

Risk Mitigation Design for Supply Chain Activities in the Printing Industry with House of Risk Method

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ABSTRACT

Alvian MSMEs is a printing company that orders calendars, banners, and billboards. The problem faced by Alvian MSMEs today is that supply chain activities and production are usually late, so products experience a decrease in customer buying interest. To overcome these problems, MSMEs mitigate risks in supply chain and production activities using the HOR (House of Risk) Method. Based on Hor phase 1, 12 risk events and agents were obtained. The identification results show low-quality raw materials are the highest risk agent (A9). This risk agent has the highest value because it can cause risk events in the form of poor quality or defects (E9). In HOR phase 2, 6 priorities were obtained for risk mitigation to prevent system failure (PA3), and implementing preventive maintenance routines is a top priority. With an ETDk value of 10386, PA3 mitigation measures can reduce risk factors such as manufacturing defects, misconceptions of customer specifications, quality testing problems, improper maintenance, overuse, system failure, technical problems with printing machines, staff or management failures, no routine monitoring of machine checks (A11, A8, A4, A5, A7). Based on these findings, 6 mitigation actions were carried out to minimize risks that could potentially arise. Where one of the proposed mitigations was implementing preventive maintenance routines,

Keywords: House of Risk (HOR), Supply Chain Risk, MSMEs.

Introduction

Industry players have noticed the role of Supply Chain Management (SCM) because they realize that providing cheap, quality, and fast products is insufficient to sustain the company's survival. [1]. SCM manages the business's relationships with customers, who use the products, and suppliers, who provide raw materials to the enterprise, in addition to its internal operations. Supply Chain Management requires strong collaboration between process components to produce high-quality products and an efficient product delivery procedure that satisfies customer demands. [2]. Supply Chain Management serves to control and ensure that products are in the right place and time to meet customer demand so that there is no excessive stock or shortage in the warehouse or storage that can generate significant profits for the company. [3]. In addition, SCM is part of procurement, including selecting suppliers, assessing employee performance, providing raw materials and components, assessing risk, and directing and maintaining relationships with suppliers. [4] The supply chain application is very important, including for small and medium enterprises or printing MSMEs in maximizing the process. Coordination between producers and suppliers also helps in terms of controlling the inventory of existing raw materials because if there is a shortage of product inventory at distributors, it will result in loss of sales, while excess will result in the accumulation of products and also increased inventory maintenance costs. [5].

MSMEs have an important role in reducing unemployment and poverty [6]. Printing MSMEs, as one of the sectors engaged in the creative industry, cannot be separated from rapid changes in business governance and production technology [7]. Alvian MSMEs is a company engaged in printing, which serves calendar orders, banners/billboards. Alvian MSMEs can produce as many as 20,000 per month and 50,000 banners. Banners serve as an important communication tool in conveying information to the public, usually installed on streets or public areas, with various sizes and colors to attract readers' attention [8]. The banner production process uses Chinese flexy material and calendars use kinstruk paper. Alvian MSME consumers are found in several regions in South Sulawesi. The wide segmentation

of the Alvian MSME market will also impact the level of risk of the activities carried out. In the printing world, several risks commonly occur, including inappropriate raw material planning, product defects, stopped products, product returns from consumers, and others. If this continues, Alvian MSMEs can experience operational and financial losses. One common phenomenon in business failure in the printing sector is fluctuating profits due to seasonal influences. Seasonality is when the demand for a particular product or service experiences significant fluctuations. Seasonal periods can affect economic demand and activity patterns, which can affect a company's revenue and profits [9]. With so many complex problems, risk management is needed to help find out the risks that exist in the company.

Risk mitigation refers to the process of identifying and implementing strategies to reduce the potential risks identified in a specific process or operation [10]. Risk management is an integral part of process management that runs continuously to minimize or reduce losses and increase opportunities for the company. With a lot of activity supply chain Consists of many complex activities ranging from many actors to production processes that do not always run smoothly. Events like this can cause risks that can harm the company. [11]. So, to overcome the risks that will occur in the future, it is necessary to have a management that is used by MSMEs [12]. The purpose of supply chain risk management is to monitor, manage, and assess possible risks in the supply chain by taking the best steps to prevent disruptions and quickly correct situations if they occur. [13]. It is important to identify these risks in order to evaluate opportunities and prepare for appropriate decisions related to future activities. [14]. For example, the risk of interline is the delay in the production of billboard printing due to maintenance, causing the risk of failure in planning the production of banners/ billboards, the impact is additional costs. Therefore, in this study, Alvian Printing MSMEs as the object of research for risk identification and mitigation, especially using the House of Risk (HOR) method to reduce risks in the procurement of raw materials. [15]. This is because there is often a delay in the arrival of Raw Material in Alvian Printing MSMEs, besides that there is also often overstock or outstock.

House of Risk (HOR) is a risk management model that integrates the House of Quality (HOQ) and Failure Modes and Effects Analysis (FMEA) to identify, prioritize, and mitigate risks systematically in activities such as new product development. [16]. (HOR) is the result of the development of combining two methods that were previously commonly used as methods for the risk assessment process, namely the method House of Quality (HOQ) and Failure Modes and Effects Analysis (FMEA) to compile a Framework in proactively managing supply chain risks. [17]. The HOR model bases risk management on a preventive focus, i.e. reducing the likelihood of risk agents occurring. [18]. Method approach House of Risk (HOR) aims to reduce the likelihood of risk agents by implementing preventive measures. Most risk events (Risk Events) occur due to certain sources of risk, therefore, reducing these sources of risk is expected to reduce the potential for the occurrence of associated risk events. [19]. House of Risk is a renewable method of analyzing risk [20]. The use of HOR makes it easy for stakeholders to make decisions. Risk disclosure can be easily done, and risk disclosure is also a company medium to communicate with stakeholders. [21]. Supply chain activities in printing production centers that are quite complex, ranging from the procurement of raw materials, production processes, distribution, and marketing to the hands of consumers, have risks that may occur. [22]. This process causes the supply chain to become a complex system with structured elements, dynamic dependencies, and clear objectives. [23]. Recognizing power dynamics in supply chains will make identifying strategies to mitigate their negative impact on resilience easier. [24]. So that Supply chain risk mitigation can support management performance in terms of demand, providers, products, and information [25]. Research in Alvian MSMEs aims to identify and analyze risks that may arise during the stages of supply chain activities and develop appropriate mitigation strategies. This study used the HOR method to identify, analyze, and design effective mitigation strategies. Therefore, this study will fill the knowledge gap by investigating how MSMEs in the printing sector consider risks at the supply chain stage. This is also done to minimize risks such as delays in raw materials, overstock, outstock, etc.

Research Methods

General Stages of Research

The research was conducted at the Alvian printing shop in Makassar, which produced calendars, banners, and billboards. Data was collected from December 2023 to February 2024. Before it starts, problems are identified through observation and interviews. The HOR technique is used to assess and identify risks, particularly in the supply chain, in order to make choices throughout the problem identification phase.

Data Collection

Primary Data, is data that is directly obtained from the source. This data must be obtained through sources or experts who are used to obtain information. The primary data in this research are risk event data, risk agent data, severity, and occurrence data. Primary data collection was carried out by of interviews, surveys, and focus group discussions.

Secondary data, namely data obtained from document materials and report materials about the type of research that is related or closely related to this research.

HOR Preparation Steps

1) HOR Phase 1.

Phase 1 is used as a preventive measure by determining the priority size of the risk agent that must be given [17]. At this stage, HOR a value is obtained Aggregate Risk Priority (ARP) as shown in the following equation (1)

- a. Identify risk events (Risk Event) and risk agents (Risk Agent)
- b. Impact scale assessment (severity) from risk events with a determination scale level of 1-5, which looks at the impact of successive risks that are very small, small, medium, large, and very large.
- c. On a scale of 1 to 5, which indicates that the likelihood is likely not to occur, the probability of occurrence is minor, the probability is likely to occur, or it is very likely to occur, event opportunities (occurrence) in each identified risk agent are assessed.
- d. Calculation of potential risk of ARP using the following formula:

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

Where:

O_j : Opportunity for the occurrence of sources of risk (occurrence)

S_i (1): Impact of risk events (severity)

R_{ij} : Relationship or correlation between risk events and sources of risk

- e. Ranking and Pareto charts of risk sources based on ARP values from largest to smallest.

2) HOR Phase 2.

Phase 2 is a priority to find the most appropriate course of action.

- a. Identify preventive actions for the prevention of sources of risk.
- b. Determine the correlation between risk events and risk agents using a scale value of 0, 1, 3, or 9 to express no correlation, weak correlation, slight correlation, or strong correlation.
- c. Calculation of the formula for the total effectiveness value of each preventive action as follows:

$$TE_k = ARP \sum_j E_{jk} \quad (2)$$

Where:

TE_k = Total effectiveness of each mitigation strategy action

ARP_j = Aggregate Risk Priority (ARP) Value

E_{jk} = Relationship or correlation between preventive action and risk agent

- d. Degree of Difficulty assessment with difficulty assessment values 3, 4, 5, which shows mitigation actions are easy to implement, mitigation actions are quite difficult to implement, mitigation actions are difficult to implement

- e. Assessment of Effectiveness to Difficulty (ETD_k) with the formula:

$$ETD_k = TE_k / D_k \quad (3)$$

Where:

ETD_k : Effectiveness to Difficulty

TE_k : Total effectiveness of the predetermined mitigation strategy

D_k : The level of difficulty in carrying out mitigation actions

- f. Perform preventive ranking based on ETD_k values from largest to smallest.

Results and Discussion

HOR Phase 1

By examining supply chain activities in Alvian printing MSMEs, we can see activities or subprocesses at each stage of the process. This mapping makes it easier to identify supply chain activities and coverage. In addition, this mapping helps identify risks and determine where such risks may arise. At this stage, data was collected by observation and interviews with experts (management and workers).

Table 1. Mapping of supply chain activities

Major Process	Sub Process
Plan	<ol style="list-style-type: none"> Analyze customer demand. Production planning based on demand and production schedule. Planning the needs of raw materials, labor, and equipment. Scheduling machine maintenance.
Source	<ol style="list-style-type: none"> Search for raw materials Purchase raw materials and negotiate prices and delivery terms with suppliers. Raw material Checking Process Raw material storage process Order Acceptance
Make	<ol style="list-style-type: none"> Typesetting, Image assembly, Setting Machine. Platemaking, Printing presses and binding.
Delivery	Proper fulfillment of customer orders and delivery of products
Return	<ol style="list-style-type: none"> Handling of defective or non-compliant product returns. Arrangements for the replacement or refund process to the customer.

Table 2. Risk identification

Major Process	Risk Event	Risk Agent
Plan	<ol style="list-style-type: none"> Sudden changes in customer demand Planning errors resulting in overstock or stockout Delays in the production or delivery of raw materials Machine maintenance scheduling error. 	<ol style="list-style-type: none"> Changes in market trends, promotions, or offers from competitors lack of valid historical data Disruptions in supply chains, including delays from suppliers No routine monitoring on machine checking
Source	<ol style="list-style-type: none"> Late delivery from suppliers Low quality of raw materials or not by standards Sudden increase in raw material prices 	<ol style="list-style-type: none"> Logistical problems and production problems on the part of suppliers Errors in the acceptance or testing of raw materials, unreliable suppliers Changes in economic policy, market fluctuations, increases in transportation or production costs
Make	<ol style="list-style-type: none"> Damage or failure of production equipment Delays in the printing process resulting in shipping delays Poor or defective print quality 	<ol style="list-style-type: none"> Improper maintenance, overuse, system failure Technical problems with printing presses, staff failure, or management Low-quality raw materials
Delivery	Delay or damage in the delivery of goods	failure in packaging or courier
Return	<ol style="list-style-type: none"> High rate of return due to low product quality Customer dissatisfaction leading to returns 	<ol style="list-style-type: none"> Manufacturing defects, misunderstanding of customer specifications, problems in quality testing. Late delivery, breach of contract, change of customer preferences

Table 3. Risk events identified

Kode	Risk event	Severity (Si)
E ₁	Sudden changes in customer demand	3
E ₂	Planning errors resulting in overstock or stockout	5

Kode	Risk event	Severity (Si)
E ₃	Delays in the production or delivery of raw materials	3
E ₄	Machine maintenance scheduling errors	5
E ₅	Low quality of raw materials or not following standards	5
E ₆	A sudden increase in raw material prices	2
E ₇	Damage or failure of production equipment	5
E ₈	Delays in the printing process resulting in shipping delays	4
E ₉	Poor or defective print quality	4
E ₁₀	Delay or damage in the delivery of goods	4
E ₁₁	High rate of return due to low product quality	4
E ₁₂	Customer dissatisfaction leading to returns	3

Table 4. Risk Agents Identified

Kode	Risk Agent	Occurrence (O _i)
E ₁	Changes in market trends, promotions, or offers from competitors	2
E ₂	lack of valid historical data	5
E ₃	Disruptions in supply chains, including delays from suppliers	4
E ₄	No routine monitoring on machine checking	4
E ₅	Errors in the acceptance or testing of raw materials, unreliable suppliers	5
E ₆	Changes in economic policy, market fluctuations, increases in transportation or production costs	2
E ₇	Improper maintenance, overuse, and system failure	5
E ₈	Technical problems with printing presses, staff failure, or management	5
E ₉	Low-quality raw materials	4
E ₁₀	failure in packaging or courier	2
E ₁₁	Manufacturing defects, misunderstanding of customer specifications, problems in quality testing	4
E ₁₂	Late delivery, breach of contract, change of customer preferences	2

Once the risk event and risk agent are identified and measured, the next step is to assess the relationship between them. This is necessary because the emergence of one or more risk agents can cause the emergence of one or more risk events and vice versa. Relationship values of 0, 1, 3, and 9 were used to assess this relationship.

From each risk event and agent, proceed with mapping the value of Aggregate Risk Potential. The calculation of the ARP value is used to determine the priority of risk agents that need to be addressed first and give preventive measures to risk agents. Each ARP value is obtained through calculations using the formula:

$$ARP = O_j \times \sum Si Rij$$

Table 5. Phase 1 HOR calculation

Activity	Risk event	Risk Agent												Severity (S _i)	
		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂		
Plan	E ₁	3					1							3	3
	E ₂	3	9	9	9	3	3							3	5
	E ₃	3	9	9	9	9	1	9						9	3
	E ₄							9	9					9	5
Source	A ₅					9				9			9		5
	E ₆	3	9				3			9				1	2
	E ₇				9			9	9	9			9		5
Make	E ₈				9			9	9	9	3			9	4
	E ₉				9	9		3	9	9			9		4
	E ₁₀										9	3	3		4
Delivery	E ₁₁				3	9		3	3	9			9		4
	E ₁₂	1					1				9	9	9	9	3

Activity	Risk event	Risk Agent												Severity (S _i)
		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂	
Return	Occurrence (O_i)	2	5	4	4	5	2	5	5	4	2	4	3	
	ARP_j	16	45	28	80	79	6	88	82	97	15	84	38	
	Ranking	10	7	9	5	6	1 2	2	4	1	11	3	8	

Calculating the ARP_j value in Table 5 shows that the highest risk agent is low-quality raw materials (A₉). This risk agent has the highest value because it can cause risk events in the form of poor quality or defects (E₉). The relationship between the A₉ risk agent and the E₉ risk event is strong. The risk agent that has the lowest ARP value is changes in economic policy, market fluctuations, and increases in transportation or production costs (A₉). This risk agent causes a risk event in the form of a sudden increase in raw material prices (E₆).

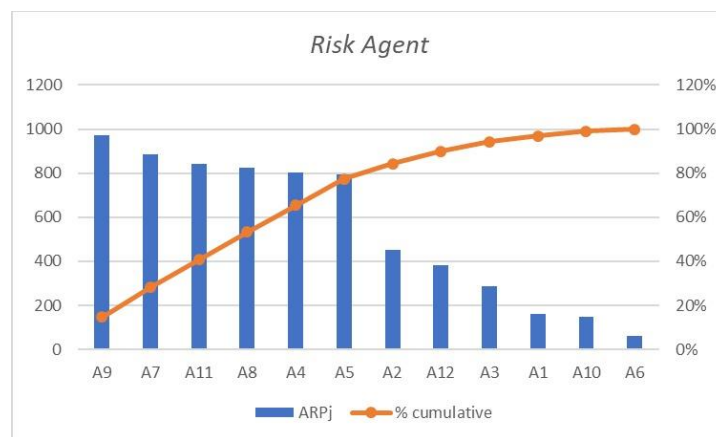


Figure 1. Pareto Diagram

The basis of risk evaluation in the final stage of HOR phase 1 is a Pareto diagram of the risk source's Aggregate Risk Potential (ARP) value. The Pareto diagram shows the sources of risk that are priorities for handling. In this risk evaluation, the 80:20 principle of the Pareto chart is used, which means that handling 20% of priority risk sources or more is expected to affect the overall improvement of other risk sources. Based on Figure 1, it can be seen that with the Pareto principle of 80 / 20, 6 risk agents were obtained from 12 risk agents, namely A9, A7, A11, A8, A4, A5, which became the dominant cause in the emergence of risks in the supply chain of Alvian printing MSMEs.

A risk evaluation is carried out to determine which sources of risk should be prioritized in the mitigation strategy. Pareto charts are analytical tools used in risk evaluation. First, ARP_j values are sorted from highest to smallest. Table 6 shows the cumulative value of agent risk and its cumulative percentage value.

Table 6. Calculation of percentage and cumulative percentage of ARP_j

Risk Agent	ARP _j	%	% Kumulatif
A ₉	972	15%	15%
A ₇	885	13%	28%
A ₁₁	840	13%	41%
A ₈	825	12%	53%
A ₄	804	12%	65%
A ₅	795	12%	77%
A ₂	450	7%	84%
A ₁₂	384	6%	90%
A ₃	288	4%	94%

A₁	162	2%	97%
A₁₀	150	2%	99%
A₆	60	1%	100%

HOR Phase 2

House of Risk Phase 2 is a continuation of HOR Phase 1. The dominant risk results obtained from HOR phase 1 will be mitigated. Risk strategies were successfully identified through focus group discussions with experts.

Table 7. Phase 2 HOR calculation

Risk event	Risk Agent						ARP _j
	PA ₁	PA ₂	PA ₃	PA ₄	PA ₅	PA ₆	
A₉	9	9	1			1	972
A₇		1	9	9	9	9	885
A₁₁			9	9	9	9	840
A₈			9	9	9	3	825
A₄			9	9		1	804
A₅	9	9					795
Total effectiveness of action (TE_k)	1590	1678	31158	2376	2295	1977	
Difficulty of acting (D_k)	3	8		3	0	6	
Effectiveness to difficulty ratio of action (ETD_k)	5301	4197	10386	7921	5737,5	6592	
Rank of action	5	6	1	3	4	2	

The results of the focus group discussion (FGD) with the company resulted in as many as 6 handling strategies for risk agents. After determining the handling strategy, experts reassess the correlation between risk agents and handling strategies. The correlation value is given to calculate the total Effectiveness and Degree of Difficulty to see the level of effectiveness and difficulty in the designed handling strategy.

Table 8. Sequence of mitigation strategies based on the results of HOR Phase II

Kode	Mitigation Action	RANKING	(TE _k)	(D _k)	(ETD _k)
PA1	Establish clear material quality standards and ensure suppliers' compliance with those standards.	5	15903	3	5301
PA2	Develop contracts governing the quality of raw materials and the consequences if they are non-conforming	6	16788	4	4197
PA3	Implement a regular preventive maintenance schedule to prevent system failure	1	31158	3	10386
PA4	Monitor system performance continuously and perform necessary maintenance before a failure occurs	3	23763	3	7921
PA5	Conduct training for staff on the correct understanding of specifications and test procedures	4	22950	4	5737,5
PA6	Perform rigorous quality testing during every stage of production to detect defects early	2	19776	3	6592

Table 7 shows how HOR phase 2 assesses the relationship between risk factors and mitigation actions. The results show that one risk factor can be anticipated by taking risk mitigation actions and that one of those risk factors can be prevented by taking risk mitigation actions. Table 8 shows the ranking order of mitigation actions from highest to lowest based on ETD_k values. Alvian printing MSMEs can perform 6 priority mitigation actions, as shown in Table 8. To prevent system failure (PA3), implementing a preventive maintenance routine is a top priority. With an ETD_k value of 10386, PA3 mitigation measures can reduce risk factors such as manufacturing defects, misconceptions of customer specifications, quality testing problems, improper maintenance, overuse, system failure, technical problems with printing machines, staff or management failures, no routine monitoring of machine checks (A11, A8, A4, A5, A7).

Conclusion

This research concluded that the risks found in the printing supply chain activities of Alvian MSMEs are as follows: Changes in market trends, promotions or offers from competitors, and economic fluctuations that may affect transportation or production costs. In addition, the lack of valid historical data can also be an obstacle to making the right decision. Disruptions in the supply chain are also risks that must be faced, such as supplier delays or technical problems with printing machines that can disrupt the production process. Improper maintenance or overuse can also lead to system failure, resulting in delays in production or even financial losses. The quality of raw materials is also an important factor, as low-quality raw materials can result in a final product that does not meet the standards or specifications expected by customers. Problems in packaging or shipping can also occur, such as failures in packaging or errors in the shipping process that result in damage or loss of goods. To reduce these risks, companies need to implement the right strategy. This includes regularly monitoring machine checks and ensuring proper maintenance is performed regularly. In addition, it is important to establish good relationships with reliable suppliers and conduct rigorous quality testing on raw materials and final products. In addition, companies must also be responsive to market changes and economic policies by diversifying products or optimizing production processes and supply chains. Thus, the company can minimize the impact of potential risks and continue to operate efficiently and effectively. Risk Agent priority A9, A7, A11, A8, A4, A5 will be mitigated action.

Apart from that, there are recommendations for mitigation strategies from the research results are as follows: Establishment of clear material quality standards and supervision of compliance with standards by suppliers (PA1), as well as the development of contracts governing the quality of raw materials and their consequences if they are not compliant (PA2). In addition, implementing a regular preventive maintenance schedule (PA3) and continuous monitoring of system performance help prevent system failure (PA4). Training staff on correctly understanding specifications and test procedures is also required (PA5), while rigorous quality testing during each production stage helps detect defects early (PA6). By implementing these measures, the company can improve the reliability of its operations, minimize risks, and maintain high product quality.

In this study, the highest mitigation action was proposed to be applied to Alvian MSMEs, namely preventing system failure (PA3) and implementing preventive maintenance routines, which is a top priority. With an ETDk value of 10386, PA3 mitigation measures. Therefore, it is recommended that further research be carried out on more than one or multiple MSMEs to validate the HOR method's effectiveness across different scenarios within the printing industry.

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