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Application of house of risk to analyze supply chain risks in MSMEs (food processing industry)

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ABSTRACT

Supply chain risk management plays a pivotal role for businesses, regardless of their size—be it large industries or Micro, Small, and Medium Enterprises (MSMEs). Even in MSMEs, supply chain risk management is crucial to mitigate potential risks stemming from various events. Consider BS, an MSME producing bread in Cilegon city, established in 2020, aspiring for market expansion. However, BS faces internal challenges such as fluctuating flour availability, recurring machine breakdowns twice a month, and consumer returns due to order discrepancies. Thus, this study aims to analyze supply chain risks to proactively prevent these recurrent events. The method employed here is the House of Risk. Through data processing, 32 risk events were identified by mapping supply chain activities based on the SCOR principle. From these events, 18 risk agents were derived, highlighting critical areas that require resolution. Employing a Pareto diagram, six priority risk agents have been identified for immediate resolution.

1. Introduction

BS Micro, Small, and Medium Enterprises (MSMEs) operates in the bread-making and trading industry, situated in Cilegon City. Established in 2020, BS specializes in producing diverse bread types, ranging from stuffed bread and white bread to bagels and more. Known for its healthy, preservative-free products, BS offers items with a relatively short shelf life. With an aspiration for market expansion, BS aims to become a supplier for Indonesian minimarkets and supermarkets.

In its production activities, BS is undoubtedly inseparable from supply chain activities. Based on the results of interviews with the owner of BS, it is known that BS has several problems, namely, it is difficult to get a consistent and quality supply of raw materials according to company standards, especially in flour raw materials. The price of bread raw materials has increased by around 10% (Flour IDR 270,000 to IDR 300,000 per 25 kg) due to the limited availability of raw materials, the COVID-19 pandemic, and others. The occurrence of breakdowns in production machines on average 1-2 times a month (January 5, 2023, March 2, 2023, and March 13, 2023) disrupt the production process. Errors in ordering the type and amount of raw materials to suppliers, so re-ordering and shipping are necessary. Customers return bread products that are not up to standard or damaged, so BS must replace the product. The problems that occur can result in the disruption of supply chain activities at BS it can cause company losses.

Supply chain management is one of the strategies that can be developed in the face of industrial competition. Supply chain management contributes significantly to efficiency, quality, and competitiveness in Indonesia's manufacturing industry. Supply chain management is the management of activities covering the entire process, from material procurement, material supply, and production processes to distributing products to customers [1]. A critical aspect of supply chain management is good coordination between all parties involved, such as suppliers, manufacturers, distributors, and customers. Accurate and timely

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information must flow smoothly throughout the supply chain activities to be effective, efficient, responsive, and integrated [2].

Supply chain management has a broad scope from suppliers to end consumers; supply chain activities must be appropriately managed to avoid a risk to the company. Risk is the possibility of a deviation from expectations that can cause losses to the company. These risks can arise from both internal and external companies [3]. Companies must identify and understand potential supply chain risks, such as supply instability, demand fluctuations, policy changes, quality problems, and operational disruptions [4]. In facing risk, companies must implement supply chain risk management to maintain smooth operations and business sustainability.

Supply chain risk management is a concept used to help companies understand, evaluate, and mitigate all possible risks to increase the probability of success and reduce the risk of failure. Supply chain risk management is vital in maintaining the supply chain system so that possible risks do not disrupt it. Supply chain risk management combines the concept of supply chain and risk management. Risk management is the process of identifying, measuring, and controlling a risk that can threaten a company's or project's assets and income that can cause damage or loss. Risk management involves identification, analysis, evaluation, and mitigation [5].

Previous research that discusses supply chain risk mitigation includes analyzing and improving risk management in the supply chain of tapioca flour products researched by Afifah [6] by determining criteria using the Supply Chain Operation Reference (SCOR) dimension and solving methods using the House of risk (HOR) approach. His research aims to determine the priority risk sources that must be mitigated and provide proposed mitigation actions to improve or reduce the company's potential risks that can result in losses. Another study on the proposed mitigation actions for cassava giving supply chain risks at IKM IKA-KE Cilegon, Banten, which was researched by Ulfah [7], often found several risks so that the fulfillment of the number of orders still needed to be achieved. The solution method uses the SCOR approach, and the solution method uses HOR.

Based on the description of the existing problems at BS, it is necessary to conduct research on supply chain risk mitigation to find out risk events and risk sources (risk agents) that have occurred or that may occur, resulting in losses for BS by using SCOR method, identifying, analyzing, and evaluating risk events and sources using HOR.

2. Material and method

HOR aims to identify potential risk events and risk sources that may arise. The result of HOR is the grouping of risk sources based on priority according to the ARP value [8]. HOR is a stage to identify risks to be addressed. The data needed are risk event, risk agent, impact (severity), likelihood (occurrence), and correlation between a risk event and cause. The HOR method is also developed through the following stages [9]:

1. Identify risk events in each business process that can cause losses. Identification of risk events can be done through supply chain activity mapping or supply chain mapping using the help of the SCOR model, which consists of the plan, source, make, delivery, and return processes.

2. Estimate the impact of several risk events if they occur. In this case, it can be carried out using the help of a severity scale value (Si) consisting of a scale value of 1 to a scale value of 10, where a scale value of 10 indicates the impact of extreme risk events.

3. Identify the cause of risk (risk agent) and assess each risk agent's likelihood (occurrence). According to Pedekawati [8], the source of risk or cause of risk is expressed by the notation Aj, which is any factor that can cause the occurrence of previously identified risk events. In this case, it is determined using an occurrence scale value of 1 to 10, where a scale value of 1 means that it rarely occurs, and a scale value of 10 means that it occurs frequently. Risk sources are placed in the top row of the table and linked to the bottom row occurrences with the notation Oj.

Table 1.
HOR phase 1

Business Process	Risk event (Ei)	*Risk agent* (Aj)						*Severity of Risk event i* (Si)
		A1	A2	A3	A4	…	An	
Plan	E1							S1
	E2							S2
Source	E3							S3
	E4							S4
Make	E5							S5
	E6							S6
Delivery	E7							S7
	…							…
Return	En							Sn
Occurrence of Agent *j (Oj)*		O1	O2	O3	O4	…	On	
Aggregate Risk Potential *j (ARPj)*		ARP1	ARP2	ARP3	ARP4	…	ARPn	
Priority Rank of Agent *j*								

Table 2.
Supply Chain Activity Mapping at BS

Process	Activity
Plan	Bread raw material requirement planning
	Scheduling bread production time
	Cost budget planning
	Bread production planning
Source	Receiving bread raw materials from suppliers
	Scheduling the delivery of bread ingredients from suppliers
	Purchasing bread raw materials
	Payment of raw materials to suppliers
	Storage of bread raw materials
Make	Preparation of bread ingredients
	Bread production process
	Bread packaging process
Deliver	Bread order data collection
	Checking bread stock
	Delivery of bread orders to customers
Return	Return of raw materials
	Return of rejected products
	Return of expired products

Table 3.
Risk event identification

Process	Activity	Risk Event	Code
Plan	Bread raw material requirement planning	Critical raw materials for bread are not available from suppliers	E1
		Additional time to reorder main bread ingredients to alternative suppliers	E2
	Scheduling bread production time	Changes in the bread production schedule	E3
	Cost budget planning	The cost budget incurred is not by the plan	E4
	Bread production planning	Error in recording the type of product ordered	E5
		The amount of bread production is not fulfilled	E6
Source	Receiving bread raw materials from suppliers	The amount of bread raw materials does not match the demand	E7
		The quality of bread raw materials is not suitable	E8
	Scheduling the delivery of bread ingredients from suppliers	Late delivery of bread raw materials	E9
	Purchasing bread raw materials	Unstable price of bread raw materials	E10
	Payment of raw materials to suppliers	Errors in writing receipts for the purchase of bread raw materials	E11
	Storage of bread raw materials	Storage of bread raw materials is difficult to find, and there is damage	E12
Make	Preparation of bread ingredients	Lack of bread raw materials	E13
		Suppliers find it challenging to fulfill the need for raw bread materials if the order is sudden.	E14
	Bread production process	Not using bread dough measurements	E15
		The weight of each bread is different	E16
		Bread dough is too fluffy	E17
		The shape of the bread is not to the standard	E18
		Bread can be too dry and too wet	E19
		Bread filling container is not secure	E20
		The oven temperature is not stable	E21
		Cleanliness of production equipment is not maintained	E22
	Bread packaging process	Cleanliness during packaging is not hygienic	E23
		Damaged bread packaging	E24
Deliver	Bread order data collection	Error in calculating bread orders	E25
	Checking bread stock	Overstock at outlet	E26
		Bread is not fit for sale	E27
	Delivery of bread orders to customers	Delay in bread delivery	E28
		Errors in the delivery of bread types and flavors	E29
Return	Return of raw materials	Bread raw materials that are not in order are returned to the supplier	E30
	Return of rejected products	Damaged bread products are returned to the company	E31
	Return of expired products	Expired bread products are returned to the company	E32

Table 4.
Risk agent identification

Risk Event Code	Risk Agent	Risk Agent Code
E1	Lack of availability of main bread ingredients from suppliers	A1
E2	Lack of availability of main bread ingredients from suppliers	A1
E3	Lack of availability of main bread ingredients from suppliers	A1
E4	The price of bread raw materials has increased	A2
E5	Human error	A3
E6	Lack of availability of primary bread raw materials from suppliers	A1
	A sudden order from a customer	A4
E7	Purchase of bread raw materials not from the leading supplier	A5
	There are obstacles from the supplier	A6
	Lack of coordination and information	A7
E8	Purchase of bread raw materials not from the leading supplier	A5
	Lack of coordination and information	A7
E9	There are constraints from the supplier	A6
E10	The price of bread raw materials has increased	A2
E11	Human error	A3
E12	Storage of bread raw materials is not where it should be	A8
	There is no SOP for storing bread raw materials	A9
E13	Lack of availability of primary bread raw materials from suppliers	A1
E14	Purchase of bread raw materials not from the leading supplier	A5
E15	There is no SOP for the bread production process	A10
E16	There is no SOP for the bread production process	A10
E17	There is no SOP for the bread production process	A10
E18	Uneven oven heat	A11
E19	Uneven oven heat	A11
	Unscheduled oven temperature checks	A12
E20	Limited production equipment in the factory	A13
E21	Lack of maintenance on the machine	A14
	Unscheduled oven temperature checks	A12
E22	Lack of team member concern for cleanliness	A15
E23	Lack of team member concern for cleanliness	A15
E24	Human error	A3
E25	Human error	A3
E26	Lack of interest in bakery products	A16
E27	Lack of interest in bakery products	A16
E28	Disruption on the way	A17
E29	Lack of coordination and information	A7
E30	Some products do not meet the quality	A18
E31	Some products do not meet the quality	A18
E32	Lack of interest in bakery products	A16

4. Identify the correlation between each risk agent and each risk event. The relationship between each risk source and each risk event is expressed by the notation Rij, which is done using a correlation scale value consisting of a scale value of 0, a scale value of 1, a scale value of 3, and a scale value of 9. A scale value of 0 indicates no correlation, a scale value of 1 indicates a low correlation, a scale value of 3 indicates a medium correlation and a scale value of 9 indicates a high correlation.

5. Calculating the ARP of each risk source. The ARP value is determined due to the probability of occurrence of the risk source and the set of causal impacts of each risk event caused by the source. The determination of the ARP value uses the following formula [10]:

$$ARPj = Oj \sum_{i} SiRij \quad (1)$$

where ARP denotes aggregate risk potential, Oj denotes occurrence risk agent, Si denotes severity risk event, Rij denotes correlation between the i-th risk event and the j-th risk agent, i is index of risk event, and j is index of cause of risk.

6. Rank the risk sources based on the ARP value and the most significant value to the lowest value (Table 1).

3. Results and discussions

3.1. Risk identification

Supply chain activity mapping is used to classify BS supply chain activities. In this research, the mapping of supply chain activities is carried out using the SCOR method, which consists of five processes, namely planning (plan), procurement (source), manufacture (make), delivery (deliver), and return (return). The SCOR model is divided into two segments. The initial section is responsible for depicting supply chain processes using diagrams and frameworks, while the second segment focuses on generating indicators to assess the performance of these processes. According to the Supply Chain Council (2013), the model is structured around six fundamental processes: plan, source, make, deliver, return, and enable [11]. The supply chain activities were mapped by direct observation, interviews, and brainstorming with BS owners. Table 2 is a mapping of supply chain activities found in BS.

Risk identification in supply chain activities is carried out using field observation methods, interviews, brainstorming, and questionnaires to the owner of BS and workers in the BS production section. Supply chain

risk identification aims to find out what risks have occurred, are occurring, and will occur at BS based on supply chain activities in BS (Table 3).

After knowing the risk events in the supply chain activities, the next step is to identify the sources of risk to find out the causes of risk events to minimize the risk events. Identifying sources of risk in the BS MSME supply chain is based on the results of field observations, interviews, and brainstorming with MSMEs (Table 4).

3.2. *Risk analysis*

After completing the risk identification stage to pinpoint risk events and sources within BS, the subsequent phase involves conducting a risk analysis. This stage encompasses assessing the severity of risk events, evaluating the likelihood (occurrence) of risk sources, determining the correlation value between risk events and sources, and calculating the House of Risk (HOR) metrics.

The assessment of the severity of risk events is carried out to determine how much impact the risk events have on the output of the production process. The risk event severity is based on the results of field observations, interviews, and brainstorming with BS parties, which are considered guidelines in each field or expert (Table 5). The use of the SCOR approach model in this study aims to determine the risk events that can occur in the company's supply chain activities [4], [12].

Table 5.
Severity

Risk event code	Severity
E1	7
E2	3
E3	2
E4	2
E5	2
E6	5
E7	4
E8	5
E9	2
E10	3
E11	3
E12	2
E13	4
E14	2
E15	3
E16	2
E17	2
E18	5
E19	3
E20	3
E21	4
E22	4
E23	4
E24	3
E25	2
E26	3
E27	3
E28	2
E29	2
E30	2
E31	2
E32	7

Based on the identification stage of risk events in the BS supply chain activities, 32 risk events were obtained that had occurred or had the possibility of occurring. Plan by managing demand and supply chain plans [13], [14]. The planning process in this study consists of 4 supply chain activities: planning bread raw material requirements, scheduling bread production time, budget planning, and bread production planning. In the activity of planning bread raw material needs, there are two risk events, namely, the primary bread raw material is not available at the supplier (E1) with a severity value of 7 and the addition of time to reorder the primary bread raw material to alternative suppliers (E2) with a severity value of 3.

There is one risk event in scheduling bread production time, namely changes in the bread production schedule (E3) with a severity value of 2. In the cost budget planning activity, there is one risk event, namely, the cost budget issued is not by the planning (E4) with a severity value of 2. In the bread production planning activity, there are two risk events, namely errors in recording the products ordered (E5) with a severity value of 2 and the amount of bread production not fulfilled (E6) with a severity value of 5.

The source is raw material inventory management, acceptance, supplier selection, procurement strategy, and performance management [13]. The source process in this study consists of 5 supply chain activities:

- receiving bread raw materials from suppliers
- scheduling the delivery of bread raw materials from suppliers
- purchasing bread raw materials
- paying for bread raw materials to suppliers
- storing bread raw materials

In the process of receiving bread raw materials from suppliers, two risk events occur. Firstly, there's the issue of the amount of bread raw materials not aligning with the order (E7) rated at a severity value of 4. Secondly, the quality of the received bread raw materials might not meet the required standards (E8) with a severity value of 5. Scheduling the delivery of these materials from suppliers introduces the risk of delayed deliveries (E9) rated at a severity value of 2. Purchasing bread raw materials carries the risk of price fluctuations (E10) with a severity value of 3. Moreover, the payment process involves the risk of errors in receipt documentation for purchased bread raw materials (E11) rated at a severity value of 3. Lastly, storing bread raw materials presents the risk of difficulty in locating them and potential damage (E12) with a severity value of 2.

Manage orders or production schedules, production activities, and engineering or customization [15], [13]. The making process in this study consists of 3 supply chain activities: the preparation of bread raw materials, the bread production process, and the bread packing process. In the bread raw material preparation activity, there are two risk events: the lack of bread raw materials (E13) with a severity value of 4 and suppliers having challenges meeting the needs of bread raw materials if a sudden order (E14) with a severity value of 2.

Table 6.
Occurance

Risk agent code	Occurrence
A1	7
A2	3
A3	2
A4	3
A5	2
A6	2
A7	3
A8	4
A9	3
A10	3
A11	2
A12	1
A13	2
A14	2
A15	5
A16	1
A17	2
A18	1

Table 7.
Risk event and risk agent correlation

Risk Event Code	Risk Agent Code	Correlation
E1	A1	9
E2	A1	3
E3	A1	3
E4	A2	9
E5	A3	9
E6	A1	3
	A4	1
E7	A5	3
	A6	1
	A7	3
E8	A5	3
	A7	3
E9	A6	3
E10	A2	9
E11	A3	9
E12	A8	3
	A9	3
E13	A1	9
E14	A5	3
E15	A10	3
E16	A10	3
E17	A10	3
E18	A11	3
E19	A11	9
	A12	3
E20	A13	3
E21	A14	9
	A12	3
E22	A15	9
E23	A15	9
E24	A3	3
E25	A3	9
E26	A16	1
E27	A16	1
E28	A17	1
E29	A7	3
E30	A18	9
E31	A18	3
E32	A16	1

In the production process activity, there are eight risk events, namely not using the bread dough measure (E15) with a severity value of 3, the weight of each bread is different (E16) with a severity value of 2, the bread dough is too fluffy (E17) with a severity value of 2, the shape of the bread is not by the standard (E18) with a severity value of 5, bread can be too dry and too wet (E19) with a severity value of 3, the bread filling container is not safe (E20) with a severity value of 3, the temperature in the oven is not stable (E21) with a severity value of 4 and the cleanliness of production equipment is not maintained (E22) with a severity value of 4. In the bread packing process activity, there are two risk events, namely lack of hygiene during packaging (E23) with a severity value of 4 and damaged bread packaging (E24) with a severity value of 3.

Delivery involves managing finished goods inventory, requesting product and order information, product distribution, and final installation at consumer locations [13]. The delivery process in this study involves three supply chain activities: data collection of bread orders, checking bread stock, and shipping bread orders to customers. In the process of collecting bread orders, there is one risk event: errors in calculating bread orders (E25) with a severity value of 2. In the process of checking bread stock, there are two risk events: overstock at the outlet (E26) with a severity value of 3 and bread that is not suitable for sale (E27) with a severity value of 3. In the process of delivering bread orders to customers, there are two risk events: delays in delivering bread (E28) with a severity value of 2 and errors in delivering bread types and flavors (E29) with a severity value of 2. Return is the management of all activities related to returning to the supplier or receiving returns from the supplier [13], [16]. The return process in this study comprises three supply chain activities: returning bread raw materials, returning rejected products, and returning expired products.

In the case of returning bread raw materials, there's a single risk event: bread raw materials that don't match the order being returned to the supplier (E30) with a severity value of 2. In the returning of rejected products, another risk event exists: damaged bread products being returned to the company (E31) with a severity value of 2. Regarding returning expired products, there's a risk event involving expired bread products being returned to the company (E32) with a severity value of 2. Assessment of the likelihood of occurrence of risk sources (occurrence) is carried out to identify the frequency of occurrence or probability of occurrence of each risk source [17]. The assessment of the likelihood of occurrence of risk sources (occurrence) based on the results of field observations, interviews, and brainstorming with BS parties, considered guidelines in each field or expert, are as follows (Table 6). Determining the correlation or relationship between risk events and sources is used to determine the correlation value between each risk event and the source that causes the risk to occur in the BS supply chain activities.

The results of the correlation assessment or relationship between risk events and risk sources based on field observations, interviews, and brainstorming with BS parties, considered guidelines in each field or expert, are as follows (Table 7). The scale used in determining the correlation in this study is a scale of 0, 1, 3, and 9.

Table 8.
Priority order of risk agent

Risk Agent Code	ARPj	%ARP	%CUM	Rank	Category
A1	903	43.5%	43.5%	1	Risk agent Priority
A15	360	17.3%	60.8%	2	
A3	144	6.9%	67.7%	3	
A2	135	6.5%	74.2%	4	
A7	99	4.8%	79.0%	5	
A11	84	4.0%	83.0%	6	
A14	72	3.5%	86.5%	7	
A5	66	3.2%	89.7%	8	
A10	63	3.0%	92.7%	9	
A18	24	1.2%	93.8%	10	
A8	24	1.2%	95.0%	11	
A12	21	1.0%	96.0%	12	
A6	20	1.0%	97.0%	13	Risk agent Non-Priority
A13	18	0.9%	97.8%	14	
A9	18	0.9%	98.7%	15	
A4	15	0.7%	99.4%	16	
A16	8	0.4%	99.8%	17	
A17	4	0.2%	100.0%	18	
A14	72	3.5%	86.5%	7	
A5	66	3.2%	89.7%	8	

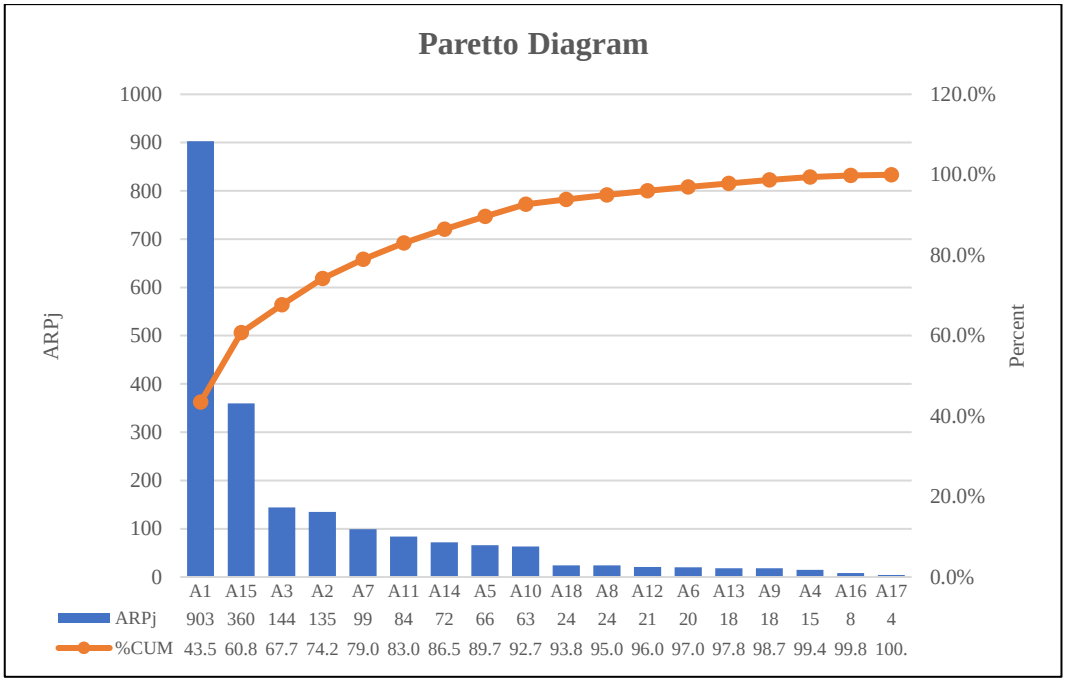

Figure 1. Pareto diagram

Scale 0 explains that there is no correlation, scale 1 explains that the source of risk plays a low role in generating risk, and scale 3 explains that the source of risk plays a moderate role in generating risk. Scale 9 explains that the source of risk plays a significant role in generating risk [18], [19].

After calculating HOR and obtaining the ARP value, the next step is to evaluate the risk [20]. The formula of ARP is provided by equatioan (1). This stage is carried out to determine the risk sources that will be prioritized for mitigation or prevention by ranking or sorting based on the ARP value from highest to lowest, which can be seen in the following table (Table 8). To perform risk mitigation on prioritized risk agents, we use a tool in the form of a Pareto diagram (Figure 1).

Priority risk sources in BS supply chain activities consist of 6 risk sources: the lack of availability of the primary bread raw material from suppliers (A1) with an ARP value of 903 and a cumulative 43.5%. The lack of availability of the primary bread raw material from suppliers is due to supply disruptions, increased demand, and dependence on one supplier, causing the bread production process to be hampered and unable to meet consumer demand. Lack of team member concern for cleanliness (A15) with an ARP value of 360 and a cumulative 60.8%.

Lack of team member concern for cleanliness is due to workers' lack of supervision and adequate cleaning tools, which can lead to trust and loyalty to the business and an increased risk of spreading disease and infection. Human error (A3) with an ARP value of 144 and a cumulative 67.7%. Human error is due to the workers' need for more focus on the work, which can disrupt the production process and cause losses. The price of bread raw materials has increased (A2) with an ARP value of 135 and a cumulative 74.2%.

The price of bread raw materials has increased due to the large number of requests and other factors, such as government regulations and others, which can lead to reduced profits for the company.

Lack of coordination and information (A7) with an ARP value of 99 and a cumulative 79.0%.Lack of coordination and information is due to the absence of definite cooperation, causing difficulties in understanding tasks and making it difficult to make the right decisions. Uneven oven heat (A11) with an ARP value of 84 and a cumulative 83.0%. Uneven oven heat is due to the lack of maintenance and the absence of scheduled maintenance, so that it can result in products produced not according to standards. Risk sources included in the 80% highest cumulative ARP value are prioritized to be resolved first because they have the most significant influence on the company and need to overcome them by taking preventive steps to minimize or eliminate these risk sources [21].

4. Conclusions

Based on the description above, it can be concluded that there are 32 risk events and 18 risk agents from supply chain problems in BS MSMEs. From the ARP calculation, which has been prioritized using a Pareto diagram, the following priority risk agents are obtained: Lack of availability of main bread ingredients from suppliers, Lack of team member concern for cleanliness, Human error, The price of bread raw materials has increased, Lack of coordination and information, and uneven oven heat. Furthermore, of the six priorities, risk mitigation should be carried out to obtain preventive actions against these risks.

Declaration statement

Nuraida Wahyuni: **Conceptualization, Methodology, Supervision, Project administration**. Maulana Malik Ibrahim: **Data curation, Validation**. Dyah Lintang Trenggonowati: **Resources, Validation, Formal analysis**. Shanti Kirana Anggraeni: **Resources, Visualization, Investigation**. Evi Febianti: **Data curation, Validation**. Ratna Ekawati: **Writing - Review & Editing**.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [NW], upon reasonable request.

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