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Evaluating Breakdown of Wheel Loader Heavy Equipment Using Failure Mode and Effect Critical Analysis Method

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ABSTRACT

Autonomous maintenance is considered a comprehensive approach to detecting machine and equipment breakdown. PT. A is an enterprise engaged in heavy equipment services. Even though the company has implemented autonomous maintenance management, there has been damage and operational failure of the wheel loader machine. A practical evaluation is needed to determine the breakdown's cause. This study aims to identify the causes of malfunctions or machine components to determine effective remedial measures. Failure Mode Effect and Criticality Analysis method is used as a research approach. This study begins by identifying the three most significant damage rankings, then calculating the highest level of critical value, using the Pareto diagram recommendation for improvement using the 5W + 1H analysis. The results showed three critical failure modes: the starter dynamo component with a value of 324, the main pump with a value of 288, and a radiator with 294. This study also instigates recommendations for improvements to minimize the factors that cause critical failure.

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1. Introduction

Material handling is an important activity to support the smooth production process of manufacturing companies (Noor, 2020; Mas'ud et al., 2022). Predictable maintenance of material handling equipment is one way to prevent disruption of activities supporting the production process. PT. A is a company engaged in heavy equipment services for production activities (Tafsirojjaman et al., 2022; Mas'ud & Wahid, 2022). PT. The company provides a variety of heavy equipment to support the client company's operational activities. PT. C is a customer of PT A. One of the heavy equipment used is a wheel loader. Furthermore, Wheel loaders are heavy equipment with many functions, including lifting material, leveling mounds of material, taking material, land clearing, and striping in the working area of PT. C, Wheel Loader is used for taking and preparing raw materials to be put into the conveyor, which will lead to the next stage of the production process. The way the Wheel loader works is when the loader digs, the bucket is pushed against the material. If it is fully loaded, the tractor will reverse, and the bucket will be lifted to be moved to another place (Scheu et al., 2019; Norfaeda et al., 2020).

PT A provides at least eight Wheel Loaders units, which must be available a day before a request is made to use the unit. The excessive equipment demand requires autonomous and predictive

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maintenance to provide excellent service (Cunbao et al., 2011; Rislamy et al., 2020). Even though PT. A has carried out routine inspections on the maintenance of the material handling. However, equipment breakdown has occurred frequently, which can be summarized in Figure 1.

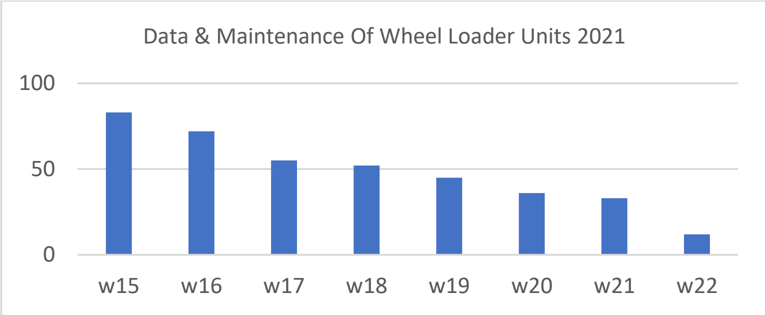

Figure 1. wheel loader Breakdown in 2021
Source: data processing result

Even though the company has implemented unit management and periodic maintenance, several unit breakdowns still disrupt the production process. Figure 1. shows the wheel loader unit data for one year in 2021. It can be seen that the W-15 unit has the most severe breakdown and maintenance rate of up to 83 times, followed by the W-16 with 72 times the breakdown and maintenance.

Preventive and autonomous maintenance to classify the potential causes and impact of failures that may arise both on spare parts and equipment systems (Masfufah & Munir, 2019; Nishioka et al., 2022). A comprehensive approach to analyze the causes of disruption, namely the Failure Method Critical Effect Analysis (FMECA) method (Ullah et al., 2022; Ciani et al., 2019). In addition, The FMECA is a tool for determining components' failure levels and identifying the problem by analyzing the causes of element failure (Rahman & Fahma, 2021; Firmansyah & Basuki, 2021)). Implementing the FMECA method has positively impacted the evaluation of the critical failure of equipment in the packaging industry (Rahman & Fahma, 2021). This study has identified 14 failure modes and ten critical failure mode points, which was obtained in the household appliance product industry FMECA approach is also valuable for identifying fifteen failure modes and four critical failure on press machines in the automotive industry (Ogbonnaya et al., 2021; Dzulyaddain et al., 2020). In line with empirical research in implementing FMECA has existed, further study in implementing FMECA is still needed to enlarge the industry coverage of empirical research.

This research aims to identify and evaluate the critical level of the wheel loader components to establish recommendations for improvement. This study has been differentiated from empirical research by (Andriansyah & Sulistyowati, 2020; Dzulyadain et al. 2014; Rahman & Fahma, 2021). These researchers have conducted research in various industries as follows: the packaging industry, automotive industry, and household appliances industry, while in this study, the objects used were heavy equipment in the service industry. Furthermore, the existing model for determining the critical point in empirical studies used a risk matrix to determine the critical point for the failure mode. In contrast, this study used the critical table model to determine the critical point for the failure mode.

2. Literature Review

a. Maintenance

Maintenance is related to obtaining maximum production results based on realistic production plans following the production capacity of the equipment, the work field, and the surrounding environmental conditions faced. It is necessary to carry out equipment management (Noor, 2020; Choi & Lee, 2022). One of the efforts in carrying out tool management is maintaining machines and facilities related to tools. According to (Ansori & Mustajib, 2013), maintenance implementation machines and other facilities can run smoothly and provide good quality production results. The age of the machine is endeavored to exceed its depreciation age.

b. From FMEA to FMECA

Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent possible failure modes. Failure modes include defects, conditions outside specified specifications, or product changes that cause the product to not function (Gaspersz, 2002). FMEA is a suitable method to analyze the causes of failure by setting failure priorities. To achieve a priority rating of the failure mode identification and its effects, carried out using a quantitative index. This rating is obtained from the Risk Priority Number (RPN), which is given by multiplying occurrence (O), Severity (S), and Detection (D) (Risk Priority Number = S x O x D) (Ciani et al., 2019). Even though FMEA is a suitable method for setting failure priorities, FMEA still has drawbacks, namely its use that is less flexible in design improvement (Rahman & Fahma, 2021b). At the same time, FMECA is a technique for evaluating or designing the reliability of components in a system by examining the potential failure modes to determine the impact, both from the success of the system or the safety of users and equipment, so that the most critical conditions possible for these components can be identified (Dzulyaddain et al., 2020).

c. Cause and Effect Diagram and 5W + 1H

The cause and Effect diagram is a tool to visualize the relationship between variations in quality characteristics and potential causes (Park et al., 2011). This diagram is used to look for causes that affect comprehensive component breakdown. The 5W 1H analysis can be used at the improvement stage to develop an improvement plan that includes the main improvement target: why an action plan needs to be done, were considered as the plan implemented, who is related to will work on the planned activities, when as timespan action be implemented, and finally how related o to do the plan (Djamal & Azizi, 2015; Wardana & Mahbubah, 2022).

3. Methodology

a. Sampling and Procedure

This research was based on a descriptive qualitative approach as in-nature data in the form of writing from both people and observable behavior (Dzulyaddain et al., 2020). This method was used to determine the causes and factors of component failure. Surveys, interviews, brainstorming, and documentation were used as the data collection methods (Sugiyono, 2010). The survey was conducted to determine the condition of the equipment, historical data collection, and documentation. Interview activities determine company activities, equipment performance, and a breakdown description.

The research object is a wheel loader type of heavy equipment operated in an industrial area in Gresik City, East Java province. The questionnaires were distributed to determine the effects and causes of the occurrence of objects in the study. The results of distributing the questionnaires were the type of breakdown, the breakdown factor, and the consequences. Moreover, brainstorming was used to seek recommendations for improvement. Furthermore, research documentation is used to strengthen research results. Five respondents in this study consisted of a senior mechanic, two mechanics, an assistant mechanic, and an operator who had worked for more than five years.

b. Data Calculation method

This research stage has begun with collecting breakdown data of wheel loaders in 2021. The next step was sorting the breakdown types from most significant to most minor using a Pareto chart. The next step was to conduct interviews with respondents to find out the failure mode that occurs in the form of the type of component and the cause of the breakdown. The following stage included the calculation of the RPN value. The RPN value was obtained after the respondents filled out the questionnaire. At this stage, the researcher summarizes all the potential and records failures of the tools with the result of the score, severity, occurrence, detection, and criticality matric (Yssaad & Abene, 2015).

Table 1. Severity Rank

Duration of service interruption Severity (S)	Criterion of severity	Value
Less than eight hours	Very catastrophic	10
Seven h	Catastrophic	9
Six h	Very serious	8
Five h	Seriously	7
Four h	Medium	6
Three h	Significant	5
Two h	Minor	4
One h	Very Minor	3
30 min	small	2
<30min	Very small	1

Source: (Yssaad & Abene, 2015)

It can be seen in Table 1. that the severity rating ranges from 1 to 10. Rank 1 indicates the behavior of the breakdown with no visible impact, and score 10 is the severity level with a duration of the breakdown of more than 8 hours. Table 2 represents the likelihood occurrence ranking.

Table 2. Occurrence rank

Possible rate of Occurrence (O)	Criterion of Occurrence	Value
Once every 12 years	Failure near zero or no	1
Once every ten years	Narrow, failure isolation	2
Once every eight years	Low, often fails	3
Once every six years		4
Once every four years	Average, occasional failure	5
Once every two years		6
Once every year		7
Once every six months	High, frequent failures	8
Once every month		9
Once every week	Very high, very high failure	10

Source: (Yssaad & Abene, 2015)

It can be seen in Table 2 that the frequency of failure of a function is broken down from the frequency of once per week with the highest ranking score of 10 and the frequency of occurrence of fewer than twelve years gets the lowest Occurrence score of 1. Ranking score detection can be seen in Table 3.

Table 3. detection

Level of Detectability (D)	Criterion of detectability	Value
Not detectable	Impossible	10
Difficult to detect	Very difficult	9
	very late	8
Detecting random (Unlikely)	Not sure	7
	Occasional	6
Possible detection	Low	5
	late	4
Reliable detection	easy	3
	Immediate	2
Detection at all times	Immediate corrective action	1

Source: (Yssaad & Abene, 2015)

It can be seen in Table 3. that the criteria for detectability in terms of failure were from immediate corrective action with a score of 1 and the highest score with the impossible level of detectability with a value of 10. Once the severity, occurrence, and detection score were gathered, the next stage was to calculate the Risk Priority Number (RPN) with the formula as follows:

$$RPN = Severity \times Occurrence \times detection \quad (1)$$

The calculation score of RPN then categorizes into critical values as presented in Table 4.

Table 4. Critical Score

Degree of criticality	Value	Criticality
Minor	0-30	Acceptable
Medium	31-60	tolerable
high	61-180	
Very High	181-252	Unacceptable
critical	253-324	
Very critical	>324	

Source: (Yssaad & Abene, 2015)

It can be seen in Table 4. There were six critical conditions with RPN scores ranging from 30 to more than 324. In addition, three critical conditions are acceptable, tolerable, and unacceptable, classified to take action regarding failure. The final step determines the cause of the failure using the cause and effect diagram method. This method was used because it can find the cause of failure in more detail. Next, make improvements to make recommendations for improvements with the 5W + 1 H method.

4. Results and Discussion

a. Wheel Loader Breakdown

Data on types of breakdown to wheel loaders comes from reports and records of the maintenance division in 2021. Documentation of this data produces some of the most significant breakdowns in wheel loader units. The types of breakdown with the highest frequency of wheel loader units can start with a total breakdown of 21 times, hose hydraulic leakage of 20 times, low power of 20 times, and overheating of 14 times. The unit can forward and reverse 13 times. Based on the Pareto diagram, the followings are obtained from the frequent breakdown components from the historical data of the maintenance division, which are tabulated in Table 5.

Table 5. Wheel Loader Breakdown Type

No	Breakdown type	Component Name	Component Code	Cause of Breakdown
1	Cannot Start	Starter Dynamo	1.1	Main brushes wear out
2	Leaking Hydraulic Hose	Hydraulic Hose	2.1	Cubing leakage
				Cracked hose
3	Low Power	Fuel Filters	3.1	Dirty filters
		Play Pump	3.2	Shafts not working
4	overheating	Water Cleaner	4.1	Dirty filters
		Radiator	4.2	Leaking radiators
				Less cooled water
5	Cant Forward Reverse Units	Electrical Relays	5.1	Short electric
		Selenoid	5.2	Burnt coil
				Broken solenoid

Source: Data processing result

The next stage was to perform a system failure analysis using FMECA. Table 5. Shows the eight components' breakdown in 2021, along with 12 causes of breakdown to the components. As for the results shown in table 6. Through the FMECA Worksheet.

Table 6. FMECA Worksheets

Component Code	Component Functions	Functional Failure	detection method	S	O	D	RPN	Criticality
1.1	As starting engine start	Main brushes wear out	engine start	6	9	6	324	critical
2.1	Channels high-pressure hydraulic oil into other components	Cubing leakage	Power engine	5	8	6	240	Very High
		Cracked hose						
3.1	Filter the fuel	Dirty filters	Error code panel monitor	3	8	4	96	high
3.2	Increase hydraulic oil pressure	Shafts not working	Error code panel monitor	6	8	6	288	critical
4.1	Perform air filtration that will enter the engine	Dirty filters	Error code panel monitor	3	7	5	105	high
4.2	Stabilizes engine temperature	Leaking radiators	Error code panel monitor	7	7	6	294	critical
		Water Coolant less						
5.1	Connect the electric current to the solenoid components	Short electric	Power engine	5	7	4	140	Very High
5.2	Disconnect or connect the electric current associated with other components	Burnt coil	Power engine	6	7	5	210	Very High
		Broken solenoid						

Source: data processing result

It can be seen in Table 6. that three components with a critical criterion: Dynamo Starter with an RPN value of 324, Radiator with an RPN value of 294, and Main Pump with an RPN value of 288. Figure 2. Represent visualizing of dynamo components.

Figure 2. Starter Dynamo Spare-part
Source: Mechanical Maintenance

A breakdown dynamo starter cannot be detected visually because the breakdown location is inside the component. Hence, the dynamo starter breakdown detection uses a starting system that can feel the difference when carrying out breakdown inspections. Based on the RPN calculations in the FMECA worksheet, a Pareto Diagram was drawn in Figure 3.

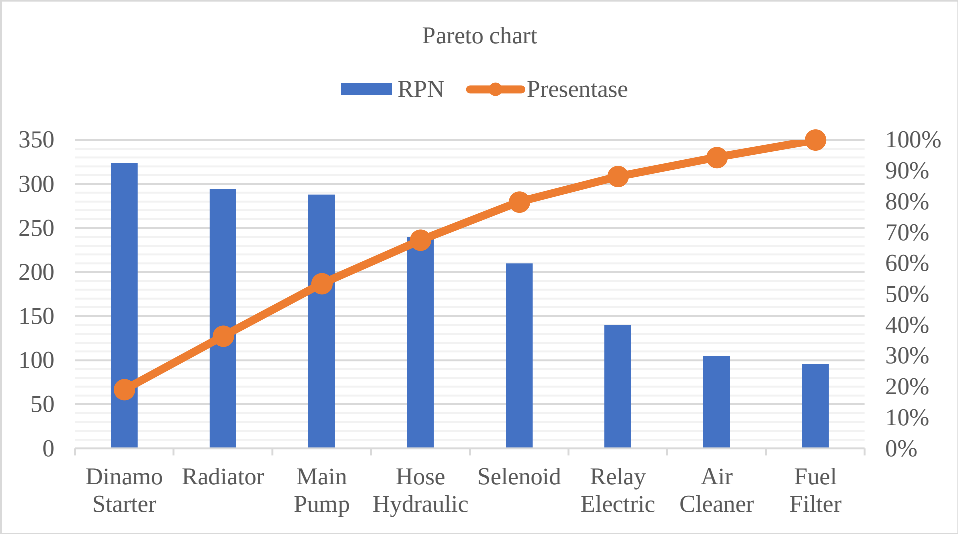

Figure 3. Pareto Charts from FMECA Worksheets
Source: Data Processing Results

The next step was to analyze the causes using the fishbone diagram. Following the principle of the Pareto Diagram 80 – 20, the priority problems that must be solved are problems with a percentage of up to 80% (Magdalena, 2019). Figure 4. shows that the three components with a problem priority of up to 80% are the starter dynamo, radiator, and main pump. This number shows the similarity between determining critical points from the FMECA Worksheet and determining the priority of problems in the Pareto Diagram.

b. Visualizing Cause and Effect Diagrams

At this stage, three components with the highest critical value are visualized according to the results of the Pareto Diagram, namely the starter dynamo component, the play pump component, and the radiator. Figures 4. to 6. represent Ishikawa Diagram.

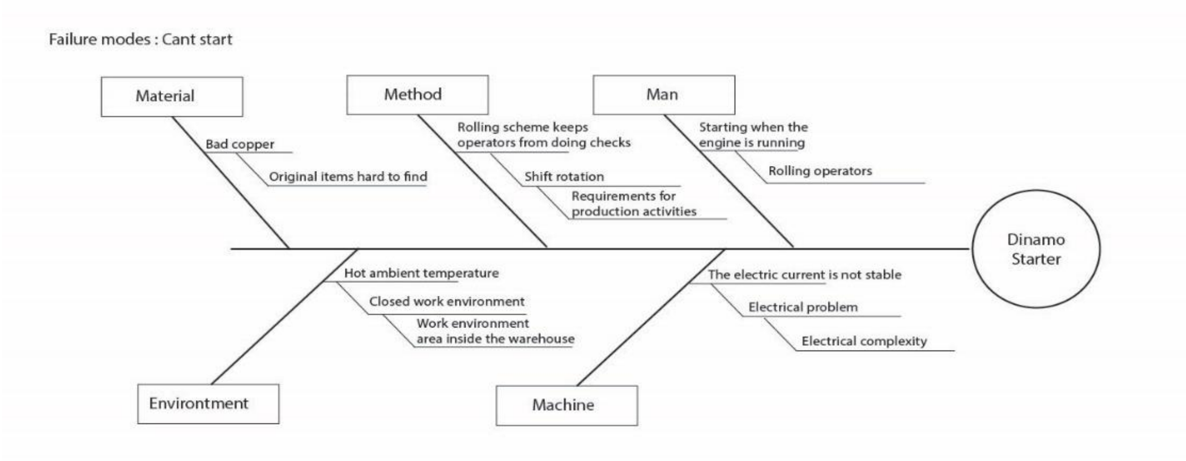

Figure 4. Cause and Effect Diagram of Dynamo Starter
Source: Data Processing Result

It can be seen in Figure 4. that the causes of the breakdown of components are hard-to-find original material factors, method factors for production activity requirements, man-rolling operator factors, environmental factors in work environment areas in warehouses, machine factors, and electrical complexity.

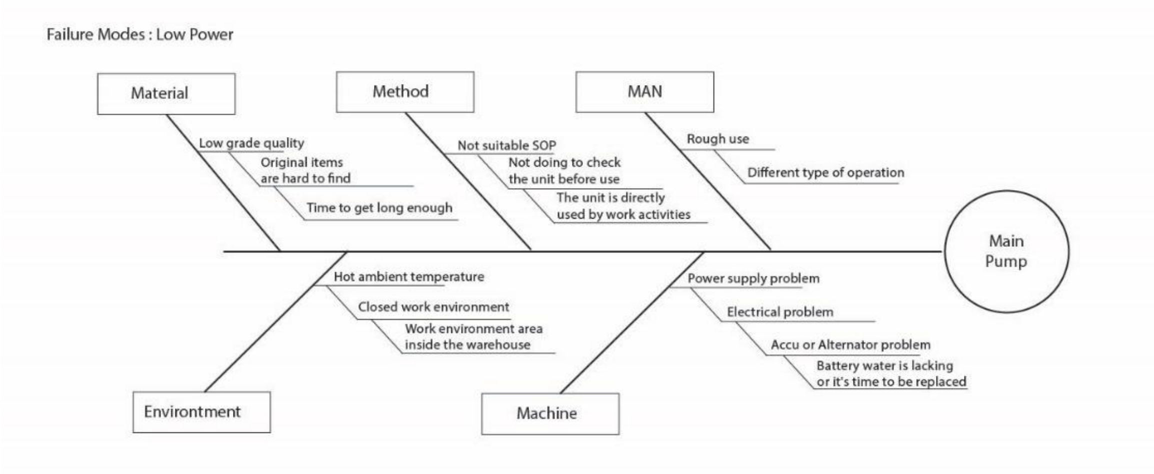

Figure 5. Leading Pump Cause and Effect Diagrams
Source: Data Processing Result

It can be seen in Figure 5. that the cause of the breakdown of the component is the material factor, the long time to get, the unit method factor is directly used by work activities, the typical operator man factor is different, the environment factor is the work area in the warehouse, the machine factor, the Accu air is lacking, or it is time to replace it.

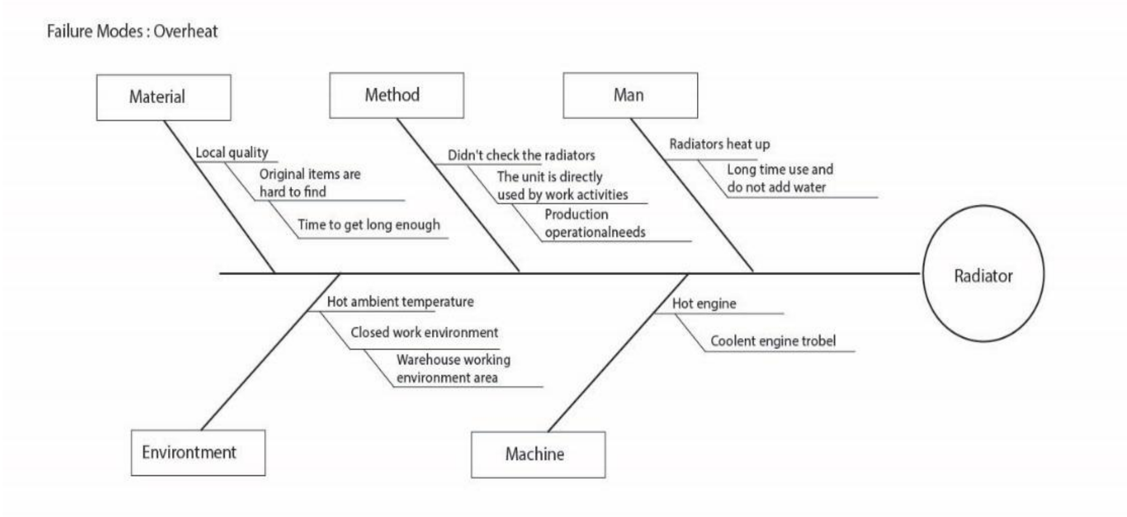

Figure 6. Cause and Effect Radiator Diagrams
Source: Data Processing Result

It can be seen in Figure 6. that the causes of the breakdown of components are material factors, time took a long time, method factors for production activity requirements, man factors for prolonged use and not adding water, environmental factors for work environment areas in warehouses, machine Coolent engine trouble. The cause and results effect diagram obtained several factors that cause a breakdown, so it needs to be overhauled. Furthermore, the 5W + 1 H analysis approach was used as scenario recommendations for improvement, as represented in Table 7.

Table 7. Improvement Recommendations

No	What	why	where	who	when	How
1	Original spare parts are hard to find	Spare part replacement takes time because most of	Purchasing Department	Purchasing staff	Pre-order Goods	Determine the estimated repair time for components,

		the components are imported.				
2	Requirements for production activities	The company's demands for operating units to achieve company targets	Operational Department	operational staff	Operational Meeting	Make an activity schedule according to the company's capacity, and add new units so that the unit's work is not too heavy
3	Rolling Operators	With continuous working hours, it is necessary to change the operator	Operations Department	Operator	Operational Meeting	Make SOP related to procedures before using the unit so that the operator ensures that the unit is in good condition
4	Work area in the warehouse	Materials that cannot be exposed to water and soft materials that require a closed area.	mechanic department	Mechanic	After using the unit	Routinely clean the unit when it has been used, and clean it with water or compressed air so that cleaning can be optimal
5	Electrical complexity	The electricity in the wheel loader system is interrelated	Mechanical Department	Mechanic	Maintenance Units	Perform preventive maintenance specifically for electricity
6	Work activities directly use the unit	Service for heavy equipment is a priority, so it must be ready to be used promptly.	Operations Department	Operator	Production activity	Ensuring the unit is ready for use by scheduling maintenance and replacing spare parts in a disciplined manner
6	Different types of operation	Each operator has a different way of operating the unit according to their habits and convenience.	Operations Department	Operator	Production activity	Conducting operational workshops following unit usage standards
7	The battery water is lacking or is it time to replace it	Continuous use so that the battery water runs out quickly	Mechanical Department	Mechanic	Maintenance Units	Do battery checks and prepare battery water stock
8	Coolant engine trouble	. Coolant problem unit heat happens if the unit is often used for a long time.	Mechanical Department	Mechanic	Maintenance Units	Ensuring the cooling system is running well and evaluating the unit usage time.

c. Discussion

The distinction of this research in comparison with empirical study can be drawn as follows: the number of critical points proposed improvements and the model for determining different essential issues, which also caused differences in the data and results. Researchers' results (Rahman & Fahma, 2021) focused on observing defects in the packaging production process and making SOPs for handling dusty paper using the FMECA method. The research result (Andriansyah & Sulistyowati, 2020) focuses on finding waste that affects the causes of defects and distinguishing the production process's capability level using the Six Sigma and FMECA methods. In addition, the researchers (Dzulyaddain et al., 2020) focused on finding sub-system breakdowns in the press machine and making recommendations for repair costs using the FMECA and RCM methods. Meanwhile, this study focuses on finding critical components in wheel loader heavy equipment and making suggestions for improvements using FMECA, Cause and Effect Diagrams, and 5W + 1H analysis. With recommendations for improvements from the results of this study, companies can use them in making policies for repairing wheel loader units because the causes and impacts are so complex that they affect various parties within the company to realize company productivity.

5. Conclusion and Future Work

This research finding can be summarized at three points as follow. The five highest types of breakdown were obtained: cannot start with a total breakdown of 21 times, hydraulic hose leakage 20 times, low power 20 times, overheat 14 times, unit cant forward reverses 13 times. In addition, there are eight components with 11 causes of breakdown, namely starter dynamo components with worn primary brush failure mode, hydraulic hose components with cubing leakage and cracked hose failure modes, fuel filter components with dirty filter failure mode, main pump components with shaft failure mode not functioning, air cleaner components with dirty filter failure modes, radiator components with leaky radiator breakdown and insufficient Coolant, electric relay components with electric short failure modes, solenoid components with burnt coil failure modes and broken solenoids.

Three critical failure mode points are obtained: the starter dynamo component with a value of 324, the main pump with a value of 288, and a radiator with a value of 294. The second point represents the results from calculating the RPN value for each failure mode and determining the critical point causing the breakdown. Based on the results of determining the critical point with FMECA, then examine for the causes of failure using the Ishikawa Diagram found factors, namely original goods that are difficult to obtain, Requirements for production activities, Rolling Operators, Work areas in warehouses, Electrical complexity, Units directly used by work activities, Distinctive different operations, less battery water or it is time to replace it, and Coolant engine trouble. From the factors causing the breakdown, then make recommendations for improvement.

Limitations in this study include a deficiency of supporting data due to the firm's disclosure policy. Further research with disclosure accessible access is needed in order to gain comprehensive, insightful data. This research also focused on one brand unit of heavy equipment, which meant a limited result in capturing critical points on maintenance management of the heavy equipment units. In addition, this research can be further developed by instigating maintenance schedules or proposing maintenance costs using the Reliability Centered Maintenance (RCM) method, observing for machine effectiveness values using the Overall Equipment Effectiveness (OEE) method, and calculating component life using the Life Cycle Cost method.

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