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Maintenance Cost Analysis Using Cost of Unreliability (COUR) Method with Business Consequence Analysis: A Case Study of a Shot Blast Machine

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Abstract. *Losses caused by unreliable machines in a production line will affect the total cost losses from a manufacturing company's production process. Based on historical data of damage that has been obtained from the maintenance department of XYZ companies, the MACH MWJ 9/10 Shot Blast Machine is the machine that has the highest-level frequency of damage. This machine is useful for cleaning sand or residual production dirt that sticks to workpieces that have been cast in the casting process, especially for E-Clips components. The research's purpose is to determine the value of cost losses due to machine unreliability using the Cost of Unreliability (COUR) method, with Business Consequence analysis (BC) analysis. The cost effects of these costs include Corrective COUR and Downtime COUR. The final calculation of COUR shows that the total cost of COUR Downtime caused by the unreliability of the machine is greater than the total Corrective COUR. After calculating the COUR, an analysis of the business consequences resulting from the machine's unreliability is carried out using a risk matrix. The analysis results show that the shot blast machine's critical components are in the red or high-risk category and have a very high Probability of Failure (PoF). The results of COUR analysis with business consequence analysis will be an input for the company to make a machine maintenance system policy, especially for the MACH MWJ 9/10 Shot Blast machine's critical components. In general, this research's novelty is to combine the application of the Cost of Unreliability method with an analysis of the effects of the Business Consequence caused by the machine's selected critical components.*

Keywords: *Cost of Unreliability, Maintenance, Corrective, Downtime, Business Consequence.*

I. INTRODUCTION

The role and function of machine maintenance in the modern manufacturing industry have grown rapidly, becoming increasingly important and more challenging in today's dynamic business environment (Atmaji, 2015). This change because the machine maintenance function's effect will significantly impact its total costs in the company's production cycle (Alhilman, 2017). Machine maintenance is generally defined as a combination of all technical, administrative, and managerial actions during a given cycle to maintain or restore a state in which the machine can perform the functions as required (Bokrantz et al., 2020). Machine maintenance is carried out as a strategic decision to eliminate and minimize the potential for failure, breakage, stopping, and damage to equipment or machines (Patidar et al., 2017). The purpose of machine maintenance is to maintain the reliability of the machine so that it can operate properly. Therefore, a good, precise, and consistent strategy is needed to maintain the production process's continuity. If a company is unable to perform proper machine maintenance, it will cause the machine to be unreliable and cause losses, both time loss and total production cost loss. The cost of unreliability caused by a damaged production machine can be calculated using the Cost of Unreliability (COUR) method (Alhilman, 2017; Vicente, 2012).

According to research by (Crespo Márquez et al., 2012; Salonen & Deleryd, 2011b, 2011a; Stenström et al., 2016), all costs that are the result of all situations related to the problem of failure, including costs associated with the maintenance program that is not run correctly will be affected into general production cost. Meanwhile, the COUR studies production facilities as a network for system reliability and the costs incurred when the system fails to do its work, which is used to

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determine the risk of machine losses (Narbaev & De Marco, 2014; Olowosejeje et al., 2019; Vicente, 2012). The higher the level of reliability, the greater the machine's chance to work in its optimal function, and the lower the losses due to unreliability. To support problem-solving related to the costs incurred by machine unreliability, it is also necessary to consider the application of the six sigma to explore the company's overall production system, especially in reducing the cost of poor maintenance system (Aldairi et al., 2017; Kumar Sharma & Gopal Sharma, 2014; Prashar, 2014; Youssouf et al., 2014). XYZ company is a manufacturing company engaged in manufacturing military products and other commercial products in Indonesia. Although the company has carried out maintenance activities, there is still a lot of damage, especially to the machines in the e-clips production process. From the observations, it is found that the most frequently damaged machines in the production process of e-clips are the shot blast MACH MWJ 9/10 machines (see Figure 1).

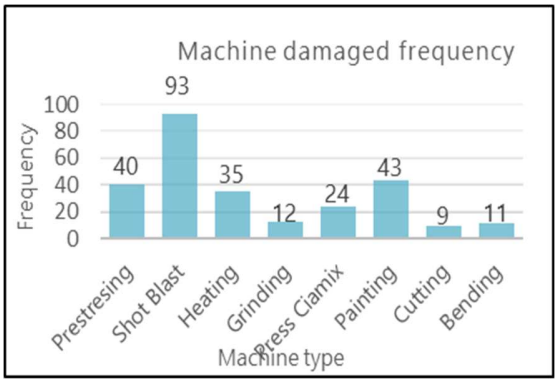

Figure 1. The frequency of damage in the e-clips production process line

Figure 1 shows the frequency of damage in the e-clips production line, which the Shot Blast machine has the highest damage frequency among the other machines. Shot Blast machine maintenance activities carried out by PT. XYZ consists of preventive, corrective, and emergency maintenance. Corrective and emergency maintenance activities are carried out following the failure that occurred when the machine was damaged. The damage that occurs results in the increase of the maintenance costs, so it is necessary to find the costs arising from the machine damage.

This paper proposes a machine unreliable cost analysis using the Cost of Unreliability (COUR) method and the Business Consequence analysis (BC) analysis, especially for the critical component of shot blast MACH MWJ 9/10 machine. This paper is organized as follows. Section one provides an introduction, section two provides a research method, part three contains the result and discussion, and finally the conclusion, and some remarks presented in section four.

II. Research Method

This research was conducted in several stages, starting from problem identification, literature review, field observation, data collection, calculation of reliability and cost of unreliability, business consequence analysis, and conclusions and suggestions (see Fig 2). In this study, the Shot Blast MACH MWJ 9/10 machine was chosen as the research object, then the selection of critical systems and subsystems of the machine was based on Pareto analysis. Shot blast machine is a machine used by the Cast Forging and Railroad Division (TC-AP) to clean workpiece of e-clips from the remaining dirt from the casting before the next process is the painting process. In general, e-clips production starts from material cutting using a cady machine, chamfering process in grinding machine, then heating in the induction heating machine, bending by press machine, tempering process, shot blasting, painting, final check and packing product. Pareto analysis is a quality control tool that sorts data classification from the highest frequency to the lowest frequency (Talib et al., 2015). Pareto is used to compare the categories of events sorted by their size. The value in the Pareto analysis is obtained from the Risk Priority. Number (RPN) calculation. RPN is a method for identifying critical components or criticality of a component (Atmaji et al., 2018). The stages for RPN calculation are to do a total calculation of three factors, namely severity, occurrence, and

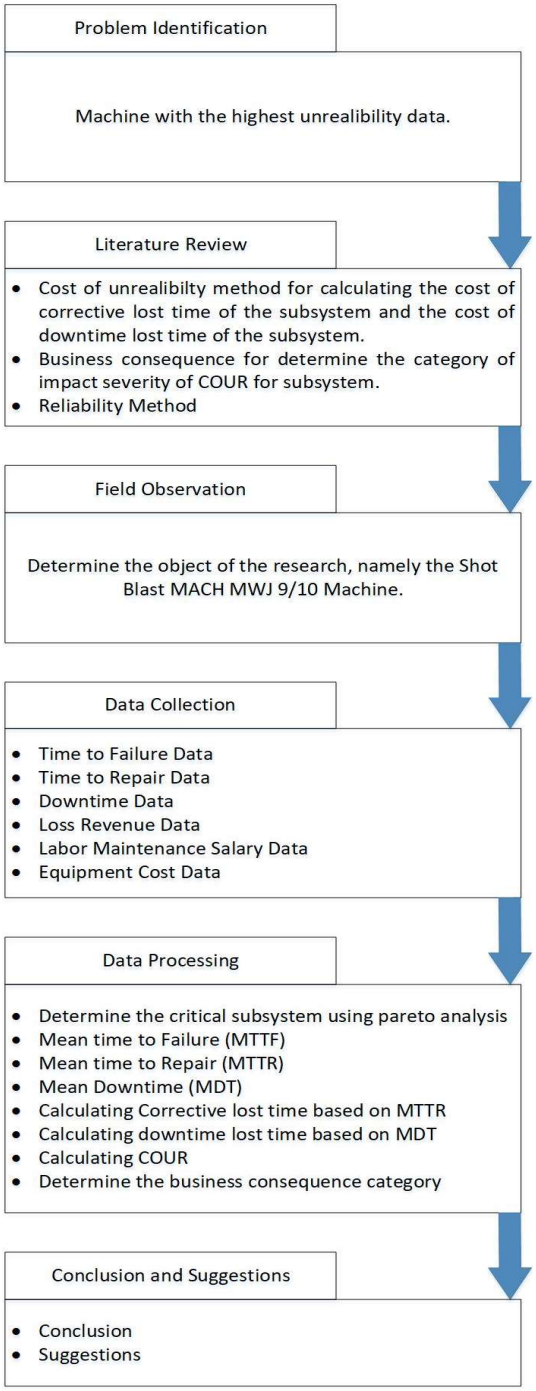

Figure 2. Research method

detection. Severity is the level of impact caused by failure. The event is the frequency of failure or component damage, and detection is the detection level when a component fails.

Based on the selected critical subsystem or component, then the damage data history of each component is used to determine the Mean Time To Failure (MTTF), Mean Time To Repair (MTTR) and Mean Downtime (MDT). Mean Time To Failure is the average interval of damage from a damage distribution, whereas Mean Time To Repair is the average component repair time. Mean Downtime is the average time the component stops operating.

The calculation of MTTF, MTTR, and MDT values in the exponential, normal and Weibull distributions are as follows (Joglar, 2016; Pascual & Kumar, 2016; Sheng & O'Connor, 2017; Turan et al., 2011):

Exponential Distribution MTTR=1/λ ... (1)

Normal Distribution MTTR=μ ... (2)

Weibull Distribution MTTR= (1+x)^n=θ.Γ(1+1/β) ... (3)

The next step is processing and analyzing data using the COUR method. The first step is determining money lost, time lost, and failure rate for the critical subsystem. Calculation of money lost is from equipment costs, labor maintenance costs, and lost production costs data. Time lost is obtained from mean downtime and mean time to repair data. Then the failure rate is obtained from the meantime to failure. After the COUR analysis, then the business consequences analysis was applied to find the effect of the machine's unreliability. The detail of the variable for this research is explained step by step as follow. Figure 2 shows the flow of the

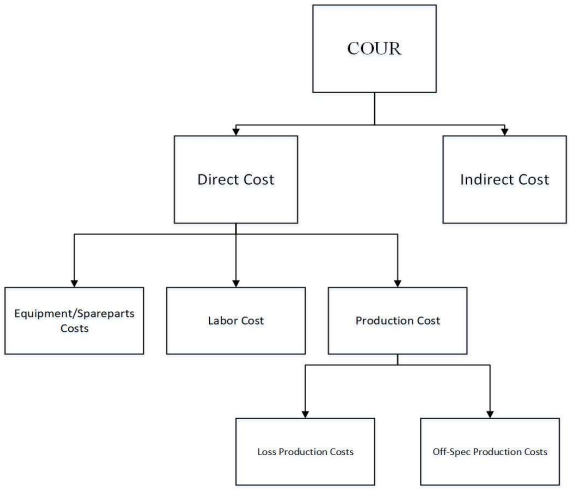

Figure 3. Cost of Unreliability Model

research method applied in this research.

Cost of Unreliability (COUR)

COUR analysis is the result of all situations related to the problem of failure, unreliable machine, and unproperly of maintenance program (Crespo Márquez et al., 2012. The calculation uses the COUR method to determine the potential loss of revenue due to the machine's inability on the production line. Figure 3 shows the model that describes the costs used in COUR calculations.

Figure 3 shows that the COUR consists of the two main costs, which are

COUR = Direct Cost + Indirect Cost ... (4)

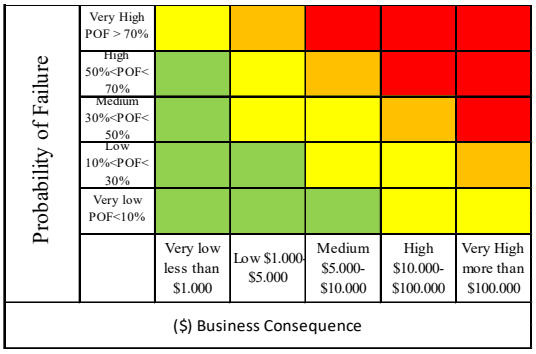

Figure 4. Business consequence matrix

Table 1. RPN Calculation Percentage

Subsystem	RPN	Percentage	Cumulative
Blade	504	31%	31%
Filter	384	23%	54%
Rubber	360	22%	76%
Exhaust	288	17%	93%
Plat	112	7%	100%

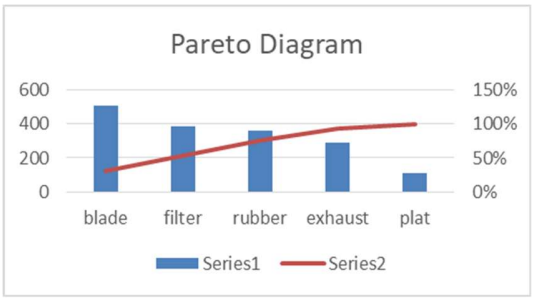

Figure 5. Pareto Diagram

Direct Cost

Direct cost is a cost that has a direct cause and effect relationship with reliability events. Direct costs are affected by Equipment / spare parts costs, labor maintenance cost, and production cost. Equipment cost is costs incurred to replace the engine or machine components. Labor maintenance cost is costs incurred to pay workers in maintenance and repair activities. And production cost is costs incurred due to production.

Indirect Cost

Indirect costs of COUR are costs that do not have a direct relationship with the incidence of reliability. Costs included in indirect costs are the cost of being a reactive organization, the cost of sloppiness, and the cost of lost business. The cost of being a reactive organization is organizations that carry out reactive maintenance, such as preventive maintenance. The cost of sloppiness is poor reliability is usually associated with other production elements such as safety, health, quality, and environmental performance. Then the cost of lost business is poor reliability can affect the target and the amount of production.

Cost of Unreliability Calculation

The Calculation of Cost of Unreliability can be done in several stages. The following stages of COUR calculation are failure rate, time lost, and money lost. The failure rate can be calculated using data obtained from mechanical damage. The failure rate calculation can use the following equation:

Failure Rate = 1/MTTF ... (5)

Time lost can be caused by repair time and engine downtime. The time lost calculation uses the following equation:

Corrective Lost Time/years = MTTR x S ... (6)

Downtime Lost Time/years = MDT x S ... (7)

The money lost on corrective and downtime is calculated to determine the costs incurred due to machine reliability. Money lost calculation uses the following equation:

Corrective/Downtime COUR

= LPC+ EC+LC ... (8)

with

LPC = Lost Production Cost

EC = Equipment Cost
LC = Labor Cost

Business Consequence

Business risk helps management make the best decisions from indicators of failure measured by money or unreliable costs. The risk increases over time because reliability decreases over time. If the high-risk value means that the right action must be taken to overcome the problem, if it does not take the right action, the business risk experienced by the company will be considerable (Bustinza et al., 2017; Ibarra et al., 2018; Landscheidt et al., 2018). Conversely, if the value of risk is low, then it is not appropriate to overcome the problem. The business consequences resulting from the machine's unreliability, which is analyzed using a risk matrix, as shown in Figure 4 that shows the Business Consequence applied in this research. The matrix is between the value of Probability of Failure (PoF) and the cost that affected by B.

III. Result and Discussion

This study aims to calculate the cost of unreliability arising from the shot blast machine subsystem. So, the method used for this research is the Cost of Unreliability (COUR). The first step that must be done is to determine the critical system and subsystem of the shot blast machine.

Determination of Critical Systems and Subsystems

The selection of critical systems is made by selecting from several systems on the MACH MWJ 9/10 Shot Blast machine. This machine has three main systems, which consist of an electrical, mechanical, and hydraulic system. A mechanical system is a system that has elements that interact with each other in mechanical principles. Mechanical systems have 13 main subsystems. An electrical system is a series of components, and electricity money aims to start the engine and maintain machine performance efficiently. The electrical system has four main subsystems. And the hydraulic system is a system or equipment that works based on the ability of liquid substances. The hydraulic system has three main subsystems. Based on the damage data in 2016-2019, the system with the highest damage frequency on the MACH MWJ 9/10 Shot Blast machine is a mechanical system with 49 times the frequency of damage and a percentage of 89.09%. So, the selected system is mechanical. After that, proceed with selecting critical subsystems of the mechanic system. The determination of critical subsystems is using RPN parameters based on machine damage data. Table 1. is a result of the RPN calculation of the critical subsystem.

From Table 1 RPN calculation, the cumulative percentage for the blade subsystem is 31%, for a filter is 54%, rubber is 76%, the exhaust is 93%, and for plate is 100%.

To determine the critical component that will focus on research, the Pareto diagram with the principle of 80:20 is used to choose 80% of 100% of the predetermined RPN values. The result of the Pareto diagram is shown in Figure 5.

Figure 5 shows the critical subsystems that focus on this research are 3 components: blades, filters, and rubber. After determining the critical subsystems, the next step is to do reliability calculations. The first step is to determine the Time to failure, Time to repair, and downtime of the subsystems.

Time To Failure, Time To Repair, and Downtime Determination

The distribution test of TTF, TTR, and DT of Shotblast MACH MWJ 9/10 machine subsystems uses Minitab 17 software to determine what distribution is suitable from the failure data. The confidence level used is 99% or 0.99. To determine each critical subsystem's suited distribution, the results are compared and analyzed between the normal, Weibull, and exponential distributions. The result of the distribution test is shown in Table 2.

Table 2 shows that the one with the smallest Anderson Darling (AD) value and a P-Value greater than 0.01 is the Weibull distribution. So, the proper distribution of rubber, blade, and filter subsystem for Time To Failure is Weibull distribution.

Table 3 and Table 4 are the Time To Repair (TTR) and Down Time (DT) results sequentially.

Table 2. TTF Distribution Test Results

Subsystems	Distribution	AD Value	P-Value	Selected
Rubber	Normal	2.551	<0.05	Weibull
	Exponential	0.516	0.461	
	Weibull	0.324	>0.250	
Blade	Normal	1.493	<0.005	Weibull
	Exponential	1.854	0.010	
	Weibull	0.303	>0.250	
Filter	Normal	2.160	<0.005	Weibull
	Exponential	0.512	0.467	
	Weibull	0.192	>0.250	

Table 3. TTR Distribution Test Results

Subsystems	Distribution	AD Value	P-Value	Selected
Rubber	Normal	4.535	<0.005	Weibull
	Exponential	2.065	0.007	
	Weibull	1.764	>0.010	
Blade	Normal	2.191	<0.005	Weibull
	Exponential	3.054	<0.003	
	Weibull	1.065	>0.010	
Filter	Normal	1.409	<0.005	Weibull
	Exponential	0.975	0.109	
	Weibull	0.926	0.015	

Table 4. DT Distribution Test Results

Subsystems	Distribution	AD Value	P-Value	Selected
Rubber	Normal	4.152	<0.005	Weibull
	Exponential	7.276	<0.003	
	Weibull	1.754	<0.010	
Blade	Normal	2.190	<0.005	Weibull
	Exponential	2.632	<0.003	
	Weibull	1.126	>0.10	
Filter	Normal	1.039	0.006	Weibull
	Exponential	0.689	0.255	
	Weibull	0.619	0.091	

Table 3. shows the TTR distribution test result of a critical component. Table 3 shows that all subsystems are suited to the Weibull distribution. From table 4. the DT distribution result shows that all subsystems are also suited to the Weibull distribution.

MTTF, MTTR, and MDT Calculation

After determining the distribution of each subsystem, the next step is to determine the Mean Time To Failure (MTTF), Mean Time To Repair (MTTR), and Mean Downtime (MDT) for each critical component. To find the MTTF, MTTR, and MDT values, the Avsim +9.0 software is used. The MTTF, MTTR, and MDT results are shown in Table 5, Table 6, and Table 7, consecutively.

Table 5. MTTF Calculation Results

Subsystems	Distribution	(1/β+1)	MTTF (Hour)
Rubber	Weibull	1.137	650.32
Blade	Weibull	1.518	3114.7
Filter	Weibull	1.382	2138.4

Table 6. MTTR Calculation Results

Subsystems	Distribution	(1/β+1)	MTTR (Hour)
Rubber	Weibull	0.9732	4.209
Blade	Weibull	0.9175	2.215
Filter	Weibull	1.2894	14.441

Table 7. MDT Calculation Results

Subsystems	Distribution	(1/β+1)	MDT (Hour)
Rubber	Weibull	1.280	18.548
Blade	Weibull	0.9197	2.501
Filter	Weibull	1.227	15.290

From Table 5, it is known that the MTTF value for rubber is 650.32, for blades is 3,114.7 and for filters is 2,138.4 hours. Table 6 shows that the MTTR value for rubber is 4.209, for blades is 2.215 and for filters is 14.441 hours. Table 7 shows that the MDT value for rubber is 18.548, for blades is 2.501 and for filters is 15.290. After determining the MTTF, MTTR, and MDT. The next step is to calculate the calculation of failure rate and time lost based on corrective

Table 8. Failure Rate Calculation Results

Subsystems	Interval Study (Hour)	Number of Failures	MTTF	Failure Rate
Rubber	15360	6	650.32	0.00153770
Blade	15360	3	3114.7	0.00032106
Filter	15360	3	2138.4	0.00046764

time and downtime.

Failure Rate

Before calculating COUR, the failure rate of the subsystem must be calculated. The failure rate is the number of failures per unit time. To calculate the failure rate required interval study data in units of an hour, the number of failures from the subsystem, and MTTF calculation data. Because the unit of time used is the hour, the failure rate follows the time unit used. In this study, the study interval conducted during the study amounted to 15360 hours. The number of subsystems failures is the number of failures in the rubber, blade, and filter subsystem for one year. And MTTF is the average time that a subsystem has failed, which is obtained from the previous calculation x the amount of damage to the subsystem for one year. The formula used to calculate is failure rate = 1/MTTF. The following table is the result of the calculation of the failure rate.

From the calculation of the failure rate, the estimated failure rate for rubber is 0.00153770, then the blade is 0.00032106, and for the filter is 0,00046764. After calculating the failure rate, the next step is to calculate the time lost based on MTTR and MDT.

Time Lost

In Lost Time calculations, there are two types of calculations, namely Lost Time for Corrective and Lost Time for Downtime. To calculate Corrective Lost Time, we need data failure rate, number of subsystem failures, and MTTR. Then to calculate the Downtime Lost Time required data failure rate, the number of subsystem failures, and MDT.

From Table 9, it can be seen that the highest corrective lost time filters with 43,323 corrective lost time, and the lowest corrective lost time are a blade that is 6,645 hours.

From Table 10, the highest downtime lost time is rubber with 111.288 downtimes lost time and the lowest downtime lost time is a blade that is 7.503 hours. Next, is the calculation of money lost, but some data must be determined before calculating money lost, namely Equipment cost, Labor Cost, and Lost Production Cost.

Equipment Cost Data

Equipment cost data is calculated based on the depreciation of equipment used by the company for maintenance activities. The following is the formula used to calculate the cost of operating equipment.

$$EC = \frac{1}{N} (I\text{-}S) \quad \ldots (9)$$

I = Initial Asset Value / Total acquisition price.
N = Length of Asset Period
S = residual value / residual assets of productive life

After calculating, the following annual depreciation/depreciation expense is obtained.

Based on Table 11, the total equipment cost is IDR 276.500,00. The next step is to determine

Table 9. Lost Time Corrective Calculations

Sub-systems	Failure Rate	Number of Failures	MTTR	Corrective Lost Time
Rubber	0.00153770	6	4.209	25.254
Blade	0.00032106	3	2.215	6.645
Filter	0.00046764	3	14.441	43.323

Table 10. Downtime Calculations

Sub-systems	Failure Rate	Number of failures	MDT	Downtime Lost Time
Rubber	0.00153770	6	18.548	111.288
Blade	0.00032106	3	2.501	7.503
Filter	0.00046764	3	25.010	45.870

Table 11. Equipment Cost Data

Equipment Name	Price (IDR)	Depreciation Expense/Year
Screwdriver 1	200.000	50.000
Screwdriver 2	300.000	75.000
Hammer	50.000	12.500
Box Wrench 13	16.000	4.000
Box Wrench 14	16.000	4.000
Box Wrench 17	16.000	4.000
Box Wrench 19	16.000	4.000
Box Wrench 30	16.000	4.000
Box Wrench 32	16.000	4.000
Pliers (1 set)	460.000	115.000

Table 12. Labor Cost Data

Number of Technicians	Fee/Month (IDR)	Technician Cost/Month (IDR)	Technician Fees / Hour(IDR)
3	5.000.000	15.000.000	46.875

the labor cost data.

Labor Cost Data

The labor cost is calculated from employees' basic salary every month that is converted into hours. There are several conditions to count the cost of maintenance labor: the average basic salary of a PT maintenance employee. XYZ is IDR 5.000.000, and the maintenance employee work time is 20 days a month, and there are 2 shifts per day. One shift lasts for 8 hours, then the total effective working hours per month is 320 hours. And also, the number of maintenance employees involved in carrying out maintenance activities is 3 people. The following is a calculation of labor cost maintenance.

Based on Table 12, the total labor maintenance cost is IDR 46.875. The last data required for COUR calculation is lost production cost.

Lost Production Cost

Lost Production Cost is data on the company's amount of loss due to damage and maintenance activities.

Lost production =

(Machine capacity/hour) x (Product price/pcs)

= 2400 x IDR 18.250,00

= IDR 43.800.000,00

The next step is COUR or money lost calculation.

Money Lost

This calculation requires the calculation of lost production costs, equipment costs, and labor maintenance costs. COUR calculation is divided into two, namely corrective COUR and downtime COUR. The following is an example of a corrective COUR calculation for the rubber subsystem.

Lost Production Cost =

lost revenue/hour x corrective lost time

= IDR 43.800.000,00 x 25,254

= IDR 1.106.125.200,00

Labor Maintenance Cost =

technician fee/hour x corrective lost time

= IDR 46.875,00 x 25,254

= IDR 1.183.781,25

Meanwhile, Equipment Cost is obtained from the total depreciation of equipment costs per year, which is IDR 276.500,00. After calculating the lost production cost, equipment cost, and labor maintenance cost, the rubber's corrective COUR subsystems value can be calculated from the sum of the three. It is IDR 1.107.585.481,25. The next step is to calculate the downtime COUR,

Table 13. COUR Corrective Calculations

Subsystems	Lost Production Cost (IDR)	Equipment Cost (IDR)	Labor Cost (IDR)	Corrective COUR (IDR)
Rubber	1,106,125,200.00	276,500.00	1.183.781,25	1.107.585.481,3
Blade	291.051.000.00	276,500.00	311.484,37	291.638.984,37
Filter	1.897.547.400.00	276,500.00	2.030.765,62	1.899.854.665,6

Table 14. COUR Downtime Calculations

Subsystems	Lost Production Cost (IDR)	Equipment Cost (IDR)	Labor Cost (IDR)	Downtime COUR (IDR)
Rubber	4.874.414.400,00	276.500,00	5.216.625,00	4.879.907.525.00
Blade	328.631.400,00	276.500,00	351.703,12	329.259.603,10
Filter	2.009.106.000,00	276.500,00	2.150.156,25	2.011.532.656,30

which is the same as the corrective COUR calculation.

From Table 13. the highest corrective COUR is filter IDR 1.899.854.665,6, and the total corrective COUR of the rubber, blade, and filter subsystem is IDR 3.299.079.131,24.

From Table 14, the highest downtime COUR is rubber IDR 4.879.907.525, and the total downtime COUR of the rubber, blade, and filter subsystem is IDR 7.220.699.784,37. After calculating COUR corrective and downtime, the next step is to determine COUR corrective and downtime's business consequence category.

This business consequence determination aims to see how severe the impact of the resulting unreliability is.

Business Consequence

A business risk matrix is a simple tool developed to assist management in the decision-making process, maintaining the lowest possible risk value. Business consequences are carried out using the 5x5 business risk matrix. To do business consequence requires POF value data and unreliable cost from a subsystem for its parameters. POF is the probability that a component or subsystem has failed. The following is an example of the POF calculation for the rubber subsystem.

R (t) = e-λt
R (3840 jam) = e-(0,0015377x3840)
R (3840 jam) = 0,00270 (0,27%)
Q (t) = 1 – R (t)
Q (3840 jam) = 1 – 0,0027
Q (3840 jam) = 0,9973 (99.73%)

After calculating the POF, the next step is determining the business consequence using the business risk matrix.

From Table 15 can be known that for corrective COUR, the rubber, blade, and filter subsystem are in the red category, which means it needs to be noticed by the company immediately. The blade, rubber, and filter subsystems are included in the red category, which means that the company needs immediate attention, with a POF value> 70%, classified as very high for all subsystems. Then, the blade subsystem's business consequences are high and for the rubber subsystem and the filter are very high.

Table 16 shows that for downtime, COUR has the same results as corrective COUR, the rubber, blade, and filter subsystem are in the red category, which means it needs to be noticed by the company immediately.

Table 15. Business Consequence of Corrective COUR

Probability of Failure						
	Very High POF > 70%				Blade	Rubber, Filter
	High 50%<POF<70%					
	Medium 30%<POF<50%					
	Low 10%<POF<30%					
	Very low POF<10%					
		Very low less than IDR 10.000.000	Low IDR 10.000.000 - 50.000.000	Medium IDR 50.000.000 - 100.000.000	High IDR 100.000.000 - 1.000.000.000	Very High more than IDR 1.000.000.000
(IDR) Business Consequence						

Table 16. Business Consequence Downtime COUR

Probability of Failure						
	Very High POF > 70%				Blade	Rubber, Filter
	High 50%<POF<70%					
	Medium 30%<POF<50%					
	Low 10%<POF<30%					
	Very low POF<10%					
		Very low less than IDR 10.000.000	Low IDR 10.000.000 - 50.000.000	Medium IDR 50.000.000 - 100.000.000	High IDR 100.000.000 - 1.000.000.000	Very High more than IDR 1.000.000.000
(IDR) Business Consequence						

Corrective Money Lost Comparison

The corrective money lost is compared to the research and from the company. The highest corrective lost time/year is the filter subsystem. This shows that the problem of reliability is bad for the company for the costs incurred. For the company's COUR calculation, the value of equipment depreciation is considered 0 because to do maintenance. The company is still using the equipment that is still functioning well but exceeds its useful life of four years. So, the company's corrective COUR calculation is different from the research corrective COUR calculation, and the value of Equipment Cost causes this. The difference between the company

and research COUR corrective calculations can be seen in Figure 6.

Based on figure 6, the company's COUR corrective calculations with the research are not appropriate because the company is still using equipment that is still functioning well even though it has exceeded the service life to repair the machine. Corrective COUR for rubber from the research is IDR 1.107.585.481, while from the company is IDR 1.107.308.981. And then for the blade subsystem from the research is IDR 291.638.984,4 while the company is IDR 291.362.484,4. And for the filter subsystem, the corrective COUR from the research is IDR 1.899.854.666, while from the company is IDR 1.899.578.166. But if the equipment is used continuously, the function of the equipment decreases over time.

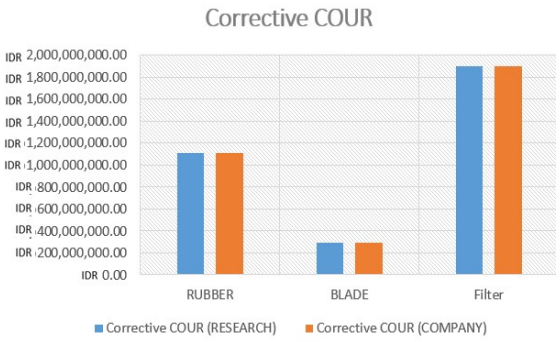

Figure 6. Corrective COUR Analysis

Downtime Money Lost Comparison

The highest COUR downtime is the rubber subsystem, the second highest is the filter subsystem, and the last one is the blade subsystem. The company's COUR calculation is the same as the corrective money lost. The value of equipment depreciation is considered 0 because to do maintenance, and the company still uses the equipment that is still functioning well but exceeds its useful life of 4 years. So, the company's downtime COUR calculation is different from the research downtime COUR calculation, and this is caused by the value of Equipment Cost too. The difference between a company and research COUR downtime calculations can be seen in Figure 7.

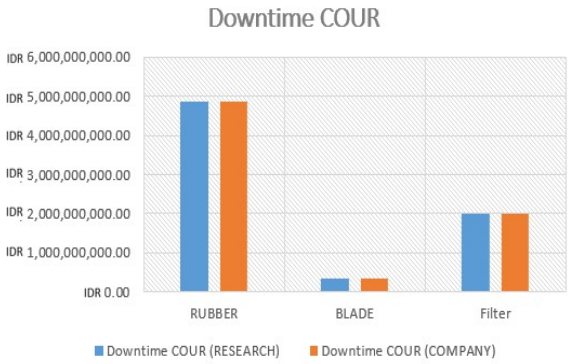

Figure 7. Downtime COUR Analysis

Based on figure 7, the calculation of COUR company downtime with the research is not appropriate because the company is still using equipment that is still functioning well even though it has exceeded the service life to repair the machine. Downtime COUR for rubber subsystem from the research is IDR 4.879.907.525 while from the company is IDR 4.879.631.025. And then for the blade subsystem from the research is IDR 329.259.603,1 while from the company is IDR 328.983.103,1. And for the filter subsystem, the downtime COUR from the research is IDR 2.011.532.656, while the company is IDR 2.011.256.156.

Based on the COUR calculation results, it is found that the business risk category of machine reliability is a consideration for the company in taking improvement, which focuses on the optimal preventive maintenance scheduling. Based on data of money lost, time lost, and failure rate, the results of COUR calculations are time and cost losses due to the unreliable machine of Shot Blast MACH MWJ 9/10.

IV. CONCLUSION

Overall, this research was to determine the value of cost losses due to machine unreliability using the Cost of Unreliability (COUR) method with Business Consequence analysis. The cost effects of these costs include Corrective COUR and Downtime COUR. Based on the calculation of time losses and critical subsystem costs using the COUR method, we obtained corrective lost time due to the rubber subsystem's corrective

maintenance activities by 25.254 hours, blade subsystem by 6.645 hours, and filter subsystem by 43.323 hours. Then also obtained the downtime lost time caused by the subsystem that stopped the rubber subsystem by 111.288 hours, the blade subsystem for 7.503 hours, and the filter system for 45.870 hours.

The costs obtained due to the critical subsystem's unreliability based on corrective time or the length of repair time are IDR 3.299.079.131,24 and based on downtime or the length of time stops at IDR 7.220.699.784,37. And the calculation of time loss and critical subsystem cost of the machine based on the COUR method is used to be a consideration for companies in taking action to improve machine reliability. And based on the business consequence calculation using the business risk matrix, the COUR corrective and COUR downtime for critical machine subsystems, namely rubber, blade, and filter, are in the red category or the high-risk area.

It can be concluded that further action is needed in minimizing the unreliable machine cost and optimizing the preventive maintenance activities of these critical subsystems to prevent higher risks and consequences from the MACH MWJ 9/10 Shot Blast machine. The company can use the Risk and Reliability Centered Maintenance (RRCM) method to create a proposed detailed maintenance task in scheduling maintenance to increase overall maintenance costs.

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