

Development of Risk Evaluation and Mitigation Systems for Logistics System

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ABSTRACT

Logistic activities are significant activities that pose various risks for the company. These risks can affect the company's performance. To be able to compete in the globalization era, companies need proper risk management. This study aimed to develop Risk Evaluation and Mitigation Systems. We offered four stages: risk identification, risk analysis, risk evaluation, and risk response. A case study was conducted to implement the proposed Risk Evaluation and Mitigation Systems. The results indicated that the proposed Risk Evaluation and Mitigation Systems were proven to be appropriately applied to evaluate company risks and provide mitigation recommendations.



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1. Introduction

Globalization forces companies to focus on company activities to face competition [1] [2]. One of the most critical company activities is a logistic activity [3] [4]. Good logistics management can increase customer satisfaction because the product, quality, quantity, and location shipped are correct [5]. In logistical activities, various risks often arise, and it affects supply chain performance [6] and risks arising from the impact of an event and uncertainty [7] [8]. Risk can disrupt the flow of material, information, and cash flow, which in turn can affect sales and increase costs [9]. To compete, companies need to have proper logistical risk management [10] [11]. Therefore, mitigation activities are needed to manage risks.

Several previous studies have proposed methods for managing supply chain risk. One popular method is the House of Risk (HOR) proposed by Pujawan and Laudine [12]. Several methods for supply chain risk management include the integration of the HOR and the Fuzzy Analytical Hierarchy Process [13], the HOR, and the Analytical network process [14], DEMATEL [15], and Quality Function Deployment (QFD) [16]. Several other methods are Fuzzy AHP [17], AHP [18], Fuzzy Bayesian-based Failure Mode Effect Analysis (FMEA) [19], and fuzzy-based HOR [20]. Wijai and Phongchai [21] used the HOR



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to analyze blood supply chain risk management. Ratnasari, et al. [22] analyze supply chain risk management in a newspaper company. Immawan and Putri [23] implement HOR to assess supply chain risk. Furthermore, Asbjørnslett [24] adopts a proactive approach to dealing with newly changing risks. Wee, et al. [25] discussed mitigation strategies in logical risk management from the perspective of process flow.

Based on previous research, one of the popular methods implemented in supply chain risk management is HOR. Unfortunately, the estimated loss and the possible risk have not been considered in assessing the risk. Therefore, this study aims to develop a Risk Evaluation and Mitigation System based on the HOR method. This study provides a new contribution to the Risk Evaluation and Mitigation System in company logistics activities. This complete paper structure is presented as follows: part 2 discusses Proposed Risk Evaluation and Mitigation Systems or Method and case studies; part 3 presents results and discussion, and lastly, part 4 concludes the study.

2. Methods

2.1 Proposed Risk Evaluation and Mitigation Systems

This research constructed four stages in the proposed Risk Evaluation and Mitigation Systems, such as risk identification, risk analysis, risk evaluation, and risk response (Fig. 1). The detailed description of each stage is explained as follows:



Fig. 1. Four Stages Risk Evaluation and Mitigation Systems

Risk Identification

At the risk identification stage, this study proposes risk identification based on the company's business process. Business processes were based on five business aspects: supplier, receiving, tracking, delivery, and customer. This business process is modified from the business aspects of the supplier, input, process, output, and customer. At this stage, each business process was recorded for risks, causes of risk, and impacts. The risk assessment is presented in the risk analysis section.

Risk Analysis

At this stage, risk analysis was based on the Likelihood and Consequence values. Likelihood scores were obtained from the risk causes assessment based on five rating scales. The risk causes a likelihood scale is presented in Table 1. All risk causes at the risk identification stage were assessed for the Likelihood level of the risk causes. Consequently, this assessment was based on the value of the loss resulting from the impact of the risk. This study proposed a Consequence Assessment based on the losses resulting from the impact of the risk. All risk impacts were estimated by the amount of loss incurred.

Furthermore, the big loss was in conversion to the Consequence scale. This study suggested five Consequence Loss scales, which are presented in Table 2. The results of the Likelihood and Consequence assessment were used for the risk evaluation stage.

Table 1. Likelihood (L) Scale for risk causes

Scale	Description	Parameter
5	Almost Certain	Mismatch always occurs every week
4	Likely	No-Mismatch occurs within the last 1-2 month(s)
3	Possible	No-Mismatch occurs within the last 3-5 months
2	Unlikely	No-Mismatch occurs within the last 6-11 months
1	Rare	No-Mismatch occurs within the last one year period

Table 2. Consequence (C) Scale for risk effects

Scale	Description	Parameter
5	Catastrophic	Loss > IDR. 1,000,000,000
4	Major	Loss IDR. 500,000,000 - IDR. 1,000,000,000
3	Moderate	Loss IDR. 100,000,000 - IDR. 500,000,000
2	Minor	Loss IDR. 10,000,000 - IDR. 100,000,000
1	Insignificant	Loss < IDR. 10,000,000

Risk Evaluation

Risk evaluation is a stage to evaluate the level of risk posed. At this stage, risk evaluation was based on calculating the Risk Priority Number (RPN). The RPN scores were generated from the Likelihood (L) and Consequence (C) assessments. The RPN formula is presented in Equation (1). Furthermore, this study projected five risk level categorization scales, which are presented in Table 3. RPN measured all risks to determine the level of risk. The RPN value was formed to calculate the mitigation priority presented in the risk response stage.

$$RPN = L \times C \tag{1}$$

Risk Response

This stage described the mitigation proposals and calculated mitigation priorities. Mitigation proposals were designed based on the causes of risk. The list of mitigation proposals was used as input for the calculation of mitigation priorities. The mitigation priority calculation was modified from the House of Risk (HOR) model. The mitigation priority model can be seen in Table 4. In the mitigation priority model, the value of the

relationship between the causes of risk j and the mitigation action k is denoted as E_{jk} . The E_{jk} values used were 0, 1, 3, and 9. 0 indicated there was no relationship. 1 showed an innate but weak relationship between the causes of risk and the proposed mitigation. 3 represented a moderate relationship between the causes of risk and the proposed mitigation. Nine indicated that there was a strong relationship between the causes of risk and the proposed mitigation.

Table 3. Risk level scale based on RPN

Description	Parameter
Very high	RPN value of 21-25
High	RPN value of 16-20
Moderate	RPN value of 11-15
Low	RPN value of 6-10
Very low	RPN value of 1-5

Furthermore, the RPN value of the risk cause j (RPN_j) and E_{jk} was exemplified to calculate the Total Mitigation Effectiveness (TEM). The TEM formula is presented in Equation (2). Mitigation proposals were also assessed based on the level of difficulty (D_k). The mitigation D_k value showed the difficulty in mitigating due to unpredictable risks. This study exercised a Likert scale of 1 to 5. The higher the D_k value, the more difficult mitigation was to be carried out. The value of D_k was utilized to calculate the effectiveness-difficulty mitigation ratio (EKM). The EKM formula for each mitigation is presented in Equation (3). Mitigation priorities were based on the order of the ECEC values from largest to smallest.

$$TEM_k = \sum_j RPN_j E_{jk} \quad \forall k \tag{2}$$

$$EKM_k = \frac{TEM_k}{D_k} \tag{3}$$

Table 4. Mitigation Priority Calculation Model

Cause Code	Risk Cause (j)	Mitigation Code (k)							RPN (j)
		M1	M2	M3	M4	...	...	Mk	
1	Cause 1	E_{11}	E_{12}	E_{13}	E_{14}	...	...	E_{1k}	RPN_1
2	Cause 2	E_{21}	E_{22}	E_{23}	E_{24}	...	...	E_{2k}	RPN_2
...
j	Cause j	E_{j1}	E_{j2}	E_{j3}	E_{j4}	...	...	E_{jk}	RPN_j
Total mitigation effectiveness		TEM_1	TEM_2	TEM_3	TEM_4	...	...	TEM_k	
Mitigation difficulty		D_1	D_2	D_3	D_4	...	...	D_k	
Mitigation effectiveness-difficulty ratio		EKM_1	EKM_2	EKM_3	EKM_4	...	...	EKM_k	
Mitigation priority ranking						...	...

2.2 A Case Study

A case study was conducted in a chemical and pharmaceutical company in Indonesia to apply the proposed Risk Evaluation and Mitigation Systems. The logistics activities of the company were the focus of the problem in this study. Currently, the company's logistics activities were carried out internally. However, the company planned to transfer all logistics management to a third party (Third-party logistics (3PL)). Three 3PL candidates need to be considered in logistics management. The company also tries to overcome logistics management through internal companies. Therefore, it is necessary to evaluate risks and determine mitigation priorities in managing logistics in this company.

3. Results and Discussion

The four stages of risk evaluation and determining mitigation priorities are described in the following sub-sections.

3.1 Risk Identification

Risk identification was performed in the logistics department, referred to as the supplier, receiving, tracking, delivery, and customer business processes. The results of risk identification, causes of risk, and impacts can be seen in [Table 5](#). Thirty-three (33) risks were collected for this problem. Furthermore, these 33 risks identified the causes of the risks and the impacts of the risks. There were 33 causes of risk and 29 impacts that result from the generated risks.

3.2 Risk Analysis

At this stage, thirty-three (33) causes of risk were successfully assessed based on the Likelihood scale. The results of the likelihood assessment can be seen in [Table 6](#). There were five causes of risk with a likelihood scale of 1, eleven risk causes with a likelihood scale of 2, and four risk causes with a likelihood scale of 3. For the 4 and 5 likelihood scales, the number of causes was eight and one, respectively. These results indicate that the likeliness and likely scale will be the dominant scale on the Likelihood assessment.

Also, the Consequence assessment was delivered based on the estimated loss of company profit. The company loss was successfully estimated for 33 impact risks. The estimation results can be observed in [Table 6](#). The results indicated ten impacts with a consequence scale value of 1, two impacts with a consequence scale value of 2, eight impacts with a consequence scale value of 3, and nine impacts with a consequence scale value of 4. Likelihood and Consequence assessment results were generated as a risk evaluation calculation presented in the risk evaluation sub-section.

3.3 Risk Evaluation

Risk evaluation was underpinned from the level of risk classified based on the RPN. The results of the risk level can be seen in [Table 6](#). It can be seen that five risks were in a low category, 14 risks were in the very low category, five risks were in the medium category, and the other five risks were in the high category. These results were utilized as the basis for proposing company mitigation.

Table 5. Risk identification

Risk No	Business Process	Risk Name	Risk Cause	Impact
1	Supplier	Purchase Order (PO) failed to be inputted	PO was not listed in the delivery request letter	The acceptance process is delayed, so that product rejection occurs
2	Supplier	The product could not be disassembled	PO was not in line with the goods	Product availability distraction
3	Supplier	RM failed to be inputted into the system	CoA (Certificate of Analysis) document was not available	The acceptance process is delayed, so that product rejection occurs
4	Receiving	The receipt was less than the delivery request order/letter	Quantity did not match with the delivery request order/letter	RM availability distraction
5	Receiving	Mismatching Inventory per batch	Material mix in one palette batch	Delayed acceptance process, so that the RM was rejected
6	Racking	There was a difference in PO receipts	Wrong entry of the PO's number	Failure to detect the number of inventory
7	Racking	There was a difference in PO receipts	Wrong item entry	Failure to detect the number of inventory, RM could not be used immediately
8	Racking	Mismatch PO Outstanding	Wrong number of goods entry	Failure to detect the number of inventory
9	Racking	Inventory mismatch	Wrong batch entry	The disruption of certain RM availability
10	Receiving	Overloading of stored Raw Material (RM)	Transfer of RM placement from another Plant	Additional warehouse rental costs
11	Supplier	PO failed to be inputted into the system	PO was not listed in the delivery request letter	The acceptance process is delayed, so that product rejection occurs
12	Supplier	The product could not be disassembled	PO was not in line with the goods	Product availability distraction
13	Supplier	RM failed to be inputted into the system	CoA (Certificate of Analysis) document was not available	The acceptance process is delayed, so that product rejection occurs
14	Receiving	The receipt was less than the delivery request order/letter	Quantity did not match with the delivery request order/letter	RM availability distraction
15	Receiving	Mismatching Inventory per batch	Material mix in one palette batch	Delayed acceptance process, so that the RM was rejected
16	Racking	There was a difference in PO receipts	Wrong entry of the PO's number	Failure to detect the number of inventory
17	Racking	There was a difference in PO receipts	Wrong item entry	Failure to detect the number of inventory, RM could not be used immediately
18	Racking	Mismatch PO Outstanding	Wrong number of goods entry	Failure to detect the number of inventory



Table 5. Risk identification (Continue)

Risk No	Business Process	Risk Name	Risk Cause	Impact
19	Racking	Inventory mismatch	Wrong batch entry	The disruption of certain RM availability
20	Receiving	Overloading of stored Raw Material (RM)	Transfer of RM placement from another Plant	-
21	Delivery	Could not send Finish Goods (FG) to an external warehouse	Transporter could not provide a fleet for transportation	FG stacking at the plant, the availability of FG in the shipping warehouse is less
22	Racking	Lack of FG for order fulfillment	Delay in sending FG to an external warehouse	-
23	Racking	There was a difference between the FG recorded and the external warehouse receipts	Wrong recording of the number of items	-
24	Racking	Additional operator working hours	There were so many orders at once	Additional labor costs for overtime
25	Delivery	Delivery could not be done immediately, it had to be verified first	The type, quantity, and batch number of goods did not match the Picking Note document	Additional working hours to re-check, late delivery of FG
26	Delivery	Delivery could not be done immediately, it had to be verified first	The type, quantity, and batch number of goods did not match the Picking Note document	Additional working hours for rechecking, Delivery Order (DO) could not be issued immediately
27	Customer	Could not be sent immediately on the date of request	There were so many orders at once	Delay or the cancellation of FG delivery
28	Customer	Could not be sent immediately due to waiting for additional goods	The volume of goods to be loaded was very small, not even one truck	Delay or the cancellation of FG delivery
29	Delivery	Could not send orders that had been made	Transporter could not provide a fleet for transportation	Delay of FG delivery
30	Delivery	Goods sent did not match the request	Items required were damaged in packaging	Addition of new packaging costs, delay of FG delivery
31	Delivery	Goods could not be sent	Items dropped and packaging damaged during the transfer	Addition of new packaging costs, delays to cancellation of FG shipments
32	Delivery	Some Pallet batches remained unsent	Delivery did not match DO	-
33	Delivery	Could not be sent immediately on the date of request	There were so many orders at once	Delay or the cancellation of FG delivery

3.3 Risk Response

Based on risk evaluation, this study proposes 14 mitigation (Ms) proposals as follows: M1 is a reminder to suppliers to include clear and correct data. M2 is a check to the supplier so that the COA is also included. M3 is a Daily Cycle Count of materials regularly and consistently. M4 is an additional lease for the external warehouse. M5 is to make sure every delivery route has a backup transporter. M6 contains a request to Customer Service so that it can issue orders gradually. M7 is for warehouse operators to

recalculate the number of items entered. M8 contains the instruction on checking the amount of cargo and clarification to the truck fleet drivers. M9 explains that every small order in number will be sent by Less Container Loaded (LCL). The M10 contains the identification and repair of defective items as soon as they are found. M11 suggests that forklift operators do movements to carry goods at low speed. M12 is the use of 3PL-company 1. M13 contains the use of 3PL-company 2, and M14 describes the use of 3PL-company 3.

Table 6. Assessment of Likelihood, Consequence, RPN, and Level of Risk

Risk No.	Risk Cause	L	Impact	Estimated Loss	C	RPN	Risk Level
1	PO was not listed in the delivery request letter	2	The acceptance process is delayed, so that product rejection occurs	IDR 100,000,000	3	6	Low
2	PO was not in-line with goods CoA (Certificate of Analysis)	2	Product availability distraction	IDR 500,000,000	4	8	Low
3	document was not available	4	The acceptance process is delayed, so that product rejection occurs	IDR 100,000,000	3	12	Moderate
4	Quantity did not match with the delivery request order/letter	1	RM availability distraction	IDR 100,000,000	3	3	Very Low
5	Material mix in one palette batch	2	Delayed acceptance process, so that the RM was rejected	IDR 50,000,000	2	4	Very Low
6	Wrong entry of the PO's number	2	Failure to detect the number of inventory	IDR -	1	2	Very Low
7	Wrong item entry	1	Failure to detect the number of inventory, RM could not be used immediately	IDR -	1	1	Very Low
8	Wrong number of goods entry	3	Failure to detect the number of inventory	IDR -	1	3	Very Low
9	Wrong batch entry	2	The disruption of certain RM availability	IDR -	1	2	Very Low
10	Transfer of RM placement from another Plant	2	Additional warehouse rental costs	IDR 182,000,000	3	6	Low
11	PO was not listed in the delivery request letter	2	The acceptance process is delayed, so that product rejection occurs	IDR 100,000,000	3	6	Low
12	PO was not in line with the goods CoA (Certificate of Analysis)	2	Product availability distraction	IDR 500,000,000	4	8	Low
13	document was not available	4	The acceptance process is delayed, so that product rejection occurs	IDR 100,000,000	3	12	Moderate
14	Quantity did not match with the delivery request order/letter	1	RM availability distraction	IDR 100,000,000	3	3	Very Low

Table 6. Assessment of Likelihood, Consequence, RPN, and Level of Risk (Continue)

Risk No.	Risk Cause	L	Impact	Estimated Loss	C	RPN	Risk Level
15	Material mix in one palette batch	2	Delayed acceptance process, so that the RM was rejected	IDR 50,000,000	2	4	Very Low
16	Wrong entry of the PO's number	2	Failure to detect the number of inventory	IDR -	1	2	Very Low
17	Wrong item entry	1	Failure to detect the number of inventory, RM could not be used immediately	IDR -	1	1	Very Low
18	Wrong number of goods entry	3	Failure to detect the number of inventory	IDR -	1	3	Very Low
19	Wrong batch entry	2	The disruption of certain RM availability	IDR -	1	2	Very Low
21	Transporter could not provide a fleet for transportation	1	FG stacking at the plant, the availability of FG in the shipping warehouse is less	IDR -	1	1	Very Low
24	There were so many orders at once	5	Additional labor costs for overtime	IDR 300,000,000	3	15	Moderate
25	The type, quantity, and batch number of goods did not match the Picking Note document	4	Additional working hours to re-check, late delivery of FG	IDR 5,000,000	1	4	Very Low
26	The type, quantity, and batch number of goods did not match the Picking Note document	3	Additional working hours for rechecking, Delivery Order (DO) could not be issued immediately	IDR 500,000,000	4	12	Moderate
27	There were so many orders at once	4	Delay or the cancellation of FG delivery	IDR 500,000,000	4	16	High
28	The volume of goods to be loaded was very small, not even one truck	4	Delay or the cancellation of FG delivery	IDR 500,000,000	4	16	High
29	Transporter could not provide a fleet for transportation	4	Delay of FG delivery	IDR 500,000,000	4	16	High
30	Items required were damaged in packaging	4	Addition of new packaging costs, delay of FG delivery	IDR 500,000,000	4	16	High
31	Items dropped and packaging damaged during the transfer	3	Addition of new packaging costs, delays to cancellation of FG shipments	IDR 500,000,000	4	12	Moderate
33	There were so many orders at once	4	Delay or the cancellation of FG delivery	IDR 500,000,000	4	16	High

Furthermore, from the 14 mitigation proposals, calculations were then carried out to determine mitigation priorities. The results of the calculation of mitigation priorities are presented in Fig. 2. These results indicated that the use of 3PL-company 1 (M12) has the highest priority, followed by the use of 3PL-company 2 (M13) and the warehouse operator recalculates the number of items entered (M7).

Risk Cause	Mitigation														RP N
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
PO was not listed in the delivery request letter	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6
PO was not in-line with goods	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
CoA (Certificate of Analysis) document was not available	0	3	0	0	0	0	0	0	0	0	0	0	0	0	12
Quantity did not match with the delivery request order/letter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Material mix in one palette batch	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Wrong entry of the PO's number	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Wrong item entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Wrong number of goods entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3
Wrong batch entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Transfer of RM placement from another Plant	0	0	0	1	0	0	0	0	0	0	0	0	0	1	6
PO was not listed in the delivery request letter	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6
PO was not in line with the goods	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
CoA (Certificate of Analysis) document was not available	0	3	0	0	0	0	0	0	0	0	0	0	0	0	12
Quantity did not match with the delivery request order/letter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Material mix in one palette batch	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Wrong entry of the PO's number	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Wrong item entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Wrong number of goods entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	3
Wrong batch entry	0	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Transporter could not provide a fleet for transportation	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1
There were so many orders at once	0	0	0	0	0	3	0	0	0	0	0	3	3	3	15
The type, quantity, and batch number of goods did not match the Picking Note document	0	0	0	0	0	0	1	0	0	0	0	1	1	1	4
The type, quantity, and batch number of goods did not match the Picking Note document	0	0	0	0	0	0	0	3	0	0	0	3	3	3	12
There were so many orders at once	0	0	0	0	0	9	0	0	0	0	0	9	9	9	16
The volume of goods to be loaded was very small, not even one truck	0	0	0	0	0	0	0	0	9	0	0	9	9	9	16
Transporter could not provide a fleet for transportation	0	0	0	0	9	0	0	0	0	0	0	9	9	9	16
Items required were damaged in packaging	0	0	0	0	0	0	0	0	0	9	0	9	9	9	16
Items dropped and packaging damaged during the transfer	0	0	0	0	0	0	0	0	0	0	3	3	3	3	12
There were so many orders at once	0	0	0	0	0	9	0	0	0	0	0	9	9	9	16
Total mitigation effectiveness	28	72	24	6	145	333	4	36	144	144	36	842	842	864	
Mitigation difficulty	4	4	5	5	3	3	3	4	3	4	4	1	5	5	
Mitigation effectiveness-difficulty ratio	7	18	4.8	1.2	48	111	1.3	9	48	36	9	842	168	173	
Mitigation priority ranking	10	7	11	13	4	3	12	8	5	6	8	1	2	14	

Fig. 2 Mitigation Priority Calculation

4. Conclusion

This study was projected to develop a Risk Evaluation and Mitigation System based on the HOR method. It succeeded in developing Risk Evaluation and Mitigation Systems. The case study results underlined that the proposed Risk Evaluation and Mitigation Systems could be appropriately applied to evaluate company risks and provide

mitigation recommendations. In this study, we ignored the interdependence of risks and between mitigations. In actual conditions, the dependence between risks and between mitigation is possible. Therefore, further studies should consider the interdependence factors of risks and mitigations.

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