The Multi-Attribute Failure Mode Analysis to Reduce Work Accident in a Metal Fabrication Company

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ABSTRACT

Metal manufacturing companies attempt to increase its productivity by streamlining the processes. However, hazards may occur. Many accidents occurred ranging from minor to severe. In designing the occupational safety and health (OSH) management system, knowledge of risk management is very important because risk management can identify risks, assess risks, and reduce risks to a reasonable extent. This study aims to identify the risk of work accidents, then classifies the risks of work accidents based on the most significant impacts and finally provides recommendations for improvements to overcome the risks of work accidents with the most significant impact. A studied case was conducted in metal fabrication company. The Failure Mode and Effect Analysis (FMEA) integrated with Analytic Hierarchy Process (AHP), i.e., the Multi-Attribute Failure Mode Analysis (MAFMA) was deployed. The results obtained in this study indicate that 14 work accident risk events have occurred and have been validated by the company. The risk classification of work accidents using the MAFMA method produces a risk value weight in decimal numbers, sorted from highest to lowest, to be included in the Pareto diagram. Based on the results of the Pareto diagram with the 80/20 principle, the events that were the researcher's focus were given three improvement proposals; namely, the hands were crushed by the blade, the head hit the top slides, and slipped. Recommendations for improvement proposals are focused on two events with the highest MAFMA score to be given a proposed improvement. Suggested improvement include workers wearing personal protective equipment (PPE) in production, adequate lighting, work instructions, paying attention to work procedures, and machine's condition.

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1. Introduction

Indonesia is a country with a vast and diverse population. The large population in Indonesia causes many manufactured products to be needed. Among the required manufacturing products is the manufacture of metal products for various needs. However, it is undeniable that manufactured metal products also require much effort and sometimes produce various accidents in the production process. The Employment Social Security Administration Agency noted that in 2017 the number of reported work accidents reached 123,041 cases, while in 2018, it reached 173,105 cases with a work accident insurance claim of IDR 1.2 trillion. In 2019 there were 114,000 cases, and there was an increase of 55.2% to 177,000 cases in 2020 (Pelatihan K3, 2023). Following existing regulations and standards to regulate workplace safety, regarding how important it is, the application of occupational safety and health (OSH) should be carried out in all companies. Various possible accidents may occur within the company's area, especially manufacturing companies with quite a hazard in their production process.

According to Stonerburner (2002), in designing an OSH management system, knowledge of risk management is very important because risk management can identify risks, assess risks, and reduce risks to reasonable limits. The Failure Mode and Effect Analysis (FMEA) method often identifies risk-causing components. Several studies have been conducted on the risk of work accidents using FMEA. Classic FMEA is used to analyse the risk of work accidents in the petrochemical industry (Kangavari et al., 2015), in construction companies (Patricio et al. (2013) & Uchoa et al. (2019)), in steel companies (Song et al., 2007), in laboratories (Rimawan & Wahyudin, 2019), and in educational equipment companies (Mirmohammadi et al., 2016). At the same time, Dagsuyu (2016) uses classical FMEA and fuzzy FMEA to analyze risks in the sterilization unit. Furthermore, Fithri et al.(2020) and Fithri et al.(2018) developed the integration of FMEA and FTA in service companies and weaving departments. Aulady (2018) also identified the most fatal and high-intensity project risks.

This study aims to identify the risk of work accidents, then classify the risks of work accidents based on the most significant impacts using the MAFMA method and finally provide recommendations for improvements to overcome the risks of work accidents with the most significant impact. This study uses the FMEA method integrated with the Analytic Hierarchy Process (AHP), called the Multi-Attribute Failure Mode Analysis (MAFMA) method. This method was chosen because it facilitates the economic aspects of the risk of accidents so that the causes of failure can be seen and the effect on costs (Braglia, 2000). The analysis technique in MAFMA is carried out using FMEA, which is approached by integrating four factors, namely chance of failure (occurrence), change of non-detection, severity, and the expected cost. The cost due to failure is calculated with a qualitative pairwise comparison. Formulation of priority ranking of causes of failure is carried out with the help of AHP or Fuzzy-AHP, thus facilitating effective and efficient analysis. A metal manufacturing company was taken as a studied case. The company provides quality products and excellent after-sales service from Indonesia to the world. The company is a specialized company in pressure vessel welding and sheet metal incorporating industrial infrastructure, including oil & gas, petrochemical, pharmaceuticals, fertilizers, agrochemicals, power generation, and thermal processing industries. Production of various metals at the company only sometimes runs smoothly without work accidents. Several hazards arise when the production and warehousing process is carried out. In several years of production, there have been many accidents that have occurred in this company, ranging from minor accidents to severe accidents. 2015 and 2016 were the years with several quite dangerous accidents, i.e., six moderate accidents have occurred, and one serious accident has occurred. The many hazards that might occur in the company area include sharp edges, falling large and small objects, electric shock, machines that use sharp blades, x-rays, slippery floors, and heights. These problems create costs considered quite large, thus affecting losses in the economic factor for the production process.

The paper is divided into six parts in which the first presents the problem background. The second part described the methodological approach deployed for the study, followed by the results and discussion in Section Three. The conclusion is presented in Section four.

2. Methodology: Multi-Attribute Failure Mode Analysis (MAFMA)

The research involves a preliminary study, literature review, and empirical study. The empirical study was conducted through observations, survey, and interviews at a metal fabrication company located in Cikarang, Bekasi. The empirical study was conducted over six months. The present study involved three respondents consisted of occupational safety and health (OSH) managers, general affairs managers, and quality assurance managers. These three respondents were chosen because they were responsible for the risk of work accidents..

This study uses the MAFMA method to look for events with the highest risk values. MAFMA is a method developed by Marcello Braglia to overcome the deficiencies in the FMEA method. Unlike FMEA, which only considers three criteria to find the worst causes of failure, MAFMA adds one essential criterion, which is economic criteria. MAFMA considers four criteria: severity, occurrence, detectability, expected cost, or what can be called costs (Braglia, 2000). According to Braglia (2000), the MAFMA method is a combination of FMEA and AHP methods, where the combined criteria are three from FMEA and cost criteria. Braglia (2000) calls this method as MAFMA method because it considers the criteria weight used. Causes of failure can be analysed and evaluated according to the weight of the criteria. The analysis technique in MAFMA is carried out using FMEA, which is approached by integrating four factors, namely chance of failure (occurrence), change of non-detection, severity, and the expected cost. The cost due to failure is calculated by qualitative pairwise comparison. Formulation of priority ranking of causes of failure is carried out with the help of AHP or Fuzzy-AHP, thus facilitating effective and efficient analysis.

The MAFMA method has the following steps (Braglia, 2000):

a) Prioritizing problems by looking at the number of failures in the production process.
b) Determining the value of each severity, occurrence, and detectability variable and then look for the RPN value.
c) Calculating the RPN value
A risk priority number (RPN) is a mathematical system that translates a set of effects with a severe level of severity to create a failure related to these effects (occurrence) and can detect failures (detection) before reaching the consumer. RPN is the multiplication of the occurrence rating (O), severity (S), and detection (D) (Carmigani, 2009).
$$RPN = O \times S \times D \quad (1)$$
d) Determining of weight criteria with AHP
Creating a pairwise comparison matrix requires quantities that can reflect the differences between one factor and another. Comparison of the level of importance of one element to another using a scale of 1 to 9. The AHP approach uses the Saaty scale ranging from 1 to 9 (Chang, 2016):
1 = Both elements are equally important
3 = One element is slightly more important than the others
5 = One element is essential or very important compared to other elements
7 = One element is clearly more important than the other elements
9 = One element is absolutely more important than the other elements
2, 4, 6, 8 = Intermediate values between two adjacent considerations
The AHP model is based on a pairwise comparison matrix, in which the matrix's elements are the decision maker's judgment. A decision maker will provide an assessment, perceive, or estimate the possibility of something happening. The matrix is found at each level of an AHP model structure hierarchy that divides a problem.
e) Conducting pairwise comparison test for expected cost
It includes the cost calculation with pairwise comparisons, distributing questionnaires to OSH managers, general affairs managers, and quality assurance managers. The calculation is done qualitatively.
f) Conducting paired comparison test four criteria which include severity, occurrence, detection and expected cost.
g) Weighting severity criteria with the causes of failure
h) Weighting occurrence criteria with the causes of failure
i) Detection criteria weighted by the cause of failure
j) Weighting cost criteria with the causes of failure
k) Calculating local priority based on equations 2 to 6.
$$\text{Local priority severity} = \frac{\text{Severity value}}{\text{Total severity}} \quad (2)$$
$$\text{Local priority occurrence} = \frac{\text{Occurrence value}}{\text{Total occurrence}} \quad (3)$$
$$\text{Local priority detection} = \frac{\text{Detection value}}{\text{Total detection}} \quad (4)$$
$$\text{Local priority cost} = \frac{\text{Cost value}}{\text{Total cost}} \quad (5)$$
l) Calculating Global Priority based on equation 6 to 9.
Global priority severity = local priority severity x severity weight (6)
Global priority occurrence = local priority occurrence x occurrence weight (7)
Global priority detection = local priority detection x detection weight (8)
Global priority cost = local priority cost x cost weight (9)
m) Calculating total priority for each cause of failure

3. Results and Discussion

This section presents the results following the aforementioned methodology. The section is organized into six parts.

3.1 Identification of risk event

The first step is the identification process to prioritize problems by looking at the number of failures in the production process. This risk event determination was carried out after an interview with the respondents. Based on the identification results, 14 risk events often significantly impact the company. The results of the identification of risk events as shown in Table 1.

Table 1. Risk event

No	Risk Event
1	Foot injured by the sharp edge of the material
2	Legs crushed by falling plates
3	Limb exposed to electric current
4	Limbs injured by components breaking suddenly during repair
5	Body parts hit the machine while doing activities around the machine
6	Limbs contaminated with chemical fluids
7	The eye is injured while machining the workpiece
8	The eye was hit by a splash of a piece of plate
9	Hand injured by sharp edges of the material
10	Hands are pressed when setting material
11	The hand is clamped by the plate clamp
12	Hands crushed by blades
13	Head hit Upper Slide
14	Feet injured as a result of slipping

3.2 RPN calculation

The severity, occurrence, and detection values are calculated based on the data provided by the company, with a predetermined scale, and are the result of discussions with the OSH manager, general affairs manager, and quality assurance manager to assess the correctness of the data. The severity assessment is the level of severity caused by work accidents. Occurrence assessment is obtained from the frequency that occurs during work accidents. The detection assessment is how well the controller can detect the risk of an incident occurring so that there are no work accidents. The risk priority number (RPN) is the priority value of event risk taken based on the company's historical data, which is quantitative. The RPN value is calculated by multiplying severity, occurrence, and detection. RPN calculations results is shown in Table 2.

Table 2 shows that ten incidents have an RPN of more than 100, namely if the sharp edge of the material injures the leg, a falling plate hits the leg, the limb is injured due to a component that is damaged suddenly during the repair, and limbs contaminated with chemical fluids, the sharp edge of the material injures hands; hands pressed when setting the material, plate clamps pinch hands, hands crushed by blades, head hit by slide the upper part, and the injured leg due to slipping. In this study, researchers focused on five events with the highest RPN values to be compared with the highest priority values in the following MAFMA calculation. The five incidents that produced the highest RPN values and became the focus of this research were the foot being crushed by a falling plate; the hand being pressed while setting the material; the hand being pinched by the plate clamp; the hand being crushed by a knife blade; and the head hitting the top of the slide.

Table 2. RPN calculation

Symbol	Incident	S	O	D	RPN
A	Feet injured by sharp edges of the material	4	4	7	112
B	Feet crushed by falling plates	5	4	8	160
C	The limbs are exposed to the electric current	3	3	10	90
D	Limbs injured by components breaking suddenly during repairs	5	3	8	120

Symbol	Incident	S	O	D	RPN
E	The limbs hit the machine parts when moving around the machine	3	3	8	72
F	The limbs are contaminated with chemical fluids	4	3	9	108
G	The eye is injured while machining the workpiece	1	3	8	24
H	A splash of a piece of plate hit the eye	1	3	10	30
I	Hand injured by the sharp edge of the material	4	5	7	140
J	The hand is pressed when setting the material	5	5	9	225
K	Hands clamped plate clamps	5	5	9	225
L	Hands crushed by blades	8	5	10	400
M	Head hit Upper Slide	8	3	10	240
N	The injured leg from slipping	3	4	9	108

3.3 Cost calculation

The calculation of the estimated cost aspect is assessed qualitatively based on the views of the respondents who are responsible for filling out the questionnaire that the researcher has given. Each respondent had a different answer based on his assessment of the costs that might be incurred due to an incident. It calculates the paired matrices between events for the cost aspect. Pairwise comparisons of cost aspects are calculated using the Analytical Hierarchy Process (AHP) weighting. The calculation of the cost aspect here uses the AHP method in which each event will be compared with other events based on which one event is more important than another. The priority calculation for the cost aspect pairwise comparison matrix is depicted in Table 3. It calculates the pairwise matrix between events for the cost aspect. Pairwise comparisons of cost aspects are calculated using the Analytical Hierarchy Process (AHP) weighting. The calculation of priorities for the cost aspect pairwise comparison matrix is also shown in Table 3. In this table, event A will be compared with B, A with C, A with D, and so on. In the first row of the second column, event A is compared with event B and produces a value of 1. A value of 1 indicates that event B is not more important than event A. In the first column's third row, event C is compared with event A and produces a value of 0.531. The value of 0.531 indicates that event C is slightly less critical than event A. The value of events A with B will be inversely proportional to events B with A, and so on. The rightmost column in the table contains priorities, namely the results of the weighting of the AHP calculations. Each event gets its priority based on the weight given before. This priority will be used for the expected cost of local priority, which will then be calculated for global priority.

Table 3. Cost calculation

Criteria	Pairwise Comparison														Priority
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
A	1	2	5	1	1/6	1	1	1	1	1/2	2	5	1	1/5	0,063
B	1/2	1	5	1	1/6	1	1	1	1	1/2	2	5	1	1/5	0,058
C	1/5	1/5	1	1	1/6	1	1	1	1	1/2	2	5	1	1/5	0,046
D	1	1	1	1	1/6	1	1	1	1	1/2	2	5	1	1/5	0,051
E	6	6	6	6	1	1	1	1	1	1/2	2	5	1	1/5	0,115
F	1	1	1	1	1	1	1	1	1	1/2	2	5	1	1/5	0,055
G	1	1	1	1	1	1	1	1	1	1/2	2	5	1	1/5	0,055
H	1	1	1	1	1	1	1	1	1	1/2	2	5	1	1/5	0,055
I	1	1	1	1	1	1	1	1	1	1/2	2	5	1	1/5	0,055
J	2	2	2	2	2	2	2	2	2	1	2	5	1	1/5	0,091
K	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1	5	1	1/5	0,036
L	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1/5	1	1	1/5	0,017
M	1	1	1	1	1	1	1	1	1	1	1	1	1	1/5	0,051
N	5	5	5	5	5	5	5	5	5	5	5	5	5	1	0,253

3.4 *Pairwise comparison of main criteria evaluation*

The next step is calculating the paired matrices between the main criteria. Pairwise comparisons of the main criteria are calculated using the Analytical Hierarchy Process (AHP) weighting. The priority calculation for the main criteria pairwise comparison matrix is presented in Table 4. In this table, the severity criteria will be compared with the occurrence criteria, the severity with detection, the severity with expected cost, and so on. The rightmost column in the table contains priorities, namely the results of the weighting of the AHP calculations. Each event gets its priority based on the weight that has been given before.

Table 4. The main criteria calculation

Criteria	Pairwise Comparison				Criteria
	Severity	Occurrence	Detection	Exp. Cost	
Severity	1	3	1	1/2	0,265
Occurrence	1/3	1	1	1/2	0,155
Detection	1	1	1	1/2	0,193
Exp. Cost	2	2	2	1	0,387

3.5 *Local and global priority evaluation*

The calculation of local priority is the sum of the values previously obtained in the RPN calculation, i.e., the Severity, Occurrence, and Detection criteria. Local priority is the value of each criterion, namely severity, occurrence, detection, and the expected cost. The local priority value of the expected cost has been obtained from a pairwise comparison between events. However, local priority values for severity, occurrence, and detection are calculated using the values in the RPN table. Calculating local priority here is dividing each value by the total number of all criteria values. The calculation of local priority for severity criteria is that for each event, the severity value is calculated divided by the total severity value. This calculation is used to find the value in the decimal form, which, if added up, will all have a value of 1. The local priority calculation for occurrence criteria is by calculating the occurrence value for each event divided by the total occurrence value. This calculation is used to find the value in the decimal form, which, if added up, will all have a value of 1. The local priority calculation for the detection criteria is that for each event, the detection value is calculated divided by the total number of detection values. This calculation is used to find values in the decimal form, which, if added together, will be worth 1.

Calculating global priority is done by multiplying the priority obtained in the pairwise comparison of the main criteria with the local priority of each criterion. Each criterion value in pairwise comparisons with the main criteria. This value is then multiplied by the local priority of each event to obtain global priority for each event at the criteria. Table 5 presents the global priority.

Table 5. Global priority

Criteria	Weight	Incidents	Local Weight	Global Weight	Criteria	Weight	Incidents	Local Weight	Global Weight
Severity	0,265	A	0,068	0,018	Detection	0,193	A	0,057	0,011
		B	0,085	0,022			B	0,066	0,013
		C	0,051	0,013			C	0,082	0,016
		D	0,085	0,022			D	0,066	0,013
		E	0,051	0,013			E	0,066	0,013
		F	0,068	0,018			F	0,074	0,014
		G	0,017	0,004			G	0,066	0,013
		H	0,017	0,004			H	0,082	0,016
		I	0,068	0,018			I	0,057	0,011
		J	0,085	0,022			J	0,074	0,014
		K	0,085	0,022			K	0,074	0,014
		L	0,136	0,036			L	0,082	0,016

Criteria	Weight	Incidents	Local Weight	Global Weight	Criteria	Weight	Incidents	Local Weight	Global Weight
		M	0,136	0,036			M	0,082	0,016
		N	0,051	0,013			N	0,074	0,014
Occurrence	0,155	A	0,075	0,012	Exp.Cost	0,387	A	0,063	0,024
		B	0,075	0,012			B	0,058	0,023
		C	0,057	0,009			C	0,046	0,018
		D	0,057	0,009			D	0,051	0,020
		E	0,057	0,009			E	0,115	0,044
		F	0,057	0,009			F	0,055	0,021
		G	0,057	0,009			G	0,055	0,021
		H	0,057	0,009			H	0,055	0,021
		I	0,094	0,015			I	0,055	0,021
		J	0,094	0,015			J	0,091	0,035
		K	0,094	0,015			K	0,036	0,014
		L	0,094	0,015			L	0,017	0,007
		M	0,057	0,009			M	0,051	0,020
		N	0,075	0,012			N	0,253	0,098

3.6 Total MAFMA evaluation

MAFMA total calculation is the last calculation to find the risk value of each event. The total MAFMA calculation is calculated by adding all the global priorities obtained from each criterion as shown in Table 6. MAFMA total calculation is the last calculation to find the risk value of each event. By adding up the global priority of severity, occurrence, detection, and expected cost, all events with the lowest to highest risk values can be identified. The MAFMA value is a ranking from 0 to 1 in decimal numbers.

Table 6. MAFMA evaluation

Incidents	S	O	D	Exp. Cost	Total	Incidents	S	O	D	Exp. Cost	Total
A	0,018	0,012	0,011	0,024	0,065	H	0,004	0,009	0,016	0,021	0,050
B	0,022	0,012	0,013	0,023	0,069	I	0,018	0,015	0,011	0,021	0,065
C	0,013	0,009	0,016	0,018	0,056	J	0,022	0,015	0,014	0,035	0,086
D	0,022	0,009	0,013	0,020	0,064	K	0,022	0,015	0,014	0,014	0,065
E	0,013	0,009	0,013	0,044	0,079	L	0,036	0,015	0,016	0,007	0,073
F	0,018	0,009	0,014	0,021	0,062	M	0,036	0,009	0,016	0,020	0,080
G	0,004	0,009	0,013	0,021	0,047	N	0,013	0,012	0,014	0,098	0,137

The next step is sorting MAFMA values from the highest to the lowest for each event, and then these values are accumulated made in the form of a percent, as shown in Table 7.

Table 7. Order of the MAFMA score from the highest to lowest score

No	Incidents	MAFMA Score	Cumulative	Percentage (%)	No	Incidents	MAFMA Score	Cumulative	Percentage (%)
1	N	0,137	0,137	13,732	8	K	0,065	0,656	65,604
2	J	0,086	0,224	22,380	9	I	0,065	0,721	72,095
3	M	0,080	0,304	30,392	10	D	0,064	0,784	78,449
4	E	0,079	0,383	38,315	11	F	0,062	0,847	84,673
5	L	0,073	0,456	45,626	12	C	0,056	0,902	90,246
6	B	0,069	0,526	52,568	13	H	0,050	0,953	95,281
7	A	0,065	0,591	59,087	14	G	0,047	1,000	100,000

3.7 Pareto chart

As shown in Table 7, event N is the event with the highest MAFMA value compared to other events. Ordering events from highest to lowest is used for Pareto chart input. The Pareto diagram in this study uses the 80/20 principle, 20% of problems have an 80% impact, and only 20% of the problems are essential; the rest are not important issues. The Pareto diagram can be seen in Figure 1. As shown by the Pareto diagram, events N and J account for 20% of the 80% of the accidents. These events are injured feet due to slipping and hand pressure during material setting. Proposed improvements are focused on these two events because they are based on the Pareto principle, the 80/20 principle.

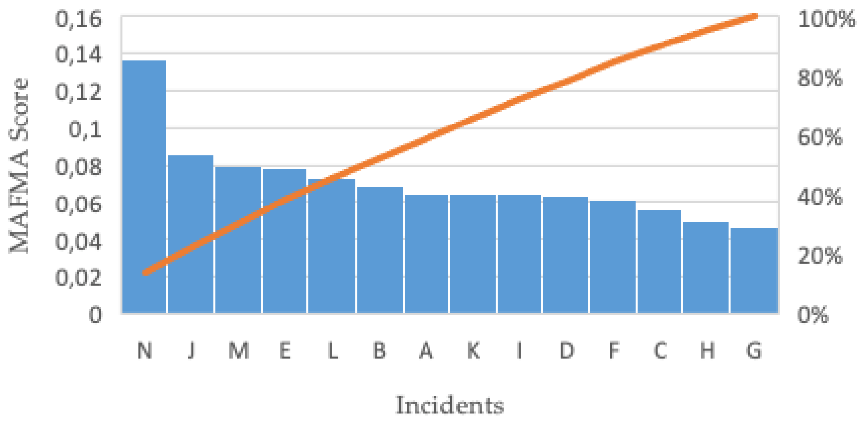

Figure 1. Pareto diagram of MAFMA score

3.8 Comparative analysis of FMEA values with MAFMA values

Comparative analysis of FMEA and MAFMA values is needed to see how far the difference between the two methods will be compared. A recapitulation of the comparison of FMEA and MAFMA values as shown in Table 8.

Table 8. A recapitulation of FMEA and MAFMA values comparison

Ranking	Incidents	
	FMEA	**MAFMA**
1	L	N
2	M	J
3	J	M
4	K	E
5	B	L
6	I	B
7	D	A
8	A	K
9	F	I
10	N	D

Table 8 summarizes the comparison of the FMEA and MAFMA methods. Each method has ten different highest-risk events. The table shows that there were nine incidents from the same two methods. The MAFMA and FMEA methods give slightly different results because the FMEA method does not consider the cost factor. The FMEA method is a quantitative method for calculating the risk value of an event. In contrast, the MAFMA method is qualitative and then converted into quantitative through weighting based on AHP results. MAFMA is a method developed to overcome the weaknesses found in FMEA. The analysis technique developed from FMEA is an analytical approach used to determine potential causes of failure (Kristyanto et al., 2015). The difficulty in implementing FMEA is related to the "live" evaluation/quantification of various factors. The Analytical Hierarchical Process (AHP) technique overcomes this by integrating the original FMEA aspects and economic considerations (Adam & Tarigan, 2022). The FMEA method is a reasonably valid method for determining the highest risk of an event. Meanwhile, the MAFMA method is also considered valid for determining the highest risk of an event because this method combines the FMEA method with the AHP method for its weighting. In Table 8 it can be seen the ranking of events from the two methods. The difference in ranking is in the event F in the FMEA method and E in the MAFMA method. The thing that causes the difference in the ranking of each event in the two methods is that in the FMEA method, the occurrence of limbs contaminated with chemical fluids (F) causes more severity compared to other events, including the occurrence of limbs hitting machine parts while doing activities around the machine (E). In the MAFMA method, the incident of limbs colliding with machine parts while doing activities around the machine (E) incurs more costs than other incidents, including limbs contaminated with chemical fluids (F). The costs incurred by the company for healing bodily injuries are of greater value than treatment due to contamination of chemical fluids.

3.9 Proposed Improvements

The events that are the focus for making proposed improvements are two out of 14 events with the highest risk value from the MAFMA method, which has been determined using a Pareto chart. Incidents that require this proposed improvement are injured feet due to slipping and pressure on the hands when setting the material. The two accidents were caused by the workers' lack of awareness of using personal protective equipment, the production area was not well-lit/dark, and there was no standard work and instructions. Several suggestions for improvement based on overcoming the two incidents with the highest FMEA and MAFMA values. These suggestions include requiring workers to wear personal protective equipment, sufficient lighting, work instructions are needed and workers must pay attention to work procedures and machine conditions. Requiring workers to wear personal protective equipment (PPE) is the first preventive suggestion to reduce injuries caused by accidents that may occur in production areas. According to OSHA (1995) , PPE is a tool used to protect workers from injury or illness caused by contact with hazards in the workplace, whether chemical, biological, radiation, physical, electrical, mechanical, and so on. Adequate lighting is essential to provide lighting in the production area. Inadequate lighting can cause accidents. According to the Decree of the Minister of Health No.1405 (2002), lighting is the amount of irradiation in a work area needed to carry out activities effectively. Work instructions and understanding work procedures are efforts to prevent accidents, including paying attention to the machine's condition, ensuring the machine are safe and ensuring the availability of machine safety devices when an accident occurs, and paying attention to the distance between machines.

4. Conclusion

The goal of this study is to identify the risk of work accidents, classify those risks according to their most important effects, and then offer suggestions for improvements to address the risks of work accidents with the greatest impact. A case study was undertaken in a metal manufacturing company. The Multi-Attribute Failure Mode Analysis (MAFMA), which combines the Failure Mode and Effect Analysis (FMEA) and Analytic Hierarchy Process (AHP), was implemented. It was found that based on the identification process, as many as 14 work accident risk events had occurred at the company. A work accident risk classification of the 14 risk events was then carried out using the Multi-Attribute Failure Mode Analysis method and a Pareto diagram; 2 risk events had a significant impact. These risks include hands being pressed when setting material and feet being injured due to slipping. The suggestions included requiring workers to wear personal protective equipment (PPE) in the production area, adequate lighting, making work instructions, paying attention to work procedures, and paying attention to machine conditions. This research has limitations as the cost was evaluated qualitatively, hence, future research needs to combine both qualitative and quantitative approach.

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