Supply Chain Risk Assessment at Poultry Slaughterhouses using House of Risk Method to Define Mitigation Action

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Abstract

A poultry slaughterhouse has a strategic role in the broiler supply chain because they determine the quality of carcass products sent to the processing industry and consumers. Slaughterhouses also act as a buffer when there is an over-supply of live birds due to the uncertainty of the production sector and the consumer market by functioning as cool storage. The series of activities to transform harvesting live birds became fresh and frozen carcasses have various risks that lead to product quality degradation and financial loss. This study aims to identify and assess the risk events and risk agents along the supply chain and then provide mitigation actions against potential risk causes to minimize the impact of losses and the frequency of risk occurring. The House of Risk (HoR) method is used because it can help identify and assess risks in each activity according to the stages of the business process. The HoR method itself combines Quality Function Deployment (QFD) with FMEA (Failure Mode Effect Analysis). This study tries to use HoR with a sequence of activities arranged according to the SCOR (Supply Chain Operation Reference) stage. HoR stage I found 26 risk events, 52 risk agents, and 12 of them are potential risk agents. The 3 highest risk agents are product mishandling, insufficient manpower, and engine breakdown. HoR phase II proposes 28 risk mitigation actions and obtained 8 selected mitigation actions that consider the difficulty level of implementation, and the company's ability both in terms of costs and human resources. The recommendations given are implementing reward and punishment, training and briefings for workers, and carrying out periodic maintenance for machines.

Keywords
Poultry supply chain, slaughterhouse, house of risk, risk assessment

1. Introduction

The poultry industry is an agribusiness industry that has a complete supply chain component from upstream to downstream. In the upstream segment, large companies have developed and controlled industries ranging from seeds, poultry feed, drugs, and vaccines, which in their role act as a driving force for input suppliers. In the downstream segment, the food industry has developed which processes livestock products into processed products and trades processed products in the domestic and international markets.

The process in each supply chain creates added value that is beneficial for each party in the production and distribution of products from breeders to final consumers (Purwaningsih et al. 2019). One chain in the supply chain of a broiler business is the processing industry that produces various processed products (Purwaningsih et al. 2016). The product quality of the processing industry is determined by the quality of the raw material in the form of the chicken carcass which is obtained from a slaughterhouse which has an important role in creating value-added products. slaughterhouse produces two types of product forms, fresh products (make to order) and frozen products (make to stock). Products processed are distributed to various business sectors such as hotels, restaurants, catering, and supermarkets in Semarang and its surroundings.

The role of a slaughterhouse in the supply chain for broilers is important considering that this product has high supply fluctuations due to the lack of coordination between large national integrator companies in planning the population size to be cultivated. This often results in oversupply and a fall in selling prices at the farmer level. One of the ways to overcome this adverse condition is the storage of frozen products. Price fluctuations due to the imbalance between

supply and demand were the most severe in 2016, the result of the import limitation policy for grand-parent stock or GPS.

The risks that occur in agribusiness can arise from several aspects, including social, political, economic, technological, and environmental aspects (Leat and Giha 2013). Measuring business risk can provide information on the probability of a loss and an estimate of the amount of loss that will occur (severity). To solve problems related to possible risks that occur along the supply chain, it is necessary to control and manage risks. The House of Risk (HoR) method is the right method in dealing with risk problems in the supply chain for broiler chickens because this method can determine the priority causes of risk and determine mitigation action strategies to reduce the impact of risks to increase the resilience of the supply chain.

The research was conducted at Chicken Slaughterhouses managed by a national integrated company located in Pabelan Salatiga. The slaughterhouses is capable of performing 44,530 live chicken slaughters in one day in the form of whole chicken, parting, and boneless. This research aims to (1) analyze the potential causes of risk, (2) determine the probability of a risk event, and (3) determine how to mitigate the risk. The difference with the usual HoR is HoR in this research identifies risk events (risk events) and risk causes (risk agents) using the work dimension of the Supply Chain Operations Reference (SCOR) which consists of a plan, source, make, deliver, return.

The supply chain risk management of livestock agribusiness is different from the supply chain for the manufacturing industry because the product is perishable, the production level is uncertain due to the weather and season, and the product vary in size and shape. Risks such as uncertainty of supplier fill rate (SFR) directly affect supply chain performance (Harbi et al. 2018). This uncertainty requires better supplier integration and coordination. Risk can also cames from the process of handling, store, and distribution from live birds to carcasses caused by non-standard practices which result in product damage. It is necessary to mitigate risks to improve product quality and reduce post-harvest losses, both in the form of weight loss and quality degradation.

2. Literature Review

2.1 SCRM for Agroindustries

In recent years, the industry has experienced incidents of violence, health crises, and natural disasters which gives a huge impact on the economy. This condition triggers the development of risk management as an important topic in the world of logistics chains, related to uncertainty in the supply chain industry (Tang and Musa 2011). Risk is defined as events that have an unfavorable, difficult to accept, or even unacceptable impact. Currently, risk assessment is an important research theme because risk has always been present as an important issue for industry (Wu and Olson 2008).

The interaction between all interrelated risks in the logistics chain is known as the concept of Supply Chain Risk Management (SCRM), define as the identification and management of supply chain risks, through coordination between members of the supply chain, to reduce the vulnerability of the supply chain as a whole (Juttner 2005). Supply chain risk management is also defined as the process of risk mitigation through collaboration, coordination, and implementation of risk management tools among partners, to ensure the long-term benefits of supply chain actors. Research on risk management in the field of agribusiness according to the type of risk can be classified into biological risks, market risks, and occupational safety risks. Risk classification and risk assessment methods are described in Figure 1.

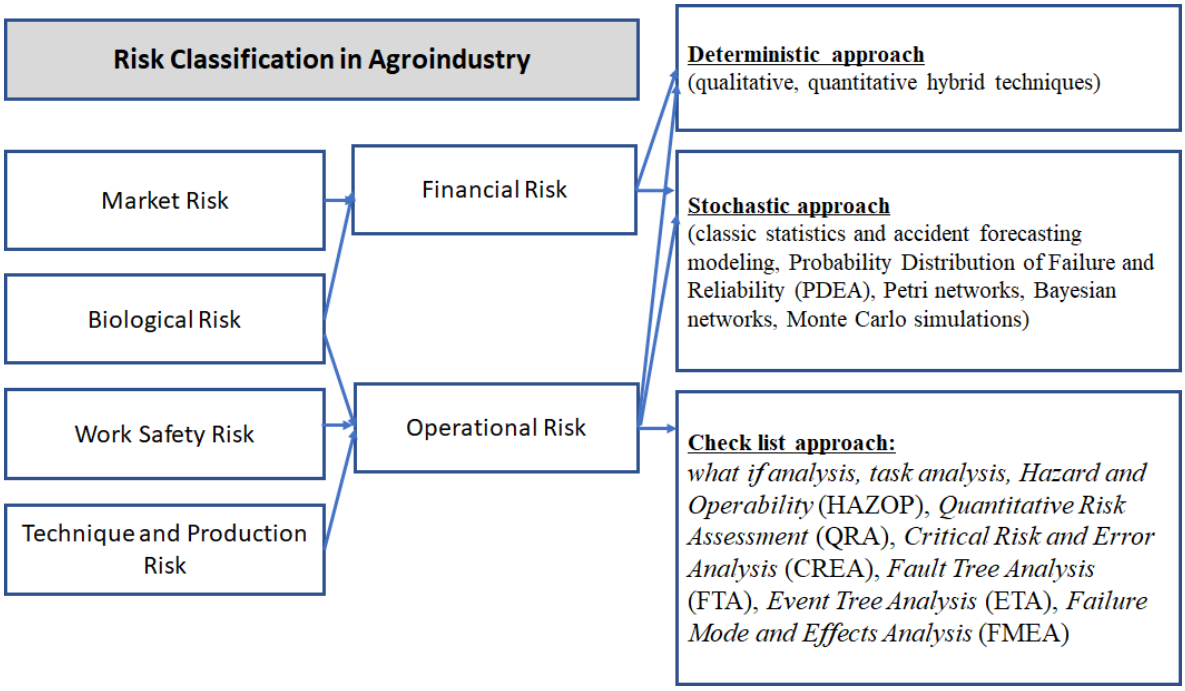

Figure 1. Risk classification and risk management methods in Agroindustry

The dependency on natural factors is quite high in agroindustries, this factor creates uncertainty in agricultural, livestock, and fishery products. Biological risks are widely studied in the field of animal science, while business risks include market risks and financial risks studies in the school of business. Other risks are production risk and safety risk, which currently can be assessed on a micro-level. Several studies in risk management using the methods mentioned in Figure 1 are presented in Table 1.

Table 1. Risk management studies

Method	Author, Publication Year
QRA	(Si et al. 2012); (Ma et al. 2013)
Fuzzy Analytical Hierarchy Process (FAHP)	(Sofyalioglu and Kartal 2012); (Lavastre et al. 2012)
Petri Network	(Zegordi and Davarzani 2012); (Aloin et al. 2012)
Bayesian network	(Zhao et al. 2012)
Probability-impact matrix	(Thun and Hoenig 2011)
HoR	(Pujawan and Geraldin 2009); (Purwaningsih and Hermawan 2019)

Methods in risk management can be classified into three categories, a deterministic approach, a stochastic approach, and several methods that used checkpoint (Ennouri, 2013). According to ISO 31000: 2009, risk management is a coordinated set of activities and methods used by an organization to control various risks that can affect its ability to achieve goals (Lark 2015). House of Risk is an integrated method between the Failure Model and Effect Analysis (FMEA) and the House of Quality (HOQ) methods (Pujawan and Geraldin 2009). The use of HoR first was in the fertilizer process industry sector (Pujawan and Geraldin 2009), procurement of material for the pulp industry (Purwaningsih, et al. 2021), and in the supply chain for the presto milkfish industry (Purwaningsih and Hermawan 2019).

2.2 Indonesian's Poultry Supply Chain

The broiler chicken farm in Indonesia, 85% are run by an integrated company, a company consisting of feed, livestock, slaughter, and the production of frozen food and ready-to-eat food in one holding company, this facilitates coordination in the supply chain (Domestic Affairs Trade Research Center 2016). The supply chain in the livestock business in Indonesia is quite complex, start from feed factories as feed suppliers, breeding farms as suppliers of doc (days old chick) or chicken seeds, farm equipment providers, cultivators or breeders, slaughterhouse, equipment suppliers for cold chain, transportation service industries, to the food business as the end of the supply chain (Purwaningsih et al. 2017). The poultry agribusiness system is a series of activities that unite natural resources, human resources, financial resources, and technological resources to process poultry through a biological and industrial process to become a product that can meet human needs and desires.

The farming agribusiness system is mapped into five subsystems accompanied by several groups of supply chains that are interconnected. An upstream agribusiness sub-system is a group that handles the provision and procurement of production facilities (chicken seeds, feed, drugs, and vaccines, as well as livestock tools). A cultivation subsystem is a group of breeders who produce live chicken livestock ready for sale. The processing subsystem and the marketing subsystem are groups that play a role in the processing of chicken meat and marketing it to consumers. This subsystem has an important role in shaping the price of chicken at the consumer level. Supporting Services Subsystem is a group of chicken agribusiness support services that consists of several functions such as regulatory, research (Agricultural and Higher Education Research and Development) functions, extension functions, information functions, business capital procurement functions, market functions, and others.

3. Methods

The risk management process is carried out in four steps, risk identification, risk assessment, risk management, and risk monitoring (Tuncel and Alpan 2010, Giannakis and Louis 2011). House of risk (HOR), which is a supply chain risk management model that combines the concepts of House of Quality and Failure modes and effects analysis (FMEA) to formulate a framework for managing Supply Chain risk. The advantage of FMEA is that it can evaluate reliability by examining the failure mode with a systematic technique. The Supply Chain Operational Reference (SCOR) model is used to facilitate interaction between parties, from suppliers to final consumers.

The sequence of steps to carry out data processing includes three stages, (1) identification of risk events, (2) HoR phase 1, and (3) HoR phase 2. Identification and assessment of risk events are carried out using the FMEA method to find the value of the severity and frequency of occurrence. House of Risk Phase 1 (HOR 1) aims to find the relationship between risk agents and risk events and prioritize risk agents based on their ARP values. Priority risk agents will be input to phase 2 of the HoR, where this stage is carried out to find priority preventive actions. After that, analysis and discussion were carried out on each risk agent and priority preventive action (Ratnasari et al. 2018). The stages or methods of research are given in Figure 2.

3.1 Risk-Event Identification

FMEA is used to calculate the level of risk obtained from calculating the Risk Potential Number (RPN) based on three factors, the probability of occurrence, the severity of impact (severity), and probability of risk discovery (detection) with a separate rating scale. Risk identification includes literature studies and field observations to study the supply chain from live birds to consumers. Data collection was carried out by observing, interviewing, and filling out questionnaires with 7 people who were directly related to the supply chain process at the slaughterhouse from the department of the production, QC, warehouse, and purchasing (handled the purchase of live birds). The questionnaire contains risk events, risk causes, and proposed mitigation actions that are assessed based on a given scale. Risk events and risk agents along the supply chain are grouped based on SCOR activities and validated by the production department.

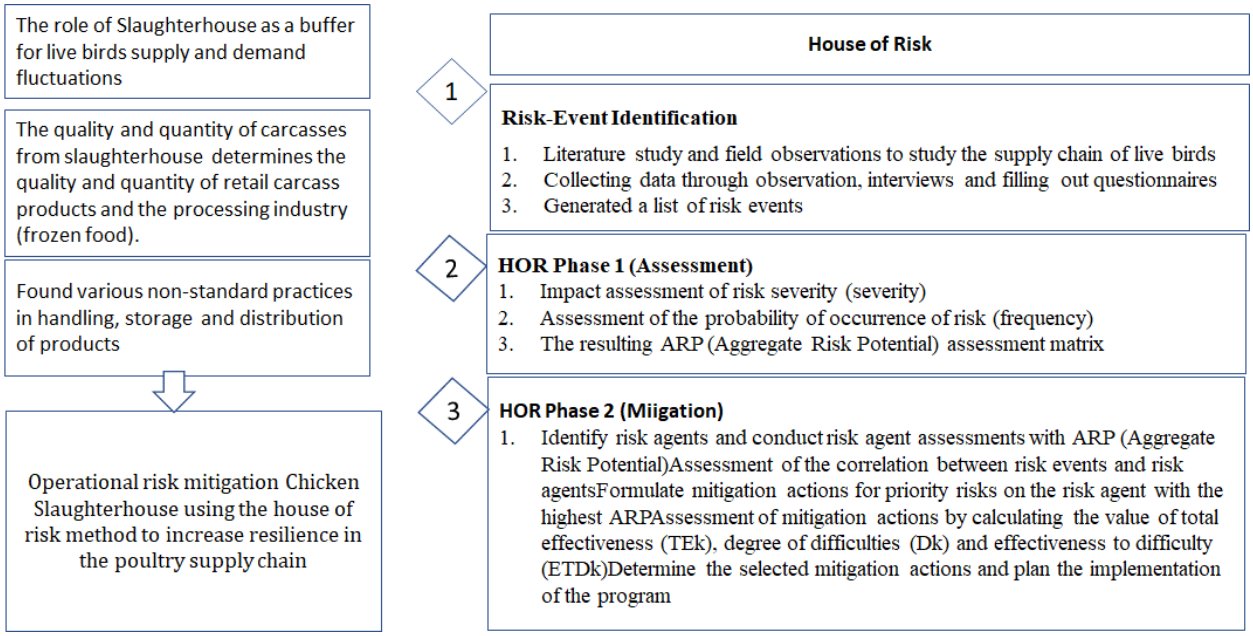

Figure 2. Research methodology

3.2 HOR Phase 1 (Phase of Risk Assessment)

Stage I of HoR is an assessment of the severity of risk events using a scale of 1 to 3, the level of frequency of risk causes using a scale of 1 to 5, and the correlation between risk events and risk causes using the scale of the research of Pujawan and Geraldin (2009). From the assessment conducted, the ARP is generated where the higher the ARP value the more dangerous the risk. Risk events with high severity and high probability of occurring should receive more attention than other risk events (Zsidisin and Ritchie 2008, Waters 2007). Phase 1 HOR connects the risk event with its cause or is called a risk agent. In risk management, this relationship is described in the relationship matrix as shown in Table 2. The degree of correlation level is specifically classified into four levels, there is no relationship with giving values (0), low (1), medium (3), and high (9). The Aggregate Risk Potential (ARP) value is then sorted from the largest to the smallest value.

Table 2. House of risk phase 1

					Risk Agent (Aj)						
Risk Event (Ei)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	*Severity*
E1	R11	R12	R13								S1
E2	R21	R22									S2
E3	R31										S3
E4											S4
E5											S5
E6											S6
E7											S7
Occurrence (O)	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	
Aggregate Risk Priority	ARP1	ARP2	ARP3	ARP4	ARP5	ARP6	ARP7	ARP8	ARP9	ARP10	
Priority Rank of Agent j											

3.3 HOR Phase 2 (Phase of Mitigation)

HOR phase 2 aims to determine mitigation actions, calculate the level of correlation between risk agents with mitigation actions or risk management strategies, calculate the difficulty level of implementing the proposed risk mitigation action, and then further processed to calculate the total effectiveness (TEk), degree of difficulties (Dk) and effectiveness to difficulty (ETDk), which are then sorted from largest to smallest and presented with a Pareto diagram that reaches 50% to be a priority mitigation action. The matrix for phase 2 HoR is shown in Table 3.

Table 3. House of risk phase 2

To be Treated Risk Agent (Ai)	*Preventive Action (PA_k)*					*Aggregate Risk Potensials*
	PA_1	PA_2	PA_3	PA_4	PA_5	(ARP_k)
A_1	E_{11}					ARP_1
A_2						ARP_2
A_3						ARP_3
A_4						ARP_4
Total effectiveness of action k	TE_1	TE_2	TE_3	TE_4	TE_5	
Degree of difficulty performing action k	D_1	D_2		D_4	D_5	
Effectiveness to difficulty ratio	ETD_1	ETD_2	ETD_3	ETD_4	ETD_5	
Rank of priority	R_1	R_2	R_3	R_4	R_5	

4. Results and Discussion

4.1 Processing of Live Birds into Frozen Carcasses

The sequence of processes for converting live birds from the harvest location to frozen carcasses in a slaughterhouse is given in Figure 3. The live bird broilers will be removed from the crates in the truck and hung on the shackles, incomplete hanging processes can cause bruising. The process of removing feathers (defeathering) using a plucker machine can erode the body parts, especially the wings. The carcass that passes through the process of the chiller drum must be at a maximum temperature of 4 ° C and if its temperature still exceeds the limit, it will be cooled back in the cooling bath covered with ice or returned to the chiller drum before going to the cutting process. After cutting, the product will be frozen in the blast freezer and stored in cool storage in sacks and stacked. Careless loading can damage the product packaging and damage the carcass. Taking products from cool storage used sequence first in first out (FIFO) and first expired first out (FEFO).

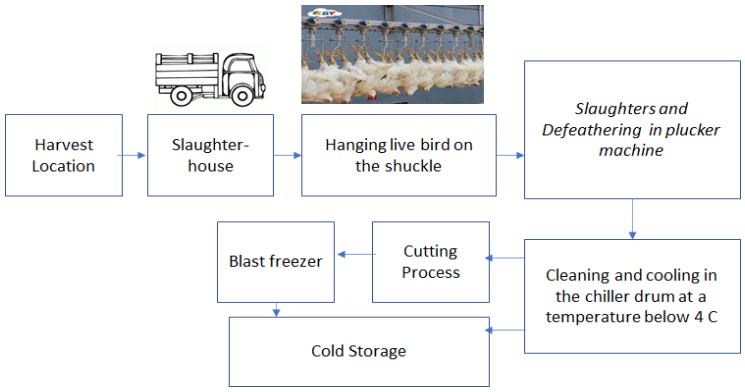

Figure 3. Processing of live birds into frozen carcass

4.2 Risk Event Identification

After mapping the activities and conducting interviews, a list of risks that occur throughout the process is obtained, the results are summarized in Table 4.

Table 4. Risk events in a series of supply chain activities

SCOR		Risk Event	Code
Plan	1	Improper broiler demand planning	E1
	2	Production capacity is not according to planning	E2
	3	Sudden change in production planning	E3
	4	The difference between the available stock and the recorded data	E4
	5	Many carcass and cut-up products are stored for a long time in cool storage	E5
Source	6	Losses in weight of broiler chickens	E6
	7	There is a defect (defect) in broiler chickens	E7
	8	Broiler price fluctuations	E8
	9	Claims with broiler suppliers that are constrained	E9
	10	Moving cages	E10
	11	Claims with choked broiler expeditions	E11
Make	12	Production schedule delays	E12
	13	Production results that do not match the desired standards	E13
	14	The build up in the work process	E14
	15	There was a mechanical failure in the production machine	E15
	16	The broiler shuts down through the shock process	E16
	17	An imperfect slaughter process	E17
	18	Chicken tumbles from the plucker	E18
	19	Accidents at work	E19
	20	Broken/leaking packaging	E20
	21	Repackaging	E21
Delivery	22	Delays in delivery	E22
	23	Product damage	E23
	24	The number of products sent did not meet the number of requests	E24
	25	The product was sent to the wrong destination or an interchangeable destination	E25
Return	26	Product returns by customers	E26

4.3 HoR Phase 1

This study resulted in 52 ARPs which were then sorted in value from largest to smallest and from this process 12 potential risk agents were obtained with the cumulative percentage in the Pareto diagram reaching 50%. These potential risk agents are shown in Table 5.

Table 5. Recapitulation of the cumulative percentage of ARP for potential risk agents

Code	Risk Agent	ARP	% Cumulative ARP	Rank
A19	Worker mishandling of products	154,3	6,7%	1
A4	The limitation number of workers (manpower)	125,7	12,1%	2
A25	Breakdown of the production machine	117,0	17,2%	3
A1	Fluctuation of demand for carcass products and cut-ups	116,8	22,3%	4
A17	The far distance from the farm to the slaughterhouse	110,9	27,1%	5
A48	Disruption of the flow, the server, and information systems	109,1	31,8%	6
A26	Un-optimum performance and discipline of workers	97,9	36,1%	7
A21	Demand factors at certain times (fasting, Eid)	89,9	40,0%	8
A3	Not available the desired body weight broiler	69,2	43,0%	9
A18	Transported unhealthy chickens	63,8	45,7%	10
A20	Natural condition factors	63,0	48,5%	11
A16	Increased mortality rate	61,0	51,1%	12

4.4 HoR Phase 2

A potential risk agent is a risk cause that is prioritized for mitigation action in phase II HoR. The mitigation actions provided can be in the form of planning, strategy, action, and evaluation. 28 risk mitigation actions were obtained from discussions with stakeholders. Assessment of risk mitigation actions includes the difficulty level of implementing mitigation actions (Dk) using a scale of 3, 4, and 5 (Kristanto and Hariastuti 2014), continued by an assessment of the correlation between risk mitigation actions and potential risk agents. Furthermore, the calculation of the total effectiveness (TEk) for each risk mitigation action, the value of TEk cannot describe how precisely mitigation actions can handle risks, the precise mitigation was done by calculation of effectiveness to difficulty (ETD). The value of the ETD is ordering from largest to smallest to determine priorities for mitigation actions according to the company's ability. The results of the sorted ETD values produce 8 selected risk mitigation actions which are shown in Table 6.

Table 6. Recapitulation of the Cumulative Percentage of Selected ETD Risk Mitigation Actions

Code	Risk Mitigation Actions	ETDk	% Cumulative ETDk	Rank
P3	Provide appropriate rewards and punishments	603,97	8%	1
P8	Plan and carry out routine maintenance	569,72	16%	2
P15	To coordinate better with the suppliers	547,94	24%	3
P1	Briefing before and after doing routine activities	444,40	30%	4
P16	To coordinate more like with the expedition	442,23	36%	5
P2	Conduct regular training for workers	391,70	41%	6
P9	Total shutdown/maintenance every year	352,62	46%	7
P17	Provide a form of complaints experienced when sending broiler chickens	303,19	50%	8

The explanation of the sorted ETD values that produce 8 selected risk mitigation actions is given in Table 7. Selected recommendations must be applicable for slaughterhouse management. Recommendations should be relatively easy to implement and have an impact on reducing the severity and frequency of a risk event. These recommendations are related to the implementation of good management for workers, machines and fostering good relationships with suppliers and with goods expedition/delivery.

Table 7. Risk Mitigation

Recommendation	Linkage with risk agents
(P3)	Rewards and punishments have a relationship with product mishandling by workers and the disciplinary attitude from workers.
(P8)	Maintenance related to machinery where processing time is very influential on the quality of the carcass. Currently, maintenance is carried out when a breakdown occurs and machines are 11 years old, implementing preventive maintenance is highly recommended.
(P15)	Planning a better strategy on the procurement process and did suppliers performance assessment. Slaughterhouses should accommodate suggestions from suppliers and together produce better supply chain performance
(P1)	Briefing to delivering right information and doing brief evaluations can avoid mistakes that occurred in activities, also increased the workers motivation.
(P16)	Good coordination and discussions with the expedition to find a way to reduce risks during transportation and distribution process.
(P2)	Providing training by providing case studies that encourage problem-solving for workers.

5. Conclusion

Risk assessment of poultry slaughterhouse with House of Risk phase 1 was found 26 risk events, 52 risk agents, and 12 potential risks. Risk agents with the largest ARP are mishandling of products, production machines breakdown, and the decrease of weight and quality of live birds caused by long-distance travel. The activity which has highest risk event (probability) is the production stage, but the activity with the highest impact (severity) is transportation activity.

HoR phase 2 generate 28 mitigation actions, proposed 8 selected mitigation actions including providing appropriate rewards and punishments, planning machine maintenance routinely, better coordination with suppliers, briefing for

worker and create better coordination with the expedition, conduct regular training for workers, overall maintenance every year, provide a form of complaints that consumers experience on distribution of products.

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