process	Checking raw material stock
		Raw material inventory planning
	Source	
C4	Raw Material Ordering	Raw material ordering
C5	Raw Material Receipt	Raw material receipt verification
	Make	
C6	Production Machining Process	Machining process
		Production finishing process
C7	Assembly Process	Component Assembly
C8	Packing Process	Packing and Quality Control
	Delivery	
C9	Storage Process in the Finished Material Warehouse	Finished product storage
C10	Distribution Process	Preparation and delivery process
		Acceptance of goods by customers
	Return	
C11	Payment Process	Confirm payment
		Claims for goods from customers
C12	Customer Evaluation and Feedback	Customer evaluation
		Company evaluation

Supply Chain Activity Mapping

Supply Chain Operation Reference (SCOR) is a tool used to map activities in business processes at wooden toy manufacturing industry (Ulfah, 2021). The mapping of supply chain activities based on the flow process is carried out systematically in five main processes, namely plan, source, make, deliver, and return. The flow process in Figure 3 is then further elaborated through the Work Breakdown Structure (WBS). WBS aims to divide work into small parts hierarchically so that every activity in the company's supply chain can be planned, implemented, and monitored more efficiently and

Table 2. Risk Event Identification Results and Severity Value

Code	Risk Event	Severity
E1	Double order data collection	1
E2	Discrepancy in order verification	2
E3	Delay in making Work Order (SPK)	4
E4	Discrepancy between product results and sample production model	4
E5	Difference between estimated production costs and costs incurred	4
E6	Shortage of parts/products produced	3
E7	Difference between estimated duration of work time and actual time	2
E8	Uncertainty in production schedule	3
E9	Uneven workload	3
E10	Difference in the amount of raw material stock in the system and warehouse data	4
E11	Damage to materials during the storage process in the warehouse	4
E12	Shortage of raw material orders	5
E13	Errors in the preparation of Purchase Orders (PO) to suppliers	4
E14	Delays in the process of delivering raw materials from suppliers	4
E15	Delays in the process of ordering raw materials	3
E16	Discrepancies in raw material products received with the PO	4
E17	Product defects in raw materials received	5
E18	Discrepancies in the size of products produced with the desired specifications	5
E19	Machine failure	5
E20	Delays in tool parts	4
E21	Delays occur at certain work stations	3
E22	Work accidents	5
E23	Uneven putty thickness	2
E24	Discrepancies in the color of the product results with the desired specifications	4
E25	Unevenness of the paint color on the product	3
E26	Uncertainty in the drying process time	3
E27	Lack of product component parts	4
E28	Discrepancies in the final assembly results with the sample model	4
E29	Product identification errors during packing	3
E30	Product damage	5
E31	Discrepancy of packing result with packing standard	4
E32	Error in data collection of finished products	3
E33	Product damage during storage	5
E34	Delay in shipping process	4
E35	Wrong destination of goods	3
E36	Product damage during transportation	5
E37	Discrepancy of products received by customers with the specifications of the order submitted	5
E38	Loss of goods during shipping	5
E39	Discrepancy of total payment with payment note	4
E40	Delay in payment from customers	3
E41	Deduction of payment fees	2
E42	Customer dissatisfaction	1
E43	Loss of customers	5
E44	Decline in company reputation	4

measurably (Saleh et al., 2025). The integration of this model can be seen in Table 1. There are 23 sub-activities packaged in a work group based on observations and interviews with the managing director, administration, HRD, marketing, QC & Shipping, head of production, and head of MDF.

Risk Identification

The risk identification process is carried out through the House of Risk (HOR) method. HOR is an integration of two research models, namely the Failure Mode and Effect Analysis (FMEA) and House of Quality (HOQ) methods. In this model, FMEA serves to analyze the level of risk, while HOQ comes from the Quality Function Deployment (QFD) method which is used to design strategies that help mitigate the sources of risk that have been identified (Rozudin & Mahbubah, 2021). Risk level analysis is done by assessing Severity and Occurrence (Liansari et al., 2020). The assessment weight is measured with a weight range of 1-5. In Severity, this scale indicates the severity of the risk impact, with 5 being the most extreme consequence. While in Occurrence, this scale indicates the level of frequency of occurrence of the risk cause. Through interviews with the Department Heads of Administration, Human Resources, Marketing, QC & Shipping, Finishing, Production, MDF, and Boring, the identification of Risk Events and Risk Agents along with their assessment weights are obtained in Table 2 and Table 3 through the House of Risk Phase 1. Risk Events are limited to real events that can be observed and have a direct impact on the process while Risk Agents are limited as causal factors that are systemic, procedural, or work habits. In other words, Risk Agent is causal, while Risk Event is consequential.

There are 44 risk events dentified as disruptions in the operational system of the company's supply chain system, so that the causes of the risks found were identified. Identification of the Risk Agent that is the source of this risk is accompanied by information on the frequency of occurrence of the cause in a risk.

Through the identification results, 44 risk events and 24 risk causes were obtained that can be analyzed for correlation with each other

Table 3. Risk Agent Identification Results and Occurence Value

Code	Risk Agent	Occurrence
A1	Manual input of order data	2
A2	Sudden changes in customer requests	1
A3	Errors in product design	3
A4	Delays in response from suppliers	2
A5	Limited production capacity	3
A6	Lack of operator skills in carrying out the production process	3
A7	Manual data collection and shipping documents	4
A8	Labor allocation is not optimal	3
A9	Data collection system is not realtime	4
A10	Lack of machine care and maintenance	2
A11	Extreme weather conditions	2
A12	Manual monitoring of inter-departmental systems	4
A13	Lack of effective communication between teams/departments	5
A14	There is a change of new work operators in the process	4
A15	Manual inventory management	3
A16	Lack of standardization and SOP Documentation	3
A17	Manual calculation of the number of parts or finished products	5
A18	Transportation constraints	2
A19	Inaccuracies in demand forecasting system	4
A20	Lack of quality inspection of receipt and delivery of goods	4
A21	Goods are not neatly arranged on site	4
A22	Power outages	2
A23	Fluctuating raw material prices	2
A24	Dependence on suppliers	2

Table 4. Risk Cause Evaluation

Risk Agent Code	ARP	Rank	Risk Agent Code	ARP	Rank
A13	1340	1	A18	464	13
A17	1085	2	A14	444	14
A16	810	3	A11	420	15
A21	796	4	A10	342	16
A9	708	5	A4	290	17
A20	696	6	A22	290	17
A12	620	7	A1	284	19
A7	584	8	A8	267	20
A6	576	9	A24	182	21
A3	549	10	A23	180	22
A15	546	11	A2	137	23
A19	472	12	A5	27	24

through the calculation of Aggregate Risk Potential (ARP). This correlation value is divided into four levels, namely 0 (no relationship), 1 (low correlation), 3 (medium correlation), and 9 (high correlation) (Ir. Ahmad Syamil et al., 2023). The ARP calculation helps companies to focus on addressing the causes of risk that have the most impact on the supply chain. ARP calculation can be done with the following formula:

$$ARPj = Oj \sum i \; Si \; Rij \qquad \text{... (1)}$$

where :

ARPj = Aggregate value of risk potential

Oj = Chance of occurrence of Risk Agent j (occurrence)

Si = Loss arising from Risk Event i (severity)

Rij = Correlation between Risk Agent j and Risk Event i

Based on the ARP calculation, the results can be seen in Table 4. A high ARP value indicates that the cause of the risk has a level of importance that needs to be addressed immediately with the right mitigation strategy.

The results of the ARP calculation are evaluated through Table 4 to facilitate the identification of risk causes that require the most attention. The prioritization of causes is done with the help of a pareto diagram through the 80:20 pareto principle in Figure 4. This principle states that approximately 80% of the consequences come from 20% of the causes (Andrias Sahulata et al., 2023). Based on this concept, 13 of the 24 Risk Agents contributed a cumulative 80%. Through the results of brainstorming with the company, 5 of the 13 main causes were selected that contributed to the majority of the main risks, namely the lack of effective communication between teams/departments, manual calculation of the number of parts or finished products, lack of standardization and documentation of SOPs, goods are not neatly arranged on site, and the data collection system is not realtime. This decision was made by considering the limited resources, time, and efficiency of mitigation implementation.

Risk Agent Mapping with Network Diagram Model

After determining the 5 priority Risk Agents, mapping is done using a Network Diagram to visualize the relationship between Risk Agent and Risk Event. The Network Diagram supports risk mitigation planning by providing a clearer picture

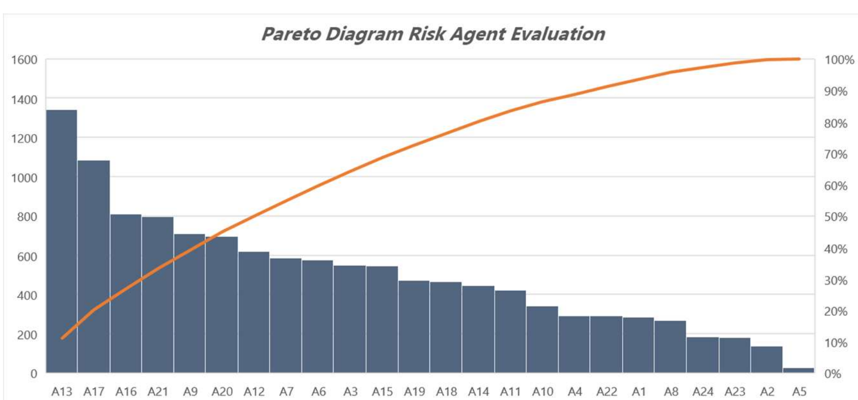

Figure 4. Pareto Diagram of Risk Agent Evaluation

Table 5. Determination of Risk Agent Cluster

Cluster	Description
1	Risk Events that have Risk Agents are still classified as low in the controllable risk group.
2	Risk Events that have Risk Agents that are included in the medium risk group.
3	Risk Events that have the number of Risk Agents are in the high risk group that need special attention.

of the sequence of activities (Tuscano & Astaneh Asl, 2024). This mapping helps identify critical points that need to be focused on in risk mitigation. The selection of these critical points is grouped into 3 clusters in Table 5.

The selection of critical risk levels is done through K-Means Clustering based on the number of main causes that affect a risk. K-Means Clustering is a data mining technique to categorize data based on similar characteristics (Solikhun et al., 2022). Grouping is done in Table 6 with 3 Initial Centroid values determined through the calculation of quartiles 1, 2, 3. Then iteration is carried out so that the iteration results are obtained in Table 6. The distance between the Risk Agent value and the centroid is calculated by the following formula:

$$\text{Euclidean Distance} = |\,data - centroid\,| \quad \dots (2)$$

where :

data = Number of Risk Agents

centroid = Center point

The K-Means process consists of clustering the data based on the Euclidean distance to the nearest centroid and recalculating the centroid position (Ahmed et al., 2020). Furthermore, iteration is carried out with the average data that has been divided into 3 clusters to ensure consistent grouping data so that the iteration results are obtained in Table 6. Risk Event that has a group with the smallest absolute distance result

Table 6. K-Means Clustering Result

Risk Event	∑ Risk Agent	Distance to C1	Distance to C2	Distance to C3	Cluster	Risk Event	∑ Risk Agent	Distance to C1	Distance to C2	Distance to C3	Cluster
		Centroid Iteration						Centroid Iteration			
		1.38	3	4.21				1.38	3	4.21	
E1	4	2.62	1.00	0.21	3	E23	1	0.38	2.00	3.21	1
E2	4	2.62	1.00	0.21	3	E24	2	0.62	1.00	2.21	1
E3	3	1.62	0.00	1.21	2	E25	1	0.38	2.00	3.21	1
E4	2	0.62	1.00	2.21	1	E26	1	0.38	2.00	3.21	1
E5	3	1.62	0.00	1.21	2	E27	4	2.62	1.00	0.21	3
E6	4	2.62	1.00	0.21	3	E28	1	0.38	2.00	3.21	1
E7	2	0.62	1.00	2.21	1	E29	4	2.62	1.00	0.21	3
E8	3	1.62	0.00	1.21	2	E30	2	0.62	1.00	2.21	1
E9	4	2.62	1.00	0.21	3	E31	3	1.62	0.00	1.21	2
E10	5	3.62	2.00	0.79	3	E32	5	3.62	2.00	0.79	3
E11	1	0.38	2.00	3.21	1	E33	3	1.62	0.00	1.21	2
E12	4	2.62	1.00	0.21	3	E34	4	2.62	1.00	0.21	3
E13	3	1.62	0.00	1.21	2	E35	2	0.62	1.00	2.21	1
E14	0	1.38	3.00	4.21	1	E36	1	0.38	2.00	3.21	1
E15	1	0.38	2.00	3.21	1	E37	4	2.62	1.00	0.21	3
E16	2	0.62	1.00	2.21	1	E38	4	2.62	1.00	0.21	3
E17	2	0.62	1.00	2.21	1	E39	2	0.62	1.00	2.21	1
E18	1	0.38	2.00	3.21	1	E40	2	0.62	1.00	2.21	1
E19	2	0.62	1.00	2.21	1	E41	3	1.62	0.00	1.21	2
E20	0	1.38	3.00	4.21	1	E42	3	1.62	0.00	1.21	2
E21	1	0.38	2.00	3.21	1	E43	4	2.62	1.00	0.21	3
E22	3	1.62	0.00	1.21	2	E44	5	3.62	2.00	0.79	3

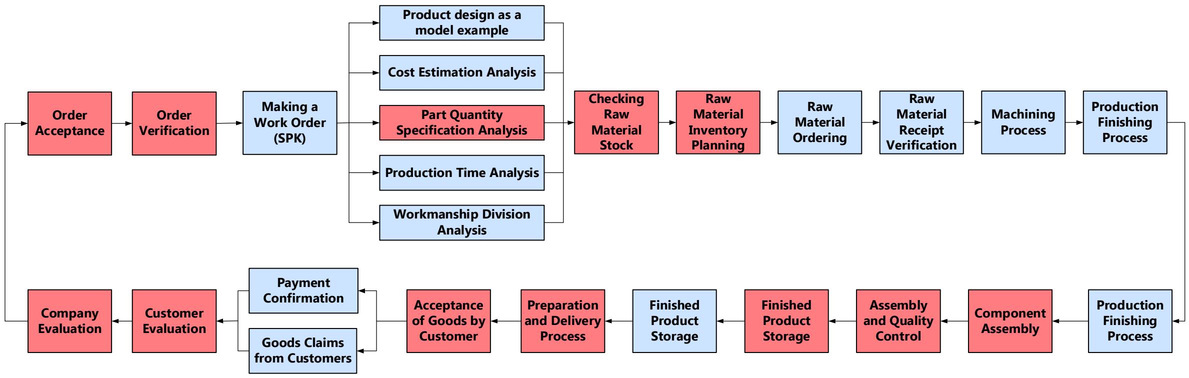

Figure 5. Work Package Risk Network Diagram

Table 7. Risk Mitigation Strategy Plan

Risk Agent	Code	Mitigation Plan	Code
Lack of effective communication between teams/departments	A13	Hold regular coordination between divisions through daily/weekly meetings and short briefings before operations begin	M1
		Implement a unified communication platform such as Slack, Microsoft Teams, or Trello to monitor workflows between teams in real-time	M2
Manual calculation of the number of parts or finished products	A17	Product code labeling for calculating the number of parts or products based on the code	M3
		Conduct regular audits by creating a daily checklist for data collection or implementing a digital inventory system	M4
Lack of standardization and SOP documentation	A16	Compile and document SOPs in written form, visuals in the work area, short videos, and digitization for easy access by all employees	M5
		Conduct regular socialization and training for all employees	M6
Items are not neatly arranged at the location		Use multi-level storage racks and location labeling as part of the implementation of the 5S system (Seiri, Seiton, Seiso, Seiketsu, Shitsuke) in the storage area	M7
The data collection system is not real-time	A9	Implement a centralized ERP system that supports integration between departments and real-time data updates so that order information can be monitored	M8

will be the selected cluster.

Based on the Risk Agent cluster grouping of each Risk Event, the Risk Agent and Risk Event relationship mapping is obtained by prioritizing Risk Events that have a high level cluster in **Figure 5**. This grouping is consistent in mapping the cause-and-effect relationship of risks from 23 sub-activities in the company.

Risk Mitigation Strategy Planning

After obtaining the Risk Agent that is the top priority, efforts are made to design mitigation strategies to overcome the causes of these risks through the House of Risk Phase 2 method. This design uses the Limitation Model approach. Limitation Model in the context of risk management is a mitigation strategy approach that focuses on limiting the impact and likelihood of risk occurrence (Andrias Sahulata et al., 2023). Mitigation strategy planning is carried out by considering the critical points of risk and brainstorming with company. A total of 8 alternative risk mitigation strategies were designed and evaluated using the AHP method, taking into account human cognitive limits. This selection refers to the theory of George A. Miller's theory which states that humans are only able to process 7 ± 2 items effectively at a time (Zucchelli et al., 2025).

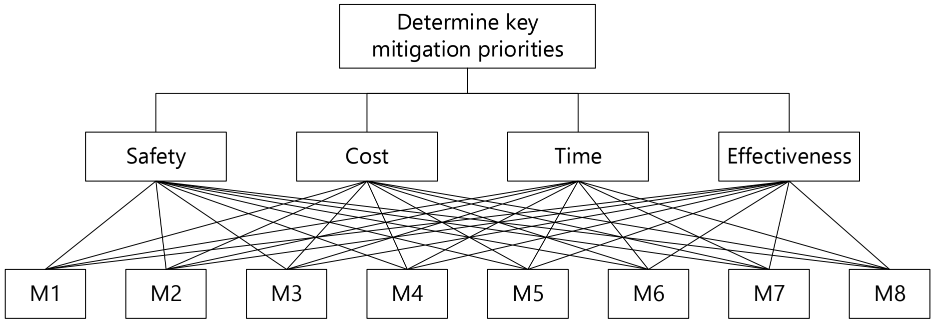

Figure 6. AHP Hierarchy Structure

Determine Key Risk Mitigation Strategies

In determining the main risk mitigation, it is carried out through the Analytical Hierarchy Process (AHP) method with the concept of Effectiveness to Difficult in the HOR phase 2 method. With the help of AHP, the priority of mitigation actions can be determined based on predetermined criteria. AHP converts qualitative values into quantitative ones so as to synthesize various considerations into a decision that is in line with intuitive judgment. (Raswini et al., 2022). Based on the criteria and alternatives that have been determined, these elements are arranged in the form of a hierarchy to facilitate data processing. The hierarchical structure is designed as an illustration of a complex problem that is organized in a multilevel structure (Fatmawati et al., 2023). Figure 6 shows the objectives, criteria, and alternatives in this study. There are 4 criteria obtained based on the results of brainstorming with company to compare the 8 alternatives that have been designed.

Then, the questionnaire was designed and the respondents were determined. The calculation of the number of questions for the questionnaire in the AHP method is carried out to ensure that all criteria and alternatives are compared pairwise and comprehensively with the assessment of three company experts, namely the President Director, Head of Marketing, and Head of Production. The number of questions to be submitted to experts is processed in Table 8.

Table 8. Calculation of Number of Questions

Level	Matrix	Cell Dimensions	Question
Goals	0		
Criteria	1	4 x 4	N(n-1)/2 = 6
Alternative	4	8 x 8	28

The opinions of the three experts were combined using the geometric mean method, which serves to process individual assessment values into one representative value as a group aggregation result (Santoso et al., 2022). The geometric mean formula is as follows:

$$GM = \left(\prod_{i=1}^{n} xi\right)^{1/n} \quad \text{... (2)}$$

where :

GM = Geometric Mean

xi = assessment value of the i-th respondent

n = number of respondents (experts)

Π = sequential multiplication symbol (x1 × x2 × .. × xn)

AHP data processing is carried out using Super Decisions Software. Super Decisions Software is a decision aid that excels in hierarchical visualization, automatic calculations, and consistency tests, making it easier and more accurate in prioritizing strategies objectively and is opensource so that it can be accessed according to established rules (A. Y. Mubarok et al., 2024). Through the geometric mean calculation results, the pairwise comparison matrix values are input into the Super Decisions Software V3.2 matrix to directly provide data consistency results.

Figure 7 shows a consistency ratio (CR) value of < 0.1 in the assessment of criteria from a group of experts, namely 0.04344, so it can be said that the data provided is consistent and can be used to calculate the priority of alternatives. The same steps were taken for alternatives to the criteria, so the consistency ratio values for alternatives based

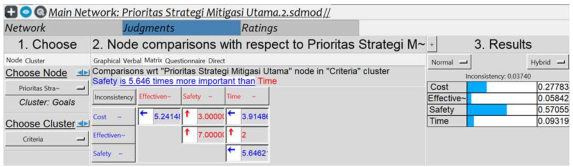

Figure 7. Consistency Ratio Combined Expert Criteria

Table 9. Consistency Ratio Against Combined Expert Criteria

Criteria	*Consistency Ratio*	Conclusion
Safety	0.06789	***Reliable***
Cost	0.02904	***Reliable***
Time	0.03726	***Reliable***
Effectiveness	0.04392	***Reliable***

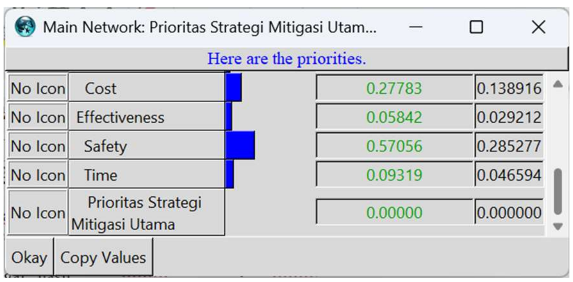

Figure 8. Priority Criteria for Selecting Mitigation Strategies

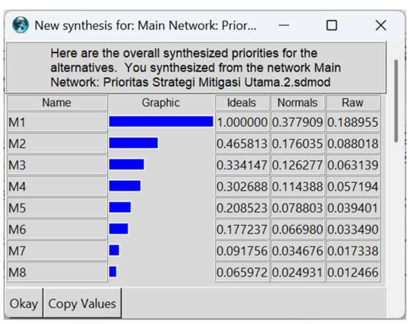

Figure 9. Synthesis Results Determination of Alternative Mitigation Strategies

on the four criteria that have been determined can be seen in Table 9.

The evaluation of the strategy using the AHP method in Figure 8 shows that the safety criterion has a dominant weight of 0.57056, followed by cost, time, and effectiveness. These results confirm that safety is the top priority in determining the risk mitigation strategy at the wooden educational toy manufacturing industry.

The results of the priority weight synthesis in Figure 9 show that alternative M1, namely routine coordination between departments through meetings and briefings, has the highest weight of 0.356148. The significant gap between alternatives indicates a clear differentiation in the decision-making process, with no trade-offs occurring. The consistency ratio value that meets the criteria (CR < 0.1) reinforces the validity of the results, so M1 is selected as the most optimal and relevant strategy.

These priority results form the basis for selecting the first mitigation measures to be implemented.

Mapping Mitigation Strategies Based on Organizational Structure

This mapping serves to place risk mitigation in the right hands, so that the organization is more agile, efficient, and measurable in preventing and overcoming problems in Figure 10. This division of responsibilities was obtained through brainstorming discussions about the company's activities and organizational structure.

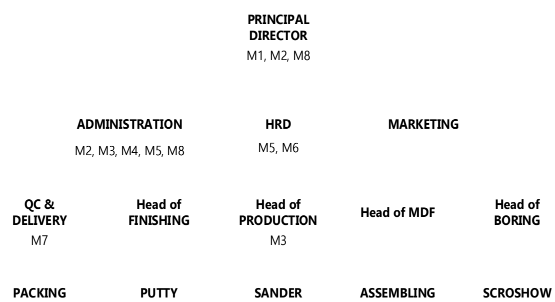

Figure 10. Mapping of Mitigation Strategy Responsibilities

Mitigation strategies M1 to M8 focus on improving coordination, operational accuracy, and system integration between departments. M1–M2 strengthen collaboration through regular meetings and an integrated communication platform, while M3–M4 improve production accuracy and stock control through product code labeling, periodic audits, and a digital inventory system. M5–M6 standardize work procedures through visual SOPs and regular training, while M7 implements the 5S system for storage area efficiency. M8 integrates all processes through a real-time data-based ERP system. All these strategies directly contribute to improving risk management effectiveness within the company's operational system.

IV. CONCLUSION

Based on the research results, 12 out of 23 sub-activities in the supply chain were identified as being concentrated in the Planning and Delivery processes, with five dominant risk causes including lack of communication between teams, manual data collection, irregular layout of goods, absence of written SOPs, and a data collection system that is not yet real-time. Mitigation strategies were designed using the House of Risk (HOR) approach and prioritization of mitigation measures through the Analytical Hierarchy Process (AHP), with improved communication and collaboration between departments identified as the primary strategy. Therefore, the 8 mitigation strategies developed can serve as considerations for companies in their supply chain risk management processes. Further research is recommended to use more comprehensive historical data, involve cross-departmental and external experts, and incorporate non-technical risks such as reputation, sustainability, and product regulations. Additionally, comparative studies with other companies in the same industry are necessary to expand the generalization of findings and validate the mitigation strategies developed. This research contributes to helping the manufacturing industry manage operational risks in a more structured manner through risk mapping and the determination of measurable mitigation strategies. This contribution is demonstrated by the prioritization of risks and mitigation strategies based on criteria relevant to the company's conditions.

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