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Risk Mitigation Design of Supply Chain at Blacksmith Metal Craft Industry Centers

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Abstract - *The metal processing industry is one of the potential industries in Gunung Kidul Regency. The business processes are still traditional with limited awareness of potential risks, which can lead to losses. Improving the business quality of blacksmiths can start with the supply chain process. The research starts with identifying sources, priority scales, and risk mitigation. This study aims to identify, and assess the occurrence and agents of supply chain risk and create a risk mitigation design from supply chain activities in the blacksmith craft industry. Collection methods include source observation, interviews, and risk owner questionnaires. The HOR method is used to prioritize risk agents. Risk mapping based on business processes with SCOR dimensions and the ranking of risk agents through Pareto analysis. The results showed a total of 37 risk events and 22 risk agents. The prioritized risk agents are no written SOP, human error in the production process, lack of worker concern for OHS, and limited human resources. Proposed mitigation actions given are making work SOPs (written), conducting regular evaluations, cultivating work SOPs, tightening supervision of production activities, providing OHS training, providing first aid kits, implementing a reward and punishment, and conducting socialization to the village community.*

***Key Words*: Mitigation, Supply Chain, HOR, Risk Agents, Risk Events**

1. INTRODUCTION

The success of a country in carrying out development is indicated by economic growth [1]. As well as, in measuring a region's economy, the amount of economic growth shows how much economic activity has impacted increasing people's income in a certain period. One of the economic drivers in Gunung Kidul Regency in supporting economic growth is the agricultural sector. This sector's metal processing craft industry produces agricultural tool products [2].

The production process in the metal handicraft industry in Kajar Village, Karang Tengah, Wonosari, Gunung Kidul is still traditional, which results in frequent work accidents due to the high level of risk and lack of awareness of using PPE. The production process is still traditional, where the craftsmen only use feeling in making products and without using a definite size standard. In addition, blacksmith craftsmen tend not to realize the risks that can result in losses and how to overcome these risks [2]. A risk is an event that is possible and can affect the achievement of company goals/objectives, which can be measured using a combination of the possibility of occurrence and the impact caused [3]. Business risks are important to understand to avoid unwanted things. Knowing the various business obstacles in the future is expected so that the company can become more competitive and worthy of being taken into account. Companies need to understand risks to properly implement risk management. The amount of risk will affect priorities in setting risk management policies. Risk management helps small business managers identify and effectively address significant risks that could threaten the company's success or survival [4].

The blacksmith craft center needs to be fostered so that it becomes an efficient business that can develop independently. The development will increase the role of the industry in the provision of goods and services and be able to create jobs and employment opportunities that have an impact on increasing community income. To support the improvement of the production process, the risk mitigation analysis process in the supply chain is needed to increase the business quality of blacksmith craftsmen [2]. Risk in a supply chain perspective arises as an event that can affect the movement of material flow from suppliers to consumers and disrupt the planned flow of material. In a supply chain, all members are interrelated, and if there is a risk to one entity, it is automatically transferred to all other members [5]. For this reason, risks that may occur in the supply chain must be controlled so business activities run smoothly and efficiently. Risks that can arise include the risk of supply disruption, the risk of supply needs and plans, the risk of purchase prices, and the risk of inefficient processes [6]. If the cause of the risk has been identified, the risk mitigation strategy will be easier to implement to minimize the impact of losses that can occur. In supply chain process risk mitigation, supply performance measurement can be done by mapping the process based on the Supply Chain Operations Reference (SCOR). SCOR is a supply chain operations reference model that divides supply chain processes into 5 core processes: plan, source, make, deliver and return [7].

Studies on risk management have been carried out in various industrial sectors, both small and large-scale industries with various existing approaches. Risk mitigation strategy planning was also carried out by Huseini [8] on business

processes at PT Benua Multi Guna by combining FMEA, SCOR, and HOR approaches to get the right risk mitigation design. In the SME sector, risk analysis and mitigation plans in the supply chain can also be carried out using the HOR method approach and system dynamics [1]. Risk mitigation in the nata de coco supply chain has also succeeded in identifying the priority causes of risk and producing several risk mitigation strategies to reduce the causes of risk using the SCOR and HOR model approaches [6].

Research at the center of the blacksmith metal craft processing industry was conducted to be able to identify risks, minimize the impact and control the risks that exist in the supply chain. The SCOR approach to identifying supply chain work activities is based on 5 processes (plan, source, make, deliver and return), and determines the source of risk priorities and appropriate risk handling priority strategies using the HOR (House of Risk) method. The HOR model is a modification of the FMEA (Failure Mode and Effect Analysis) model to quantify risk. The HOQ (House Of Quality) model is used to prioritize risk agents that need to be addressed first and determine the most effective mitigation actions that may be caused by risk agents [1]. Systematically, this method consists of two phases: the risk and risk cause identification phase (House of risk phase 1) and the risk handling phase (House of risk phase 2). In the HOR 1 phase, the dominant risk cause is determined by calculating the Aggregate Risk Potential (ARP) value. In the HOR 2 phase, the dominant risk-handling strategy is determined by considering the ease of implementing the strategy and the level of correlation between the strategy and the cause of the risk [7]. This research is expected to help in system improvements by appropriately handling existing risks.

1.1 Risk

The word 'risk' is used interchangeably in the literature with words such as 'danger' and 'uncertainty' and has several connotations. There is no common definition used by researchers in this field. The term risk is used to describe positive and negative outcomes (loss and damage and gain or profit), more commonly used to refer to the latter [9]. Risk leads to uncertainty over an event during a certain time interval where the event causes a loss, be it a small loss that is not so significant or a large loss that affects a company's survival. Risk is generally seen as something negative, such as loss, danger, and other consequences. These losses are a form of uncertainty that should be understood and managed effectively by the organization as part of the strategy so that it can become added value and support the achievement of organizational goals.

1.2 House of Risk

House Of Risk (HOR) analysis is a method for proactive risk management, where the identified causes of risk can be managed by providing an order based on the magnitude of the impact that may be caused. HOR analysis is divided into 2 stages, namely, HOR 1 is used to determine which causes of risk are prioritized for preventive action, and HOR 2 is used to prioritize preventive action by considering cost-effective resources.

Analyze the HOR model's most dominant cause of risk by calculating the Aggregate Risk Potential (ARP) value. The ARP calculation is used to prioritize risk agents that need to be addressed first to find mitigation actions or preventive actions against them. Where the ARP calculation formula is:

$$ARP_j = O_j \Sigma S_i R_{ij}$$

Where:

ARP_j : Aggregate Risk Potential of risk agent j

O_j : Probability value (occurrence) of risk agent j

S_i : Risk impact value (severity) of risk event I occur

R_{ij} : Correlation value between risk agent j and risk event i

After each risk agent's ARP value is obtained, the ARP value is ranked starting from the largest. This ARP ranking uses an 80:20 Pareto diagram which is taken into consideration in determining risk-handling priorities. The application of Pareto law in risk management is that 80% of company losses are caused by 20% of the main risks. By focusing on 20% of the main risks, it is expected that the company's risk impact of 80% can be resolved. The output results of HOR phase 1 will be the input for HOR phase 2 data.

2. RESEARCH METHOD

This research uses the House of Risk (HOR) methodology. This HOR method contains steps and a foundation for identifying, analyzing, evaluating risks, and designing mitigation strategies in the supply chain process of a company. This method focuses on preventive actions such as reducing the likelihood of risk agents appearing so that supply chain risk management is more proactive. The stages of this research method include:

a. Preparation stage

This preparation stage is carried out by selecting the object of research, observing the company's supply chain, formulating problems, and conducting literature studies that support the research process.

b. Identification and data collection stage

At this stage, data collection is carried out by mapping supply chain activities and classifying them based on the SCOR model. Then from each SCOR process, the risk events that arise are identified and the level of loss impact (severity) is determined. After the risk event and the impact level are determined, identify the risk causative agent. Risk causative agents are factors that cause the occurrence of a

risk event. Each risk causative agent is measured by the probability of occurrence value based on the frequency of occurrence that can cause losses. After the risk events and agents are identified, determine the correlation value or relationship between the two. Data related to risk events and risk causative agents are collected by brainstorming and interviews, were conducted with 6 owners of blacksmith craftsmen.

c. Data processing and risk analysis stages (HOR phase 1)

At the stage of processing risk event data and risk causative agents using Microsoft Excel. This stage aims to analyze the most dominant cause of risk and calculate the Aggregate Risk Potential (ARP) value based on the severity of the risk event and the probability value (occurrence) of the risk causative agent. This phase helps determine priority risk factors for preventive action. Table 1 is the HOR Phase 1 template [10].

Table -1: HOR phase 1

Process	Risk Event (Ei)	Risk Agent (Ai)				Severity of risk event (Si)
		A1	A2	A3	An	
Plan	E1				Rnn	S1
	E2					S2
Source	E3					S3
Make						
Deliver						
Return	En					Sn
Occurrence of agent j		O1	O2	O3	On	
Aggregate risk potential j		ARP1	ARP2	ARP3		
Priority rank of agent j		P1	P2	P3	Pn	

Information:

A1, A2, A3, …, An = Risk Agent

E1, E2, E3, … , En = Risk Event

O1, O2, O3, …, On = Occurrence value of the risk agent (Ai)

S1, S2, S3, …, Sn = Severity value of risk event (Ei)

ARP1, ARP2, …, ARPn = Aggregate Risk Priority

P1, P2, P3, …, Pn = Ranking of risk agents based on ARP values

d. Advanced data collection stage

The next stage is to collect risk mitigation actions related to the main risk causative agents that are prioritized to be addressed. This risk mitigation action data collection again uses brainstorming and interview methods. Risk mitigation actions that have been identified by company owners and employees are then determined by the level of difficulty in their implementation.

e. Risk mitigation strategy planning stage (HOR phase 2)

At this stage, what is done is to correlate the results of the HOR phase 1 risk analysis (priority risk agents) and the identified mitigation actions. This correlation relationship will be taken into consideration in determining the effectiveness level ng the probability of risk agents occurring. The output of HOR phase 1 is used as the input for this second phase. Table 2 below is the HOR Phase 2 template [10].

Table – 2: HOR phase 2

To be treated risk agent (Ai)	Preventive Action (PAk)				Aggregate Risk Priority (ARP)
	PA1	PA2	PA3	PAn	
A1	E11	E12	E13	PAn	ARP 1
A2	E12	E22			ARP 2
A3	E13				ARP 3
An				Enn	ARP n
Total Effectiveness of Action (TEk)	TE1	TE2	TE3	TEn	
Degree of Difficulty Preforming Action (Dk)	D1	D2	D3	Dn	
Effectiveness to Difficulty Ratio (ETD)	ETD 1	ETD 2	ETD 3	ETD n	
Rank	R1	R2	R3	Rn	

Information:

A1, A2, …, An = Risk agent who was elected to do the handling of

P1, P2, …, Pn = Preventive action to be performed

E11, E12,…, Enn = Correlation between preventive action and risk agent

ARP1, ARP2, …, ARPn = Aggregate Risk Priority from risk agent

TE1, TE2, …, TEn = Total effectiveness of preventive action

D1, D2, …, Dn = Degree of difficulty in the implementation of preventive action

ETD1, ETD2, …, ETDn = Total effectiveness of divide by degree difficulty

R1, R2, …, Rn = Rank of preventive action based on a sequence of grades ETD highest

3. RESULT AND DISCUSSION

3.1 Risk Identification

The identification process is carried out on all types of risks inherent in each activity that can potentially harm the company (Haryania et al., 2020). The results of data collection and risk identification are obtained in the form of risk events. Risk events are mapped based on supply chain activities with the SCOR model. The results of risk event identification are shown in table 3.

After obtaining risk events, the next process is to identify risk agents that cause risk events. The results of identifying risk agents are given a score or value of the potential level of a cause of risk events (occurrence) presented in table 4.

Table - 3: Risk event identification results

Business Processes	Activity	Code	Risk Event	Severity
Plan	Production Planning	E1	Raw material planning error	7
		E2	The unpreparedness of production facilities	4
		E3	Order from customers at the same time	7
		E4	Raw material price increases	4
		E5	A sudden change of order	6
Source	Raw material order	E6	Make sudden purchases of raw materials	6
		E7	The quantity and specifications of raw materials do not match the order details	4
	Raw material distribution	E8	Delayed raw material distribution	5
		E9	Raw material defects	4
		E10	Raw materials are not placed in a predetermined place	5
Make	Production Processes	E11	Employee indiscipline	7
		E12	Mis-hit during the iron forging process	6
		E13	Hot iron escapes from the pinch and is exposed to hands during the forging process	6
		E14	Eyes exposed to iron dust	5
		E15	Workers have shortness of breath	3
		E16	There was a collision of striking tools between workers	6

		E17	Workers exposed to splashes of iron flakes	7
		E18	Iron cutting is not according to size	4
		E19	Noise effects	5
		E20	Iron forging does not fit the desired pattern	6
		E21	Iron smoothing is not neat and sharp	5
		E22	Workers exposed to grinding tools	4
		E23	Iron overheating or melting	5
		E24	The blower is not working properly	3
		E25	Grinding tools are not working properly	4
		E26	Product manufacturing defects	6
		E27	Production stopped	5
		E28	Power outages	3
		E29	Production target not achieved	5
		E30	Wood and metal handles cannot be assembled	4
Deliver	Product checking	E31	Products are not packaged	5
		E32	Inaccurate when checking production results	5
	Product shipping	E33	Product delivery delays	5
		E34	Product damage during the shipping process	3
	Self-pickup of products	E35	Product pickup is not at the promised	6
Return	Product returns	E36	Additional cost expenditures	4
		E37	Customer complaints	5

Table – 4: Risk agent identification

Code	Risk Agent	*Occurrence*
A1	Uncertain and fluctuating demand for products	6
A2	Scarcity of raw materials	5
A3	There is no application of methods in purchasing raw materials	6
A4	Maintenance of production equipment is not carried out regularly	3
A5	Limited human resources	7
A6	Lack of supplier partners	3
A7	Communication with suppliers is less intensive	4
A8	The supplier location is far away	5
A9	Suppliers experience obstacles when distributing raw materials	4
A10	Poor quality of raw materials	4
A11	Bad weather	4
A12	There is no written SOP	7
A13	Lack of worker awareness of OHS	7
A14	Worker fatigue	6
A15	Human error during the production process	6
A16	Delays in the production process	4
A17	Quality control of products is lacking	4
A18	Less intensive communication with retail/customers	5
A19	Limited transportation equipment	4
A20	Product damage during product delivery	3
A21	Finished products are not to the customer's liking	4
A22	Replacement of defective products	3

3.2 Risk Causative Agent Prioritization

Determination of priority risk causative agents using the HOR phase 1 model. At this stage, the identification of risks and risk agents is carried out, providing risk values based on severity, occurrence, and correlation, as well as calculating the Aggregate Risk Potential (ARP) value. The dominant risk is determined based on the highest ARP value to the risk with the lowest ARP value. From the data obtained from the identification of risk events and risk causative agents, it is analyzed to obtain the priority of risk causative agents that need to be addressed based on the ARP value.

Based on the results obtained from the calculation of the Aggregate Risk Potential (ARP) of each risk agent, the next step is to evaluate the risk using a Pareto diagram. Pareto diagrams are used to help find problems that are prioritized to be resolved immediately. Figure 1 shows a Pareto diagram of the risk agent assessment:

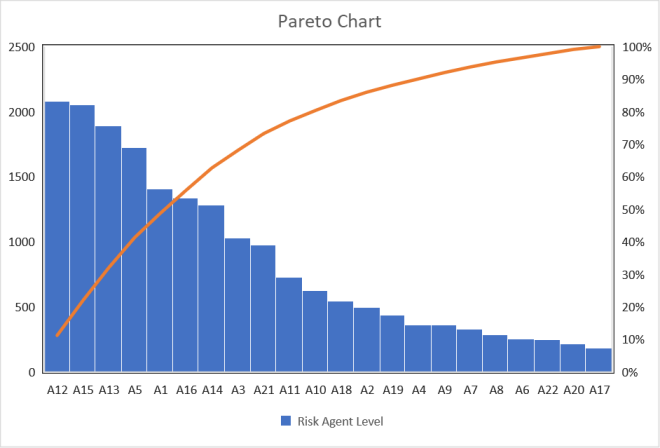

Fig -1: Pareto Diagram HOR phase 1

Based on the analysis, four dominant risk agents have the greatest risk impact on this metalworking business. The four risk agents in table 5 are priority risk agents that need to be addressed in the supply chain process.

3.3 Planning Risk Mitigation Strategy

The priority of the risk causative agents obtained needs to be addressed and then the identification of preventive or mitigation measures is carried out so that the potential for risk events can be reduced. The design of risk mitigation is determined based on the willingness of the iron craftsmen to apply and determine appropriate risk mitigation strategies as shown in table 6.

Table – 5: Priority of risk causative agents based on ARP

Code	Risk Agent	ARP	Percentage	Cumulative	Severity	Occurrence
A12	No written SOPs	2079	11.06%	11.06%	7	7
A15	Human error during production	2052	10.92%	21.99%	7	6
A13	Lack of workers' awareness of OHS	1890	10.06%	32.04%	8	7
A5	Human resources limitations	1722	9.16%	41.21%	8	7

Table – 6: Risk mitigation strategy plan

Code	Risk Mitigation	Difficulty Scale
PA1	Make SOP (written)	3
PA2	Cultivating work SOPs	3
PA3	Tighten supervision of production process activities	3
PA4	Carry out regular evaluations	3
PA5	Provide OHS training to workers	4
PA6	Provide a first aid kit at the workplace	3
PA7	Conduct outreach to village communities regarding blacksmith prospects	5
PA8	Implementing a reward and punishment system for employees	5

A risk mitigation strategy is one of the activities to manage and monitor risks, make measurements of risk mitigation strategies, reduce the impact of risks, and reduce the possibility of a risk occurring. Based on the risk agent obtained, a risk mitigation strategy is then determined based on a literature review, and discussions with several experts. To find out the validity of implementing this strategy, brainstorming was carried out with research subjects to determine their ability to apply risk mitigation strategies that include HR readiness and implementation costs.

The blacksmith metal processing industry center, which is the object of research, has caused risk agents, limited human resources, absence of clearly written SOPs, the lack of workers' concern for OHS and human error during the production process. To eliminate the causes of these risks, risk mitigation is made as shown in table 7. Furthermore, the risk mitigation strategy can be made to schedule improvements from the risk mitigation strategy plan with the aim that this risk mitigation strategy plan can be implemented and carried out by the risk mitigation plan. Prioritas rencana mitigasi risiko dapat dilihat pada tabel 8.

Table – 7: HOR phase 2

		Preventive Action								
Code	**Risk Agent**	**PA1**	**PA2**	**PA3**	**PA4**	**PA5**	**PA6**	**PA7**	**PA8**	**ARP**
A12	**No written SOPs**	9	1		3					2079
A15	**Human error during production**	9	9	9	9	3			3	2052
A13	**Lack of workers' awareness of OHS**	9	9	9	9	9	9		1	1890
A5	**Human resources limitations**							9	9	1722
	Total	54189	37557	35478	41715	23166	17010	15498	23544	
	Degree of Difficulty	3	3	3	3	4	3	5	5	
	Effectiveness to Difficulty	18063	12519	11826	13905	5791.5	5670	3099.6	4708.8	
	Rank of Priority	1	3	4	2	5	6	8	7	

Table – 8: Risk mitigation strategy plan priority

Code	Risk Mitigation	Effectiveness to Difficulty	Ranking
PA1	Make SOP (written)	18063	1
PA4	Cultivating work SOPs	13905	2
PA2	Tighten supervision of production process activities	12519	3
PA3	Carry out regular evaluations	11826	4
PA5	Provide OHS training to workers	5791.5	5
PA6	Provide a first aid kit at the workplace	5670	6
PA8	Implementing a reward and punishment system for employees	4708.8	7
PA7	Conduct outreach to village communities regarding blacksmith prospects	3099.6	8

4. CONCLUSIONS

The design of mitigation strategies using the House of Risk method resulted in 37 risk events and 22 risk agents with 4 priority risk-causing agents. The 4 main risk priorities that occur are no written SOPs, human error during the production process, lack of concern for workers, and limited human resources obtained through the Pareto principle that occurs in the metal craft processing industry center area.

Eight risk mitigation strategies were created based on four risk agents which were then ranked. Risk mitigation priorities include making SOPs (written), cultivating work SOPs, tightening supervision of production process activities, carrying out regular evaluations, providing OHS training to workers, providing first aid kits, conducting socialization to the village community regarding blacksmithing prospects, implementing a reward and punishment system for workers.

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