www.bircu-journal.com/index.php/birci
Budapest International Research and Critics Institute-Journal (BIRCI-Journal)
Humanities and Social Sciences
ISSN 2615-3076 Online)
ISSN 2615-1715 (Print)
Budapest Institute

Work Accident Analysis to Increase Work Productivity Using Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) Methods at PT. XYZ

Qurratul Aini[1], Rusindiyanto[2]
[1,2] *Fakultas Teknik, Universitas Pembangunan Nasional Veteran Jawa Timur*
qurratulaini301099@gmail.com, rusindiyanto4@gmail.com

Abstract

One of the important aspects that play a role in Increasing company productivity is work safety and security. Work carried out in workshops often causes work accidents. With this system, the company will be able to minimize the rate of work accidents, decreasing the accident rate and the severity of accidents from year to year will increase the productivity of the company's workforce. Based on this phenomenon, the purpose of this study is to determine work accidents and the effect of productivity on the workshop so as to increase work productivity and propose improvements to reduce work accidents in the workshop. The research was conducted by looking for the frequency of accidents, the severity of accidents, the tendency of accidents and the level of work productivity, and also using the FMEA and FTA methods. Based on the results of research on the level of work productivity in 2017, 2018, 2019, and 2020 of 0.0047; 0.0045; 0.0047; and 0.0051. In 2017 to 2018 it decreased, in 2018 to 2019 it increased by 4.44% and in 2019 to 2020 it increased by 8.52%. From the FMEA calculation, the highest RPN value was obtained, namely an accident that caused a torn hand with a value of 52 due to sleepy workers, lack of experience and lack of training. From the calculation of the FTA with a torn wrist accident, a probability of 0.03 is obtained. This figure shows that the accident is natural, if the probability is close to 1, the accident is unnatural and very dangerous and detrimental.

Keywords
fishbone diagram; FMEA; FTA; work accident; productivity

I. Introduction

Occupational safety and health as part of human rights is a sharp focus in the implementation of the production process. So far, the role of the occupational safety and health (K3) sector in the company is still not getting enough attention. Whereas in the era of globalization the role of K3 as an effort to minimize work accidents is an absolute requirement. PT. XYZ is a company engaged in the assembly of building and household materials made of stainless steel. PT. XYZ also has many work accidents, especially in the workshop, accidents often occur every year. One important aspect that plays a role in increasing company productivity is work safety and security. With a good work safety and security system, the company will be able to minimize the rate of work accidents for workers in the company, so that work productivity will increase. Organization must have a goal to be achieved by the organizational members (Niati et al., 2021). The success of leadership is partly determined by the ability of leaders to develop their organizational culture. (Arif, 2019).

DOI: *https://doi.org/10.33258/birci.v5i2.5345*

In various fields, especially in organizational activities, the human aspect is the main problem of every activity in the organization. Organizations have various resources that are considered as "inputs", which can be converted into "outputs" either in the form of services or goods. These types of resources consist of people, capital, technology used to support the production process, operating methods or strategies, and others. Of all these resources, the human aspect is the most important factor (Dewi & Harjoyo, 2019).

Productivity basically includes a mental attitude that always has the view that the quality of life must be better than yesterday and tomorrow better than today. So, in general, productivity is defined as a comparison between what is produced (output) and input (input). Specifically, productivity can be defined as the ability to produce something which includes increasing efficiency and speed of producing a product which is the result of a combination of effectiveness, efficiency and economy. Work safety is an effort to protect the production process, ensuring that everyone in the workplace is always in a safe condition. Work safety can help increase production. The way to deal with work accidents is to eliminate the elements that cause accidents and or hold strict supervision. (Masrofah & Michael 2020).

From the data obtained, there were previous accidents in 2017 there were 5 incidents, in 2018 there were 4 incidents, in 2019 there were 4 incidents and 2020 there were 3 accidents. Some of these accidents were accidents that occurred in the 2017-2020 period, such as those caused by grinding stones that caused the right eye to be short (red and sore) and there were also accidents such as a torn wrist due to the SS plate and this accident was classified as a fairly serious accident because it required medical care from a doctor. In this study, an analysis of work accidents was carried out using the FMEA and FTA (FTA) methods to minimize the rate of work accidents because occupational safety and health is very necessary and very important in helping the realization of good work productivity so as to increase work productivity in order to create work welfare.

II. Review of Literature

2.1 Occupational safety and health

By definition, an accident is an unplanned and unexpected event that can cause human, property, and environmental casualties as well as business opportunities. While work safety is defined as an effort to protect people from physical injury. Occupational health is defined as an effort to protect the human body and mind from diseases caused by materials, processes and work implementation. While the definition of occupational safety and health, hereinafter abbreviated as K3 according to PP No. 50 of 2012 are all activities to ensure and protect the safety and health of workers through the prevention of work accidents and occupational diseases. (Fassa, 2020)

2.2 Work Accidents

According to Notoatmodjo (2003) quoted by Aini (2020), work accidents are caused by 2 main factors, namely physical factors and human factors. Therefore, work accidents are also part of occupational health. Work accidents are unexpected and unexpected events resulting from work.

2.3 Work Productivity

According to Kusriyanto (2000:2) quoted by Sakutra (2017), work productivity is the comparison between the results achieved and the participation of the workforce per unit time. Meanwhile, according to Hasibuan (2003: 105) quoted by Saptra (2017), work

productivity is the ratio between *output* and *input*, where *output* must have added value and better processing techniques.

a. Types of productivity

When grouped, there are three basic types of productivity (Gasperz, 2000) cited by Pasaribu, et al (2017). These three basics are the simplest productivity measurement models based on the *output*/*input*, namely:

1. Partial productivity

Comparison of output to one input factor. For example, labor productivity (the ratio of labor output and input) is one measure of partial productivity. In the measurement of partial productivity, the productivity of the specific process unit can be measured.

2. Factor-total productivity The

Ratio of output to the amount of labor and capital. Net output is total output minus the number of goods and services purchased. Based on the above factors, the types of *inputs used* in the measurement of total factor productivity are only labor and capital.

3. Total productivity

The ratio of output to the total number of input factors, the measurement of total factor productivity reflects the joint effect of all inputs in producing output.

2.4 Measurement of work productivity

a. Accident frequency rate (FR)

Is a parameter used to calculate the frequency of work for every million hours worked by people.

$$FR = \frac{number\ of\ work\ accidents}{total\ man\ ,..} x\ 1{,}000{,}000.(2.1)$$

Information:

FR (n) = Number of current work accident frequency

(andrianto2017)

b. Accident Severity (SR)

Is a parameter used to calculate or measure the severity of the total lost workdays for every million people worked hours.

$$SR = \frac{It}{..} x\ 1{,}000{,}000.(2.2)$$

Note:

SR = *safety rate* (Accident severity)

andriantoIt = the number of *lost time*

tOthe = number of hours people worked

, 2017)

1. *Safe-T-Score* (STS)

   Used to show changes in the number of accidents.

$$STS = \frac{FR2-FR1}{FR1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2.3)$$

Remarks:

STS = *safety T Score* (accident tendency number)

FR2 = current accident frequency

FR1 = past accident frequency

- STS between +2.00 and -2.00 does not show a change
- STS above +2.00 indicates bad condition
- STS below -2.00 indicates improving condition

(andrianto, 2017)

2. Data analysis technique to calculate work productivity
3.

$$P2 = \frac{Op2}{tO2-\Sigma It2} x\ 100\% \text{.....(2.4)}$$

Information:
P = work productivity
andriantoop = total *output* production
tOnumber of hours people work

, 2017)

2.5 Failure mode and effect Analysis (FMEA)

According to Gaspersz (2002) cited by (pasaribu, et al. 2017), *Failure mode and effects*Analysis *(*FMEA) is a circular risk analysis technique used to identify how equipment, facilities/systems can fail and the consequences that can be generated. The results of the FMEA are in the form of recommendations to improve the reliability of the safety level of facilities, equipment/systems. In the context of Occupational Health and Safety (K3), the failure referred to in this definition is a hazard that arises from a process. Prevention of work accidents can be done by controlling the occurrence of work accidents that have a high risk both in terms of consequences, possibility of occurrence and ease of detection. Based on this, FMEA is the right method to do because the FMEA method measures the level of risk of work accidents conventionally based on three parameters, namely *Severity* (S), *Occurrence* (O) and *Detection* (D).

1. Identification of potential work accidents

At this early stage, identification of potential work accidents that can occur in building construction projects is carried out based on the findings of previous studies.

2. Determination *severity* (S), *occurrence* (O) and *detection* (D)

After obtaining the risk item, the next step is to determine the severity*S*), the probability of occurrence *(*O) and detection *(*D). The determination of the rating is obtained through a brainstorming process with parties who are considered experienced in the project under study. The determination of the three ratings will greatly determine the process of prioritizing the risk list/critical risk determination.

a. Severity

Severity rating associated with the most serious effect for a given failure mode based on the criteria of the severity scale. It is a relative rank within the scope of a specific FMEA and determined without regard to probability of occurrence or detection. Table I severity scale (*severity*).

Table 1. Severity scale (*severity*)

Rating	Criteria
1	Negligible *Severity* (negligible bad influence)
2	Mild *Severity* (mild bad influence)
3	
4	Moderate *Severity* (moderate bad influence)
5	
6	
7	High *Severity* (high bad influence)
8	
9	Potential *Severity* (very high adverse effect)

10	

Source: gaspersz, 2002 quoted by pasaribu, et al (2017)

b. Occurrence (O)

Occurrence (Occurrence)is a rating associated with the probability that a failure mode and its associated causes will be present in the item analyzed. For FMEA systems and designs, the occurrence rating considers the probability of occurrence over the design life of the product. for the FMEA process the occurrence rating considers the probability of occurrence during production. based on the criteria of the appropriate event scale. Incidence ratings have relative significance rather than absolute values determined regardless of severity or likelihood of detection.

Table 2. event scale (*occurrence*)

Degree	Based on the frequency of occurrence	Rating
Remote	0.01 per 1000 items	1
low	0.1 per 1000 items	2
	0.5 per 1000 items	3
Moderate	1 per 1000 items	4
	2 per 1000 items	5
	5 per 1000 items	6
High	10 per 1000 items	7
	20 per 1000 items	8
Very high	50 per 1000 items	9
	100 per 1000 items	10

Source: gaspersz, 2002 quoted by (pasaribu, et al.2017)

c. Detection

Detection.is a rating that corresponds to the best control from a list of control types of detection based on the criteria of the detection scaleThe detection rating considers the probability of detection of a failure mode/cause, according to defined criteria. detection is a relative rank within the scope of a specific FMEA and is determined regardless of severity or likelihood of occurrence.

Table 3. Detection scale*Rating*method

Criterion	1
Prevention	is very effective. No chance of a possible
2	probability of a cause occurring is very low
3	
4	the probability of a cause occurring is moderate. Prevention methods sometimes allow the cause to occur.
5	
6	
7	The probability of this happening is still high. Prevention methods are less effective.
8	
9	The possibility of this happening is still very high. Prevention methods are not effective. The cause is still recurring.
10	

Source: gaspersz, 2002 quoted by (pasaribu, et al. 2017)

d. Risk priority number (RPN)

The risk of each potential mode of failure / cause, consisting of a calculated product of three elements: the severity of the effect, the likelihood of the cause occurring, and the probability of detecting the cause.

$$RPN = Severity\ x\ occurrence\ x\ detection$$

2.6 Fishbone Diagram

Cause and effect diagram is a diagram that shows the relationship between cause and effect. This causal diagram is often referred to as fishbone diagram because it looks like a fish skeleton, or an Ishikawa diagram because it was first introduced by Prof. Kaour Ishikawa from the University of Tokyo 1953 (Gaspersz, 1998) quoted from Putra (2019). In this method, the level of causes from various sectors will be obtained after going through the FTA and FMEA stages. The method that will explain in a simple and detailed way is from the *machine, method, person, material*, and *environment* of a type of defect that is a priority for improvement. This step is a simple way to find the cause of work accidents.

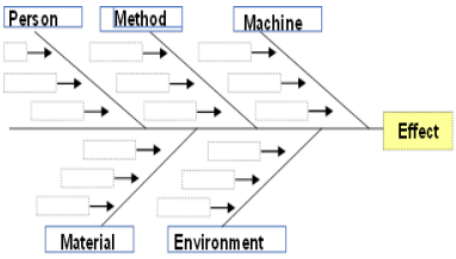

Figure 1. *Fishbone (Vincent Gaspersz.1998) quoted from Putra (2019)*

2.7 Fault tree analysis

Fault tree analysis is an analytical tool that translates graphically the combinations of errors that cause system failure. This technique is useful in describing and assessing events in the system (Foster, 2004) quoted from Bastuti (2019). The starting point of FTA analysis is the identification of failure modes at the top level of a system. A *fault tree* illustrates the state of system components (*basic event*) and the relationship between *basic events* and *top events*. FTA is a deductive reliability analysis technique and safety analysis which is generally used for complex dynamics. As used today, the FTA is a logical and graphical model that represents various combinations of undesirable events. FTA uses tree diagrams to show the cause-and-*effect* of events.

To build a *fault tree*, starting from determining the unwanted failure event or *top event*, then looking for the failure event that caused it, until other basic failures are obtained or also called *basic events* that can cause *the top event*. After the *fault tree* is built, the system failure will be analyzed with Boolean algebra that corresponds to the shape of the *fault trees* that later it will get several *basic events* and their combinations where if *the basic event* occurs, then the *top event* also occurs.set *basic* is called *minimal cut set*. Analysis to get the failures that lead to *the top event* is called qualitative analysis. In addition, qualitative analysis can also be done, namely to obtain the probability of the occurrence of *top events*.

III. Research Method

3.1 Start

Starting is the first step of a research activity.

3.2 Literature study and field study

Data collection as a theoretical basis used as a guide in analyzing the object to be studied, can be obtained from various literatures and field studies to obtain data as data processing material.

3.2 Formulation of the problem

Formulation of the problem is prepared based on the background of the existing problem and then the appropriate method is determined in solving the problem. The problem that will be used as the subject of discussion in the research is how to improve the application of work safety to increase work productivity at PT. XYZ.

3.3 Research Objectives

The objectives of the research are the objectives to be achieved in this study are: To

- find out work accidents and the effect of productivity on the workshop.
- Analyzing the risk of accident failure using the FMEA method and fishbone diagrams.
- To identify the root causes of accidents and the probability of work accidents using the FTA method.

3.4 Identification of Variables

Identifying variables based on problems obtained when conducting literature studies and field studies, so that independent and dependent variables can be known from this research.

3.5 Data Collection

Researchers collect data and information needed by companies to solve problems. The data needed include:

- Data on the number of work accidents.
- Data on the number and hours of work of employees.
- Data on the number of hours lost by employees
- . Types of work accidents.
- data.
- Factors causing work accidents

3.6 Production

a. Processing the measurement of work safety results

- Calculating the value of frequency rate, severity rate and safe T-score and data analysis to calculate work productivity

b. FMEA data processing

- Determining the rating of severity, occurrence, detection
- Calculation of RPN value
- diagram Fishbone

c. FTA data processing

- Creating a fault tree, starting from the top event to the bottom event (as an FTA diagram)
- Determination of the cut set method (Boolean algebra)

- Calculating the probability of an accident on the FTA diagram

d. Results and Discussion Analysis

From the calculation results, then analysis and discussion is carried out based on the existing problems.

e. Conclusions and Suggestions

This is the final stage of the research, namely drawing conclusions from a series of research steps carried out so that they can provide the best solutions and give suggestions for research.

f. Done.

IV. Result and Discussion

4.1 Data collection

In this study, in the completion of using the FMEA method, 25 respondents in *the workshop* were asked to fill out a questionnaire. By asking questions in writing on the research subject with a view to obtaining data about *severity, occurrence,* and *detection.* For FTA data and determining work productivity, direct observation is carried out on the object under study (at *the workshop*) so that the process can be clearly understood. The research data are the number of accidents, working hours and the number of employees.

Table 4. work accidents in 2017-2020

Year	Month												total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2017	-	-	-	1	-	-	2	-	-	1	1	-	5
2018	1	-	1	-	-	-	-	-	1	1	of	-	4
2019	1	-	-	1	-	-	1	-	1	-	-	-	4
2020	-	1	-	-	-	-	1	-	1	-	-	-	3
total													15

Source: Data PT. XYZ

PT. XYZ applies on-shift working hours with working days, namely Monday-Saturday for 9 hours, with working hours at PT. XYZ is Monday to Friday at: 08.00 - 17.00 WIB.WIB, this means the number of working hours per day is 8 hours for *12.00-13.00*each employee. At PT. XYZ gets one day off in 1 week, namely on Sundays and national holidays and also includes rest time.

Table 5. Number of workers in the *workshop* PT. XYZ year 2017-2020

Year	Number of workers (persons)	Total effective working hours per day	Total effective working days per year	Number of effective working hours per year	Total working hours people (number of hours worked a year – number of absences)
2017	24	8	299	57,408	57,256
2018	24	8	294	56,448	56,352
2019	25	8	296	2020	59,200 59,136
26	8	295	61,136	61,088	Source

: Data PT. XYZ

4.2 Data Processing

Based on the data obtained, then data processing is carried out to determine:

- The level of frequency of work accidents (FR)
- The level *severity* or severity of work accidents (SR)
- Measurement of safe T Score (STS)
- Productivity

Based on the calculation of the frequency of work accidents, the results can be seen in Table VI, the level *severity* or severity of work accidents, can be seen in table VI, the value of safe T score (STS) can be seen in table VII and productivity data can be seen in table VIII.

Table 6. The frequency of work accidents in the *workshop* in 2017-2020

Year	Number of work accidents	FR
2017	5	87
2018	4	71
2019	4	68
2020	3	49

Table 7. Severity level *of* work accidents in the *workshop* 2017-2020

Year	Number of hours lost	Number of hours worked	SR
2017	152	57256	2655
2018	96	56352	1704
2019	64	59136	1082
2020	48	61088	786

This means that in a year approximately 2655 hours are lost for every 1,000,000 hours worked or 2655hours per million hours worked.

Table 8. Safe T score (STS) measurement data in the *workshop* for 2017-2020

Year	Number of working hours	FR1	FR2	STS
2017	57256	-	87	-
2018	56352	87	71	-0.18
2019	59136	71	68	-0.04
2020	61088	68	49	-0, 28

Safe T Score (STs) is a number that has no dimensions. The meaning of positive STs indicates a worsening situation while a negative number indicates an improving condition.

Table 9. The level of productivity in the *workshop* 2017-2020

Year	Total production	number of hours worked	Hours lost	productivity
2017	269	57256	152	0.0047
2018	254	56352	96	0.0045
2019	275	59136	64	0.0047
2020	315	61088	48	0.0051

Example of calculation productivity levels are as follows:

$$Productivity = \frac{269}{57408 - 152} = 0.0047$$

a. Failure mode and effect analysis (FMEA)

- Identifying the Seriousness of the Consequences (*Severity*)

Determines the *severity failure* mode which shows the level of seriousness of the consequences or effects of the occurrence of work accidents.scale *severity* is 1-10.scale *severity failure* mode is determined by the *severity failure effects*. The following table X is the result of the *severity*.

Table 10. Rating table *Severity*

Type of accident	No.	Accident case	S
Torn	1.	Wrist hit by cutting machine	3.48
Damage to eyes	2.	Eye caught by welding sparks	2,4
	3.	Eye exposed to paint spray	2.64
	4.	Eye exposed to grinding splash	2.56
	5.	Eye exposed to welding flue gas	3.08
	6.	Eyes exposed to welding fire	2.24
Burned	7.	Left calf burned by welding fire	2.56
	8.	Treat burns from welding sparks	2.88
Sprains and injuries	9.	Feet and hands injured by loose grinding	3 ,56
	10.	Slipping*a set* while running, stepping on a tool	2.16

Source: self-processed

- Identifying *occurrences* that occur

Occurrence using a scoring form on a scale of 1 failure never occurred) to 10 (failure occurs at least once a day). The results of the assessment for occurrence can be seen in table XI below where the results of the assessment are based on observations, interviews and discussions with K3 parties from PT. XYZ.

Table 11. assessment *occurrence*

Type of accident	No.	Accident case	O
Torn	1.	Wrist hit by cutting machine	2.32
Eye	2.	Eye exposed to welding spark	5.68
	3.	Eye exposed to paint spray	2,4
	4.	Eye exposed to grinding splash	6.12
	5.	Eye affected exhaust gas welding	2.2
	6.	Eyes exposed to welding fire	4.12
Burning	7.	Left calf burned by welding fire	2.92
	8.	Treating burns from welding sparks	4.44
Sprains and injuries	9.	Feet and hands injured by loose grinding	2 ,84
	10.	Terpele*set* while running, stepping on tools	2.12

Source: self-processed

- Identifying detection method and detection rating

Similar to determining *severity* and occurrence values by using detection rating by Stamatis, detection method and detection rating can be determined. The detection rating value of the problems studied can be seen in the following table 12:

Table 12. assessment table *Occurrence*

Type of accident	No.	Accident case	D
Torn	1.	Wrist hit by cutting machine	6.44
Eye	2.	Eye exposed to welding sparks	2,4
	3.	Eye exposed to paint spray	3.36
	4.	Eye exposed to grinding splash	2.12
	5.	Eye exposed to exhaust gas welding	3.2
	6.	Eyes exposed to welding fire	4
Burned	7.	Left calf burned by welding fire	5.68
	8.	Treat burns from welding sparks	3.48
Sprains and injuries	9.	Feet and hands injured by loose grinding	4.88
	10.	Terpeles*et* while running, stepping on the tool	3.68

Source: processed by yourself

- Calculation of *Risk priority number* (RPN)

The RPN value is obtained from the multiplication of *severity*, occurrence, and *detection* where the purpose of calculating the RPN value is to find out the sequence *failure* modes that must be prioritized to be addressed first. The results of the RPN calculation can be seen in the following table 13:

Table 13. RPN calculation results

Type of accident	No.	Accident cases	S	O	D	RPN
Torn	1.	Wrist cut by cutting machine	3,48	2,32	6,44	52.0
Eye	2.	Eye caught with welding spark	2,4	5,68	2,4	32,7
	34.	Eyes exposed to paint spray	2.64	2.4	3.36	21.3
	5.	Eyes exposed to grinding splashes	2.56	6.12	2.12	33.2
	exposed	to welding flue gasses	3.08	2.2	3, 2	21.7
	6.	Eyes caught in welding fire	2.24	4.12	4	36.9
Burned	7.	left calf by welding fire	2.56	2.92	5.68	42.5
	8.	Handle burnt welding sparks	2, 88	4.44	3.48	44.5
Sprains and injuries	9.	Feet and hands injured by loose grinding	3.56	2.84	4.88	49.3
	10.	Slipping The *set* while walking, stepping on tools	2.16	2.12	3,68	16,9

From the table above, it can be seen that the incidence of accidents along with their assessment (RPN). The table also shows the differences in accident cases with different values, then the RPN value is analyzed and the cause is searched using a *fishbone*.

b. Fishbone Diagram

Fishbone method *analysis* that can be called an Ishikawa diagram or fishbone diagram**.** the method *fishbone* in this study analyzes the results of the FMEA analysis more precisely on the results of the highest RPN value, namely the type of tearing accident with the incidence of torn wrists being hit by a cutting machine.

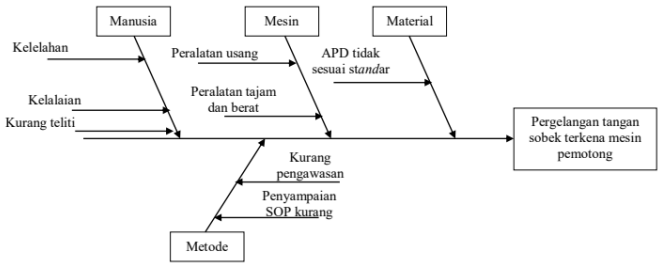

Figure 3. *Fishbone torn wrist (highest RPN*)

From Figure 2 above, it can be seen that the factors causing work accidents that have the highest RPN value that occurred in *the workshop*, the following is a discussion of the *fishbone* above.

- Human

Factors that cause work accidents from the human side are due to the level of fatigue, workers not complying with existing SOPs, lack of awareness of the importance of work safety and lack of accuracy at work. In *the workshop* expertise of the existing workers tends to be obtained from a self-taught process so that the method used is sometimes not in accordance with the SOP, which causes workers to not comply with the existing SOP. This causes workers to work in their own way, which has the potential to cause work accidents.

- Machinery

Factors that can cause a work accident on the equipment side are tools that are outdated and also a lot of sharp and heavy equipment that can be a potential hazard for workers.

- Material

The factor that causes a work accident on the material is the lack of PPE that meets the standards.

- Method

Factors that can cause a work accident in the work method are the delivery of the SOP in the workbench which is still not optimal and also the lack of supervision from the leadership of the workers so that workers tend to pay less attention to safety while working

c. Fault tree analysis (FTA)

Furthermore, potential sources of accidents occurring in the company can be identified by building a fault tree (*fault tree*), namely a fault tree analysis can simply be described as an analytical technique. This is done to determine the relationship between *top events*, with intermediate *events* with *basic events*. The results of the depiction of the FTA using the results of the highest RPN value can be seen below.

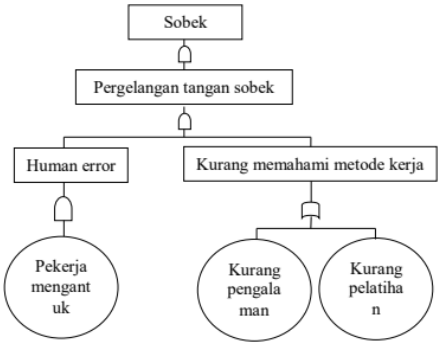

***Figure 4**. Torn wrist FTA*

After making a fault tree, the next step is to analyze it quantitatively and qualitatively. To analyze quantitatively and qualitatively the *fault tree* obtained above, will first search for the minimum *cut* set using Boolean algebra. After obtaining the minimum *cut* set, qualitative analysis will find failures that lead directly to the occurrence of *top events* and quantitative analysis using *top events* happen.

Minimum *cut set* for accidents that cause a torn wrist, for example:

T = torn
G1 = torn wrist
G2 = human error
G3 = lack of understanding of work methods
P1 = sleepy worker
P2 = lack of experience
P3 = lack of training

By placing each example in the appropriate place, According to Figure 4, a *fault tree* as shown below:

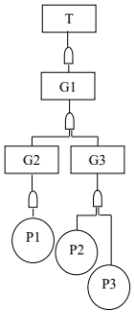

***Figure 5**. Torn wrist FTA.*

equation can be obtained *boolean*:

T = G1
G1 = G2 + G3
G2 = P1
G3 = P2 + P3

Using the top-down approach, we get:

T = G1 (because G1 = G2+G3)
= G2+G3 (because G2 = P1 and G3 = P2 + P3)
= P1 + P2 + P3

Then the minimum *cut set* of Figure 4.7 is {P1}, {P2}, {P3}

- Qualitative

Analysis The results of a qualitative analysis of a work accident that resulted in a torn wrist with a *top event* that is tear is *top an event* occurs if the following events occur, namely:

a. sleepy workers
b. lack experience,
c. lack of training.

By knowing the causes of work accidents that result in torn wrists, it is possible to overcome such incidents and as much as possible prevention must be done by emphasizing the parts as above.

- Quantitative

analysis Quantitative analysis of FTAs provides particular benefits, but as a combination of minimal *cut sets*. Then the probability of the top *event* can be estimated by the sum of the probabilities of each *cut set*. Know the probability of failure on each *base event* (p*and*ey,2005):

Table 14. Probability of work accidents resulting in tearing

Symbol	Description	Probability
P1	Sleepy worker	0.01
P2	Lack of experience	0.01
P3	Lack of training	0.01

Minimum *cut the set* obtained from quantitative analysis is {P1}, {P2}, {P3}, then from the *basic event* , the probability of a tip *event* (T) occurring is

T = P1+P2+P3

= 0.01 + 0.01 +0.01 = 0.03

Then the probability of a work accident causing injury / bruise sprain/of a known probability of 0.03. This number shows that the accident is natural, if the probability number is close to 1, the accident is unnatural and very dangerous and detrimental.

d. Recommendations for improvement

Based on the calculation of the value of the RPN (*risk priority number*), it can be seen the causes of process failures that result in work accidents.value from the highest to the lowest and then recommendations or repair solutions can be given for *RPN*each cause of the accident.

Table 15. Recommendation or improvement solution

No.	Accident	RPN	Recommendations or repair solutions
1.	Wrist was torn by the cutting machine due to negligence of workers and chatting with other workers.	52.0	Employees should be emphasized to be more careful in using tools or machines and to follow existing work instructions and not to chat while working.
2.	Feet and hands injured by loose grinding	49.3	Employees are emphasized and are required to check the condition of the machine first to avoid accidents, *after it* has been checked and it is safe, the machine can be used.
3.	Hands are burned by welding	44.5	Instructed employees to be more

	sparks, while welding while chatting with other employees so that they do not *focus* on work (negligence).		careful and given sanctions for employees who do not use personal protective equipment at work and given sanctions if they do not follow the existing work instructions
4.	Left calf burned by welding fire, the fire was too big	42.5	It is recommended to all employees to always work every day and to avoid accidents at work.
5.	Eyes hit by welding fire, not wearing glasses	36.9	Sanctions are given to violators, and if the company still repeats the mistake, it will be followed up.
6.	Eyes get splashed by grinding, because they *safety*	glas ses	not
we ar	dowelding fire, not using the face shield perfectly	32.7	Sanctions are given to violators, and if the company still repeats the mistake, it will be followed up.
8.	Eyes exposed to welding exhaust	21.7	Sanctions are given to employees who do not use personal protective equipment while working
9.	Eyes are exposed to paint spray when checking the condition *sprayer* of the jammed	21.3	Employees are emphasized to be more careful in using tools and following existing work instructions
10.	Slipping The *set* while walking, stepping on tools	16.9	*After Completing* their work, employees must clean it neatly.

IV. Conclusion

The conclusions obtained in this study at PT. XYZ is as follows:

1. Based on the results of measurements and analyzes that have been carried out, it can be concluded that the frequency of work accidents affects productivity, the severity of work accidents affects productivity and productivity measurements in 2017, 2018, 2019 decreased by 0.0047 ; 0.0045; 0.0047 due to frequent accidents compared to 2020 which increased by 0.0051.
2. Based on the measurements and analyzes that have been carried out, it can be concluded that after the calculation, the highest RPN value is 52 with a torn wrist accident, where the work accident factor is divided into 4 factors in the fishbone , namely humans, machines, materials and methods. Where is the human factor that affects fatigue, negligence, lack of accuracy at work. The machine factors that affect are obsolete equipment, heavy and sharp equipment, from the material side, the APD is not up to standard and in terms of methods, lack of supervision and lack of SOP delivery.
   The suggestions for improvement that can be given include the need for stricter supervision of workers so that workers can concentrate more when working and workers can work in accordance with existing SOPs, providing PPE that meets standards for workers, creating a conducive work environment so that workers are comfortable. while working.
3. based on FTA qualitative analysis of work accidents resulting in torn wrists, the causes: sleepy workers, lack of experience, lack of training. Based on the quantitative probability of the occurrence of a work accident that causes a torn wrist from a known

probability of 0.03. This figure shows that the accident is natural, if the probability is close to 1, the accident is unnatural and very dangerous and detrimental to workers and the company.

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