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Proposed Action of Supply Chain Risk Mitigation Air Compressor Type L Unloading ¼ HP Using Fuzzy – FMEA and Fuzzy – AHP Method in PT. XYZ

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Abstract
Established since the 80s, PT. XYZ is an air compressor manufacturing industry located in Tangerang, Indonesia. In the production process, the air compressor type L Unloading 1/4 HP has a very complex supply chain network which makes the supply chain network activities experience obstacles in the form of risks or potential risks that can occur so that it can disrupt the smooth running of the supply chain activities of this air compressor. Yet, PT. XYZ has not maximally implemented risk mitigation actions in its supply chain. The purpose of this study is to propose a mitigation action against risk events that occur along the supply chain of air compressor type L Unloading 1/4 HP using the FFMEA (Fuzzy Failure Mode and Effect Analysis) and FAHP (Fuzzy Analytical Hierarchy Process) methods. Based on the research, there were 29 identified risk events with 5 priority risk events. And of the 5 priority risk events, each has 2 proposed mitigation actions per priority risk event.

Keywords: compressor, risk mitigation, supply chain, fuzzy methods

1. Introduction

Along with the development of the industry which has entered the industrial era 4.0 and the increasingly tighter competition between companies in creating quality and cheap products but also having fast delivery or distribution to consumers is a challenge for all companies. Seeing this condition, companies are required to have a well-coordinated supply chain system. In the flow of the supply chain, of course, many issues are highlighted starting from suppliers, production processes, delivery systems (logistics), to the end users. This is due to the intense competition that is currently occurring not only between companies but competition between supply chain networks or supply chains owned by each company.

The supply chain is a network of companies that jointly work to create and deliver a product into the hands of end users. The companies involved are suppliers, manufacturers, distributors, retailers or stores, as well as supporting companies such as logistics or shipping services [1].

All parties involved in the supply chain network work best with each other, especially in terms of services. However, in every activity in supply chain activities, of course, there will be opportunities for risk which of course can hinder supply chain flow activities starting from upstream suppliers,

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manufacturing, distribution, and end users. Supply chain risks can occur from upstream suppliers, factories, distribution, and downstream distributors, as well as consumers [2]. Risk is more associated with losses caused by events that may occur within a certain time. Risks cannot be avoided but can be minimized or eliminated by carrying out appropriate risk management. Usually, one risk cause can stimulate more than one risk event [3].

Established since the 80s, PT. XYZ is an air compressor manufacturing industry located in Tangerang and has branch companies in 5 (five) major cities in Indonesia. In this study, the air compressor supply chain network that will be carried out mitigation action is the supply chain network of air compressor type L Unloading ¼ HP. The condition of the supply chain network for air compressor type L Unloading ¼ HP consists of suppliers (domestic and foreign), manufacturers, authorized distributors to end users. The large number of parties involved in the supply chain network raises the possibility of risks or potential risks that may occur along the flow of the supply chain. Among the risks that occur at the supplier's part, namely the late arrival of raw materials

However, from some of these risks, the risk that often occurs is the occurrence of air compressor product returns, where based on last year's data, the most product returns occurred in February 2018, totaling 20 products. Products that experience a return or return include damaged spare parts and an error in sending the type of air compressor to the distributor because this often happens, of course, causing the company to experience losses in terms of cost and time.

Based on the problems at PT. XYZ, the need to implement risk management in the supply chain system of PT XYZ to minimize risks and other potential risks that may occur in the flow of the supply chain (upstream to downstream) requires the application of risk management which is an effort to improve chain performance. supply gradually and continuously by addressing and preventing various risks that could potentially occur. The framework in supply chain risk management is carried out in five stages, namely determining objectives, risk identification, risk analysis, risk evaluation, and risk mitigation actions [4].

Methods that used in this study are FFMEA (Fuzzy Failure Mode and Effect Analysis) and FAHP (Fuzzy Analytic Hierarchy Process) methods. The selection of FFMEA and FAHP methods in this study, especially in the use of fuzzy in both methods, is to reduce the subjectivity of the final results of each method. FFMEA (Fuzzy Failure Mode and Effect Analysis) is a development of the FMEA method. FMEA (Failure Mode and Effect Analysis) is a method that considers risks related to failure modes, identifies and implements corrective action to resolve priority problems or problems [5].

The use of the fuzzy concept aims to emphasize the value desired by the respondent and to obtain the FRPN (Fuzzy Risk Priority Number) value. The FRPN (Fuzzy Risk Priority Number) value will determine the priority risk sequence or ranking of risk events which will later become input from the FAHP (Fuzzy Analytic Hierarchy Process).

The FAHP (Fuzzy Analytic Hierarchy Process) method will be used as a tool to mitigate priority risk events. AHP (Analytic Hierarchy Process) is a method that in principle looks for pairwise comparisons and calculates weighting factors to obtain relative priority results among the available alternatives [6].

The use of fuzzy in mitigation actions using the AHP (Analytic Hierarchy Process) method is to clarify or reinforce the weight vector value obtained from the results of the pairwise comparison questionnaire that has been filled in by the respondents.

It is important to carry out supply chain risk mitigation actions in order to minimize the risks that occur. The stages of activities in supply chain risk mitigation action consist of risk identification, risk analysis, risk evaluation, and risk mitigation. In addition, after this research is completed, it is hoped that it can increase the effectiveness of risk management in PT XYZ's supply chain system.

This study aims to carry out supply chain risk mitigation actions in order to minimize the risks that occur. The stages of activities in supply chain risk mitigation action consist of risk identification, risk analysis, risk evaluation, and risk mitigation. In addition, after this research is completed, it is hoped that it can increase the effectiveness of risk management in PT XYZ's supply chain system.

Carry out supply chain risk mitigation actions in order to minimize the risks that occur is an of important process in the industry. The stages of activities in supply chain risk mitigation action consist of risk identification, risk analysis, risk evaluation, and risk mitigation. The future prospective or this study is that the optimum proposal may improve the industrial process by increasing the effectiveness of risk management in PT XYZ's supply chain system.

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2. Methods

Research conducted at PT XYZ is a research with a quantitative approach. The research began with field observations, interviews with the supply chain system network of the air compressor type L Unloading 1 / 4HP at PT XYZ and referring to the supporting literature during the research, then direct and indirect data collection was carried out. In this study, the data required are primary data and secondary data. The primary data in this study were in the form of a questionnaire or questionnaire, namely the FMEA and AHP questionnaires. The FMEA questionnaire contains risk events while the AHP questionnaire contains the causes of risk events.

Risk events are obtained through literature studies, interviews with experts, and direct observation based on risk factors, namely supply risk, demand risk, manufacturing risk, distribution risk, product recovery risk, information risk, as well as K3 and Environmental risk. Furthermore, the data is processed using the Fuzzy-FMEA and Fuzzy-AHP methods.

Using the Fuzzy-FMEA method consists of several stages, namely [7]:

a. Determine the severity, occurrence, and detection value for each risk event.
b. Determine the fuzzy set input membership.

Table 1. Membership of Fuzzy Set Inputs

Category	Curve Shape	Fuzzy Number
Almost None	Triangles	(0 0 2)
Low	Triangles	(1 2.5 4)
Medium	Triangles	(3 5 7)
High	Triangles	(6 7.5 9)
Very High	Triangles	(8 10 10)

c. Determining Fuzzy Set Output.

Table 2. Membership of Fuzzy Set Output

Category	**Curve Shape**	**Fuzzy Number**
None (N)	Triangles	(0 0 200)
Very Low (VL)	Triangles	(100 200 300)
Low (L)	Triangles	(200 300 400)
High Low(HL)	Triangles	(300 400 500)
Low Medium(LM)	Triangles	(400 500 600)
Medium (M)	Triangles	(500 600 700)
High Medium (HM)	Triangles	(600 700 800)
Low High (LH)	Triangles	(700 800 900)
High (H)	Triangles	(800 900 1000)
Very High (VH)	Triangles	(900 1000 1000)

d. *Fuzzy Rule Bases*

Fuzzy rules bases are the rules used in the Fuzzy-FMEA method. Fuzzy rules bases consist of fuzzy input variables, namely severity, occurrence, and detection. In addition to the fuzzy input variables, fuzzy-RPN (Risk Priority Number) output is added using if-then rules. Rule bases consists of input variables totaling 125 rules (5 x 5 x 5).

e. The defuzzification process

Defuzzification is the last process in the fuzzy method, which aims to reinforce the fuzzy-RPN (Fuzzy Risk Priority Number) value. The defuzzification process uses centeroid defuzzification in Matlab software, by entering the occurrence, severity, and detection values into the input field.

In addition to using the FFMEA method, this study used the FAHP. Here are the steps for using FAHP:

a. Create a hierarchical structure.
b. Create a pairwise comparison matrix
c. Normalization of the matrix (AX)
d. Calculate consistency

$$\lambda_{max} = \frac{Priority\ weight\ (AX)}{Criteria\ weight\ (X)} \quad (1)$$

e. Calculating the consistency index (CI)

$$\lambda_{max} = \frac{\lambda\,max - n}{n-1} \quad (2)$$

f. Calculating the consistency ratio (CR)

$$CR = \frac{CI}{RI} \quad (3)$$

where:
CR = *Consistency Ratio*
CI = *Consistency Index*
RI = *Random Index*

The random index (RI) is commonly used for each matrix order. The following is a table of RIs in each matrix order [8]:

Table 3. Random Index Table

N	**RI**
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24

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7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

g. Converts matrix values into TFN (Triangular Fuzzy Number) values as follow.

Table 4. TFN (Triangular Fuzzy Number)

AHP scale	Fuzzy Scale	*Inverse* Fuzzy Scale
1	1 = (1, 1, 1) = if the diagonal is other than (1, 1, 3)	(1/3, 1/1, 1/1)
3	(1, 3, 5)	(1/5, 1/3, 1/1)
5	(3, 5, 7)	(1/7, 1/5, 1/3)
7	(5, 7, 9)	(1/9, 1/7, 1/5)
9	(7, 9, 9)	(1/9, 1/9, 1/7)
2	(1, 2, 4)	(1/4, 1/2, 1/1)
4	(2, 4, 6)	(1/6, 1/4, 1/2)
6	(4, 6, 8)	(1/8, 1/6, 1/4)
8	(6, 8, 9)	(1/9, 1/8, 1/6)

h. Determine the fuzzy synthetic extent with the following equation:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} \approx \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}\right) \quad (4)$$

In the calculation of the fuzzy synthetic extent, the comparison of the fuzzy synthetic extent is calculated with the following equation:

$$V(M2 \geq M1) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \frac{l1 - u2}{(m2 - u2) - (m1 - l1)} & \text{for other conditions} \end{cases} \quad (5)$$

i. Normalization

The next step is normalization which aims to determine the value of the weight vector for each criterion as below equation.

$$d(A_i) = \frac{\acute{d}(A_i)}{\sum_{i=1}^{n} \acute{d}(A_i)} \quad (6)$$

3. Results and Discussions

Based on the results of literature studies, interviews with academics and company experts, field observations, and data processing results, the following results were obtained presented below.

3.1 Supply Chain Network

In the supply chain network PT. XYZ contains three flows, namely the flow of products or goods, cost flow, and information flow flowing from upstream to downstream. The supply chain network of PT. XYZ is described in Figure 1 below.

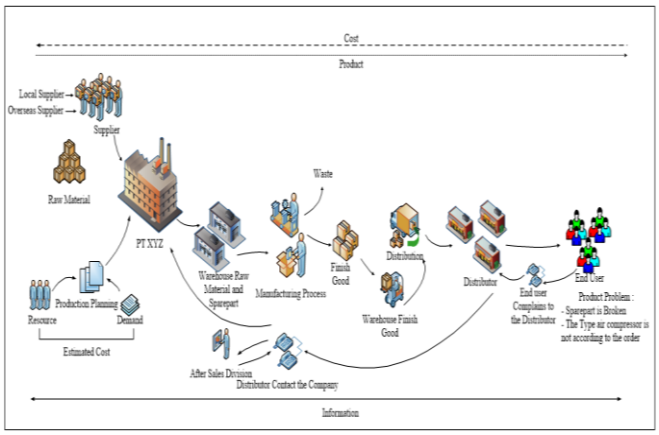

Figure 1. Supply Chain Network of PT. XYZ

In Figure 1. it can be seen that the supply chain network of PT. XYZ consists of local and overseas suppliers. Then enter the manufacturing process, the delivery process, until it reaches the end user.

3.2 Determination of Risk Factors

In the process of identifying risks [9] in the supply chain flow of air compressor Type L Unloading 1 / 4HP at PT. XYZ is to use risk factors obtained through literature studies and interviews. The following are the risk factors used for the risk identification process at PT. XYZ below.

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Table 5. Risk Factors

Risk Factors	Description
Supply Risk	*Supply risk* or the risks contained in the supply refer to the risks associated with the supply or supplier which have an impact on consumers and the company.
Demand Risk	*Demand risk* is a potential risk in the process of requesting or planning for air compressor products.
Manufacturing Risk	*Manufacturing risk* or manufacturing risk can be defined as the risk in operations or in the production process that disrupts the flow of material or information in the supply chain.
Distribution Risk	*Distribution risk* is a risk associated with the process of distributing finished products to consumers.
Product Recovery Risk	*Product recovery risk* is a risk that can occur when returning the damaged finished product to the company.
Information risk	*Information risk* is a risk that can occur in the flow of information in the supply chain system.
K3 and Environmental Risk	K3 and Environmental risk are risks related to occupational safety and health as well as the company environment in the supply chain system.

Based on Table 5. risk factors are used to identify risk events, among others supply risk, demand risk, manufacturing risk, distribution risk, product recovery risk, information risk, and K3 and Environmental risk.

3.3 Risk Identification

Based on the results of literature studies, interviews, and field observations. The 29 risk events identified [10] were described in Table 6. and Table 7. below

Table 6. Results of Risk Event Identification

Risk Factors	Risk Events	Code
Supply Risk	Error item sent by supplier	E1
	The number of items sent did not match the order	E2
	Increase in raw material prices	E3
	The raw material quality is not good	E4
	Stock raw material ordered does not exist	E5
	Late arrival of raw materials	E6
Demand Risk	Forecasting errors	E7
	Delays in material procurement	E8
	The production target was not achieved	E9
	Incompatible input of material parts into the system	E10
Manufacturing Risk	Equipment or machine problems	E11
	Spare parts having damaged	E12
	Making product parts not according to specifications	E13
	sand hardness in the molding process is imperfect	E14
	spare parts it takes less	E15
	plate steel not up to specifications	E16
	The paint thickness on the product is not suitable	E17
	Iron smelting process is not perfect	E18
	Reject products	E19
Distribution Risk	The product packaging was damaged during the shipping process	E20
	High shipping costs	E21
	Delay in the product delivery process	E22
Product Recovery Risk	The occurrence of a product return	E23
	The occurrence of a spare part return	E24
	Delay in delivery of replacement products to consumers	E25
Information Risk	Systems within the company are less integrated	E26
	the occurrence of miss communication between companies and consumers	E27
K3 and Environmental Risk	Occurrence of work accidents	E28
	The residual waste of production pollutes the environment	E29

Table 7. Results of Causes of Risk Identification

Risk Factors	Causes of Risk	Code
Supply Risk	Lack of coordination between suppliers and companies	A1
	Inaccuracy of suppliers in checking the amount of material	A2
	Changes in currency exchange rates	A3
	Inaccuracy of suppliers in checking material quality	A4
	There is a production disruption at the supplier	A5
Demand Risk	The occurrence of fluctuations in product demand from consumers	A6
	Sudden change in production plans	A7
	There is a change in the planning quantity when the schedule is running	A8
	human error	A9
Manufacturing Risk	Lack of maintenance on the machine	A10
	Laying out spare parts by stacking them	A11

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	Operator error in using the tool	A12
	The quality of the sand is not good	A13
	There is a problem in the production of spare parts at the supplier	A14
	Operator error during the steel cutting process	A15
	human error	A16
	Operator inaccuracy when setting the furnace temperature	A17
	Worker's negligence	A18
Distribution Risk	Not sturdy packaging used	A19
	Government regulations	A20
	Lack of transportation fleet owned by the company	A21
Product Recovery Risk	The product that was sent did not match the order	A22
	Spare parts unable to function or is damaged	A23
	There are problems on the expedition	A24
Information Risk	Not yet accommodated several divisions in the same system	A25
	Lack of company-consumer coordination	A26
K3 and Environmental Risk	Lack of completeness of the PPE used by workers	A27
	There is no waste treatment before the waste is disposed of	A28

Based on Table 6. And Table 7. above, it can be seen that 29 risk events were identified with 28 causes of risk.

3.4 Risk Analysis

At the risk analysis stage, data processing is carried out using the FMEA and Fuzzy-FMEA methods. The use of the FMEA method is only to determine the differences that occur before the data is processed using the fuzzy concept [11]. The results of data processing before and after are contained in Table 8. below:

Table 8. Comparison Result between FMEA and Fuzzy-FMEA

No.	Code	FMEA		Code	*Fuzzy*- FMEA	
		RPN	*Rank*		FRPN	*Rank*
1	E1	265.84	1	E11	700	2
2	E19	210.13	2	E14	700	
3	E26	206.10	3	E15	700	
4	E17	204.28	4	E26	654	3
5	E4	203.44	5	E13	640	4
6	E9	197.57	6	E1	633	5
7	E3	194.56	7	E5	627	7.5
8	E15	194.25	8	E12	627	
9	E11	188.52	9	E18	619	8
10	E7	185.94	10	E27	617	9
11	E6	184.90	11	E2	614	12
12	E5	183.39	12	E17	614	
13	E8	183.23	13	E20	614	
14	E23	180.13	14	E28	613	13
15	E16	169.38	15	E24	602	14
16	E12	158.10	16	E22	601	15
17	E18	142.75	17	E3	600	17.5
18	E20	140.22	18	E8	600	
19	E2	134.13	19	E7	585	18
20	E14	122.18	20	E25	575	19
21	E10	121.48	21	E10	558	20
22	E27	104.30	22	E9	557	22.5
23	E25	103.63	23	E23	557	
24	E13	71.82	24	E6	552	23
25	E28	71.82		E4	546	
26	E24	66.84	25	E16	546	25.5
27	E22	65.65	26	E19	515	26
28	E21	58.66	27	E21	513	27
29	E29	30.14	28	E29	337	28

From the table above, it can be seen that the RPN (Risk Priority Number) and fuzzy-RPN (Fuzzy Risk Priority Number) values for each risk event. In calculations using the usual FMEA, the retang rank or rank of each RPN value is 1 - 28, with the highest value of265.84and the lowest value is 30.14. While the results of calculations using fuzzy-FMEA, the largest value of fuzzy-RPN (Fuzzy Risk Priority Number) is 700 and the lowest value is 337.

3.5 Risk Evaluation

Risk evaluation aims to determine the priority risk of each risk event (risk event) wherein the risk mitigation action will be carried out. Risk evaluation is carried out on FRPN with the 3 largest ratings [12]. Where the decision making is based on the actual situation in the company as well as on the limited time available in conducting research.

The 3 largest FRPN ratings contain 5 risk events, namely lack of maintenance on the engine (E11), and hardness in the molding process is imperfect (E14), spare parts it takes less (E15), several divisions in the same system have not been accommodated (E26), and operator errors in using the tool (E13).

3.6 Risk Mitigation Actions

Risk mitigation action is a stage where it reduces or eliminates the possibility of certain risks or consequences [13]. Data processing in Table 9. the risk mitigation action section is using Fuzzy-AHP.

Based on calculations using Fuzzy-AHP, the following risk mitigation actions are proposed as on Table 9 below.

Table 9. Proposed Risk Mitigation Actions

No.	Causes of Risk	Weight	Proposed Mitigation Actions
1	not yet accommodated several divisions in the same system	0.262	Creating a system that can integrate all divisions in the same system Improve coordination between divisions
2	There is a problem in the production of spare parts at the supplier	0, 218	Looking for alternative suppliers Increase the availability or number of safety stock of spare parts
3	Lack of maintenance on the machine	0.201	Check periodically before and after the machine is used Make improvements in machine maintenance
4	Operator error in using the tool	0.168	Provide training to operators or employees Provide SOP for the use of each tool
5	The quality of the sand used is not good	0.152	Check the quality of the sand Perform regular sand changes after use

4 Conclusion

Based on the research results obtained 29 identified risk events in the supply chain flow of Air compressor Type L Unloading 1/4 HP. Furthermore, for risk events that become priority are 5 risk events, among others lack of maintenance on the engine (E11), sand hardness in the molding process is imperfect (E14), spare parts it takes less (E15), several divisions in the same system have not been accommodated (E26), and operator errors in using the tool (E13). Then for mitigation actions for each risk event is to create a system that can integrate all divisions in the same system, and improve coordination between divisions. look for other alternatives, and increase the availability or amount of safety stock. carry out regular checks before and after the machine is used and make improvements to machine maintenance. provide training to operators or employees, and provide SOPs for the use of each tool. check the quality of the sand and replace the sand regularly.

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