The Reliability Analysis of Railroad Switch Machine

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Abstract. The frequency of interference of the money order drive is quite high, the money order drive in the South Sumatra LRT uses the BSG-9 type. Point machines play an important role in moving train lines. If the point machine is disrupted, it can affect the safety and security of the LRT. in point machine maintenance activitiesBSG-9 does not show a reliability factor during maintenance. The purpose of this research is to determine critical components and the causes of failure using the FTA (Fault Tree Analysis) method, because the FTA (Fault Tree Analysis) method does not have a way to overcome the cause of failure, RCM (Reliability Centered Maintenance) method is needed to plan maintenance on critical components. The data used in this study is based on secondary data in the form of BSG-9 point machine fault data which serves to calculate the reliability of each critical component and determine the maintenance time interval based on the appropriate distribution results of each component data using the help of Minitab software to find reliability values, MTTF (Mean Time To Failure), MTTR (Mean Time To Repair). After analysis and calculation, it can be known the reliability and maintenance task of each component that is appropriate, for the shelf plate component, namely the scheduled restoration task with a reliability value of 19.69% and a maintenance time interval of 27 days, the handlebar components of the takeoff detection, namely the scheduled restoration task and scheduled discard task with a reliability value of 21.78% and a maintenance time interval of 24 days, PMCM module components are scheduled restoration tasks with a reliability value of 60.36% and maintenance time intervals of 106 days, money order motor termination components are scheduled restoration tasks with a reliability value of 98.22% and maintenance time intervals of 129 days.

Keywords: Railroad, Switch Machine, Reliability.

1 Introduction

Transportation consists of several modes such as land, sea, air. One of the modes of land transportation is rail. Rail is a mode of transportation or means of movement, either walking alone or rotating that is moving on the railroad [1]. Light Rail Transit (LRT) is a means of transportation using light rail with electric operation, which operates on its own line so that it is inaccessible to pedestrians and other vehicles [2]. Light rail transit operated in July 2018 and the enthusiasm of the growing community to try this transportation is unstoppable. Light Rail Transit (LRT) through areas and business centers (offices, trade) and settlements where people gather.

Light Rail Transit (LRT) requires an interlocking system to regulate travel safety and safety. The interlocking system is the brain that controls the signaling equipment in

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routing the vehicle when it departs and returns when it operates[3]. The signal is divided into two: the mechanical signal and the electrical signal[4]. The signaling system in Light Rail Transit (LRT) uses the Westrace Mark-II manufactured by Seimens Germany. The system was first operational in August 2018 at the South Sumatra Light Rail Transit, because the signaling system is new, there's some interference with signaling equipment.

Based on the data obtained from the signal and telecommunications unit of LRT South Sumatra, there are disturbances in the wesel propulsion system. Images show the frequency of the Wessel propulsion system that occurred from January 2020 to December 2022.

2 Theoretical Aspects

Reliability is the possibility or chance that a system can function as desired in a given condition and time for a specified period of time on a component or system[5]. In evaluating reliability, failures of components or systems must be clear and observable, and when failures can be evaluated in normal conditions, this is something to bear in mind[6]. There are two methods for determining the reliability of systems[7] : 1. Quantitative evaluation, distinguishing evaluation into analysis (statistics) and evaluation with simulation methods. 2. Qualitative assessment is an evaluation method performed to determine the impact of failure, with the methods FTA (Fault Tree Analysis), FMEA (Failure Mode Effect and Analysis) FMECA (Failure Modes Effect Critically Analysis, and RCM. (Reliability Centered Maintenance).

The reliability of a tool or system can be obtained using the following equation:

$$R(t) = e^{(-\lambda t)}$$

Where R(t) is the reliability of equipment at a given time (t) and λ is the failure rate of equipment in a unit of time (usually per hour or per year) The purpose of the distribution is to obtain a reliability value of a component or system by understanding the degree of damage of such components. Several types of distribution are used as the basis of calculations to determine reliability values, among others Weibull distribution, lognormal, normal, and exponential distribution. According to the formula used to determine reliability distribution parameters among others[8]:

a. The exponential distribution is used to describe the reliability of a system that fails randomly or stochastically. This distribution has the following reliability functions:

$$R(t) = e^{(-\lambda t)}$$

Where R(t) is the reliability function at time t, λ is the parameter of the failure rate, t is the time interval and e is the natural logarithm 2,71828.

b. The Weibull distribution is used to describe the reliability of a system that fails due to a gradual decline in performance. This distribution has the following reliability functions:

$$R(t) = e^{-\left(\frac{t}{\theta}\right)^{\beta}}$$

Where R(t) is the reliability function at time t, θ is the scale parameter, β is the shape parameter and t is the time interval.

b. Lognormal distribution The Lognormal distribution is used to describe the reliability of a system that has a minimum reliability value greater than zero. This distribution has the following reliability function:

$$R(t) = 1 - \Phi(\frac{Int - \mu}{\sigma})$$

Where R(t) is a reliability function at t time, Φ is a cumulative normal distribution function and μ and σ are mean parameters and standard deviations of the failure time logarithm.

c. Normal Distribution Normal distribution is used to describe the time variation until a system failure occurs affected by many factors, such as pressure, temperature, humidity, etc. This distribution has the reliability function as follows:

$$R(t) = 1 - \Phi(\frac{t - \mu}{\sigma})$$

Where R(t) is a reliability function at t time, Φ is a cumulative normal distribution function and μ and σ are mean parameters and standard distribution deviations.

Failure rate (λ) is the number of failures or damage occurring per unit of time. The rate of damage is generally described in the form of a curve commonly known as a bathub curve[9]. Based on the speed of damage, the distribution classification is divided into three: Burn In, Use full Life, and Wear Out. The relationship between damage to time can be described as follows:

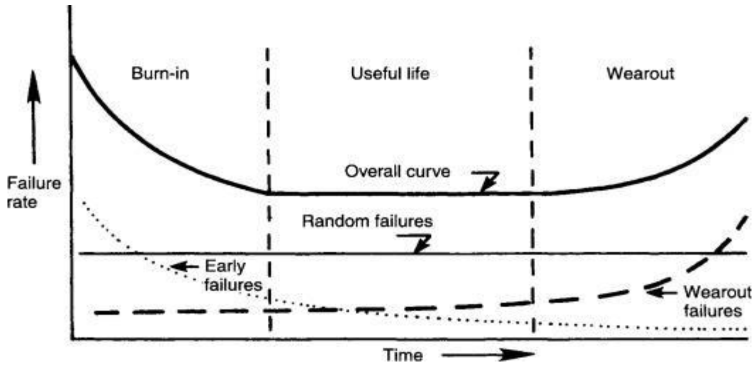


Fig.1 Bathtub Curve

There are three areas of dominant damage on the chart above. The three areas are as follows:

1. Burn In Zone, this phase describes the machine and the components working for the first time, so the reliability of the machine is still high. Failure that occurs is usually caused by misuse, material performance or under-standard workforce.

2. Useful Life Time Zone, this phase has a low and almost constant rate of damage. This period is a cycle in which the use or operation of a device is optimal so that at this stage the reliability of a machine can be determined.
3. Wear Out Zone, this phase shows a rapid increase in the rate of damage with increased duration. One of the causes of increased frequency of damage in this phase is the equipment or machinery used has exceeded the life of the product, occurrence of corrosion (characterized by rust) and non-melting maintenance.

The rate of failure of a system can be obtained by using the the following equation:

$$\lambda = \frac{number\ of\ failures}{total\ operating\ time}$$

In analyzing system or component failures, there are several factors on components during operating time, among others by Technical Method, by determining the cause of the failure of the device based on the technical aspects of the component and Statistical Methods, by establishing the relationship between component fault rate over time or using a relative frequency histogram by recording Time To Failure throughout the system operating[10].

3 Method

The data analysis method uses quantitative analysis, carried out with the help of Minitab software to analyze the reliability of the Wesel BSG-9 driver. By systematic distribution determination based on the time between damage and repair time. Aim to find out which distribution will be used to determine the MTTF and MTTR values. In determining this distribution is based on time data between damage and repair time. How to find out the distribution used with the Anderson Darling test with the help of Minitab software. If there is the smallest Anderson Darling value compared to the Anderson darling value in another distribution, then the distribution is the most relevant to the data. Next, check the p-value value produced by the Anderson Darling test. If the p-value value is greater than 0.05, we can accept the zero hypothesis (H0) which states that the data follows such a distribution. However, if the p - value value is smaller than 0.05 then the zero hypothetic (H0) is rejected and we conclude the data does not follow the distribution tested [11].

4 Result

Based on the data obtained, it can be identified that there are four critical components in the BSG-9 wesel propulsion. Critical component determination is based on the frequency of interference experienced by each component. From Figure 2 and the available interference frequency data, it is known that the track plate component is the most frequently failed component, with interference frequencies as much as 30 times over a three-year period. In addition, there are several other components that also failed, including the detection string, the PMCM module, and the wessel motor termination.

1. Calculating MTTF of Landing Plates

From the TTF data obtained, a conformity test was performed to determine Anderson Darling's value and the p-value using minitab software to find out what distribution will be used to obtain the reliability value of the Landas plate.

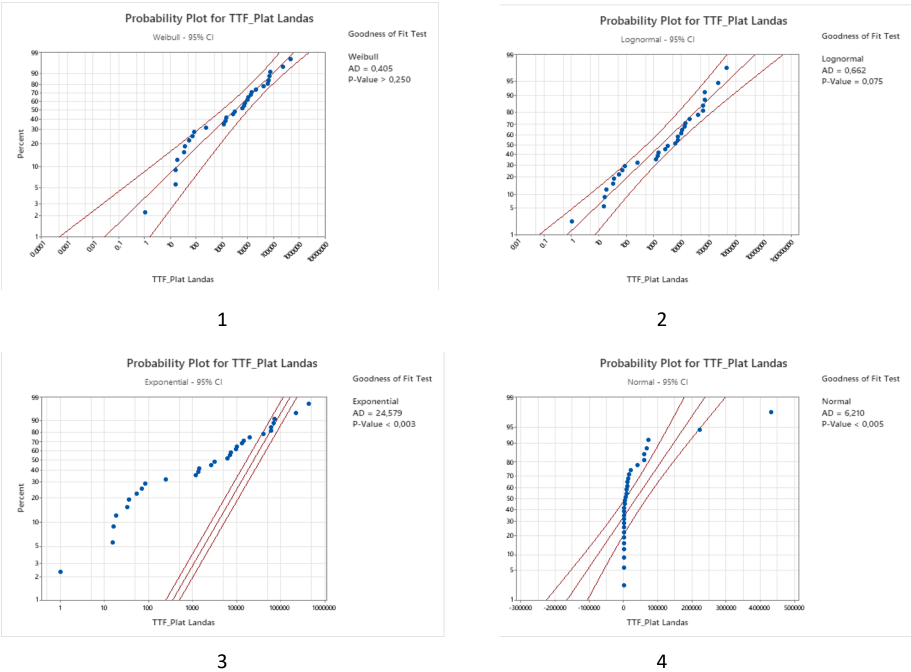


Fig 2. No.1 Weibull distribution determination test results TTF landing plate, No. 2 Test results for lognormal distribution of TTF trailing plate, no. 3 Results of exponential distribution testing TTF plates, No.4 Test results of normal distribution for TTF rotating plate

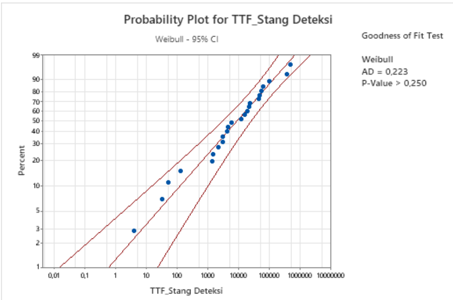
In Figure 2. No.1 the probability plot TTF of the weibull distribution of the landing plate produces an Anderson Darling value of 0.405 and a p-value> 0.25. In Figure 2. No.2 the probability plot TTF of the lognormal distribution of the landing plate results in an Anderson Darling value of 0.662 and a p-value of 0.075. In Figure 2. No.3 probability plot TTF exponential distribution of the landing plate results in Anderson Darling value 24.579 and p-value <0.003. In Figure 2. No.4 probability plot TTF normal distribution of the landing plate results in Anderson Darling value 6.21 and p-value <0.005.

Based on Figure 2, it can be seen that the data tends to follow the Weibull distribution pattern. This can be concluded based on the distribution of data close to the straight line plot of the Weibull distribution. The results of the MTTF calculation show that the greater the MTTF value, the component has a longer damage time span. The MTTF of

the landing plate is 39649.31 minutes or 27 days, indicating that the landing plate will be damaged again after 27 days from the last damage.
After obtaining the MTTF value, the reliability value of this component can be known. Calculating the reliability value of the Runway Plate with the shape and scale value parameters of the Weibull distribution. The following is the calculation process for the reliability value. Then the reliability value obtained on the current Platform Plate component is 19.69%.

4.2.1 Calculating MTTF of Detection Handlebar

From the TTF data that has been obtained, a suitability test is carried out to determine the Anderson Darling value and p-value using minitab software to find out what distribution will be used to obtain the reliability value of the detection handlebar.



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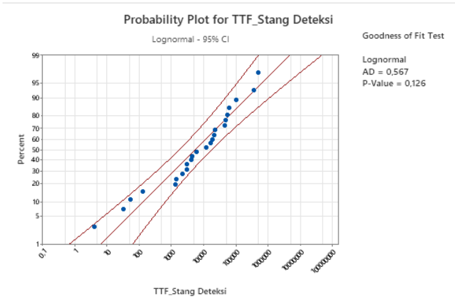

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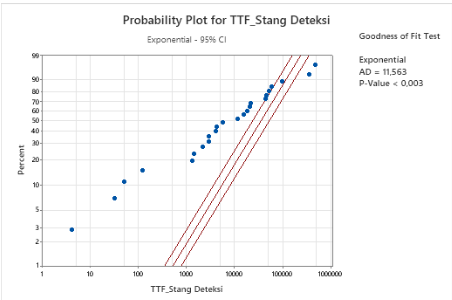

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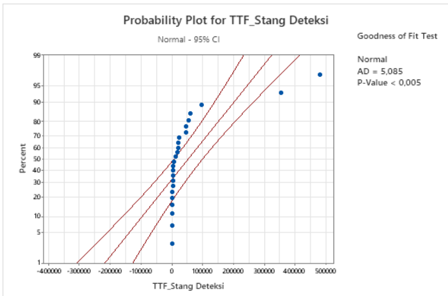

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Fig 3. No.1 Weibull distribution test result of TTF of detection handlebar, No.2 Lognormal distribution test result of TTF of detection handlebar, No.3 Exponential distribution test result of TTF of detection handlebar and No.4 Normal distribution test result of TTF of detection handlebar.

In Figure 3 No.1 probability plot TTF of weibull distribution of handlebar detection results in Anderson Darling value 0.223 and p-value >0.25, No.2 probability plot TTF of lognormal distribution of handlebar detection results in Anderson Darling value

0.567 and p-value 0.126, No.3 probability plot TTF of exponential distribution of handlebar detection results in Anderson Darling value 11.563 and p-value <0.003 and No.4 probability plot TTF of normal distribution of handlebar detection results in Anderson Darling value 5.085 and p-value <0.005.

Based on Figure 3, it can be seen that the data tends to follow the Weibull distribution pattern. This can be concluded based on the spread of data that is close to the straight line plot of the Weibull distribution. To determine the appropriate distribution, statistical testing is carried out using the Anderson Darling value. In this context, the data is said to follow a certain distribution if the Anderson Darling value obtained is the smallest compared to the Anderson Darling values of the other distributions tested. In addition, the p-value is also used as a reference, where a p-value greater than 0.05 indicates the suitability of the distribution to the data. Based on the test results, the Weibull distribution has the lowest Anderson Darling value of 0.223. Therefore, the Weibull distribution can be said to fit the data in the figure because it meets the criteria. After the appropriate distribution type for the detection handlebar is determined, the next step is to determine the parameters of the selected distribution. The shape value and scale value will be used in the MTTF value calculation process at the next stage.

Table 1. MTTF parameter values of detection handlebar

Component	**TTF Distribution Type**	**Parameters**	
		Scale (θ)	Shape (β)
Detection Handlebar	Weibull	20019,1	0,440505

After determining the type of distribution and parameters of TTF, the next step is to calculate MTTF. Calculating the MTTF value uses the parameter values θ and β. The following is the calculation process for the MTTF value. The results of the MTTF calculation show that the greater the MTTF value, the component has a longer damage time span. The MTTF of the Detection Stang is 52092.71407 minutes or 36 days, indicating that the landing plate will be damaged again after 36 days from the last damage. After obtaining the MTTF value, the reliability value of this component can be known. Calculating the reliability value of the Detection Handlebar with the shape and scale value parameters of the Weibull distribution. Then the reliability value of the current Detection Handlebar component is 21.786%.

4.2.2 Calculating MTTF of PMCM Module

From the TTF data that has been obtained, a suitability test is carried out to determine the Anderson Darling value and p-value using minitab software to find out what distribution will be used to obtain the reliability value of the PMCM Module.

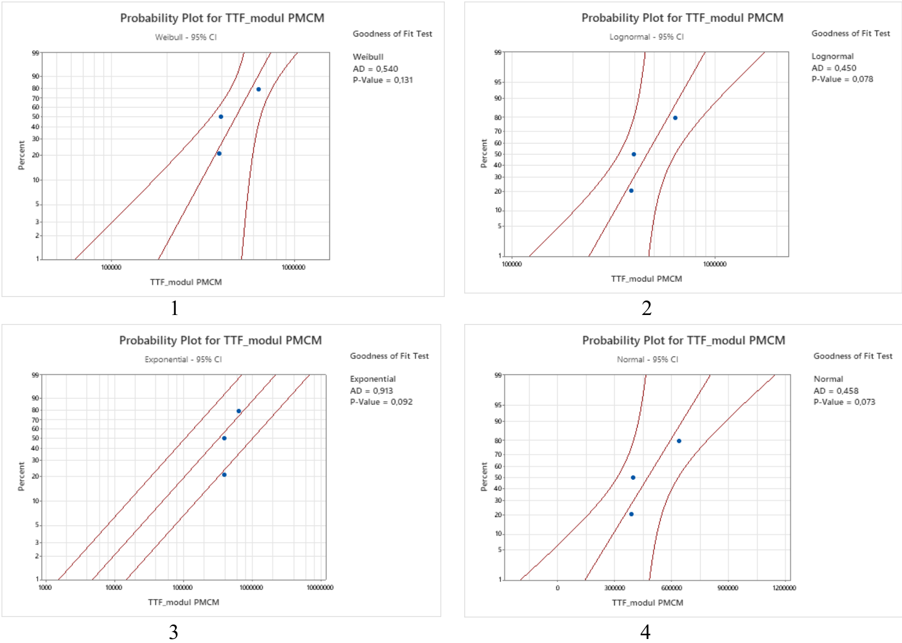


Fig 4 No.1 Test result of determining the weibull distribution of TTF of PMCM module, No.2 Test result of determining the lognormal distribution of TTF of PMCM module, No.3 Test result of determining the exponential distribution of TTF of PMCM module and No.4 Test result of determining the normal distribution of TTF of PMCM module

In Figure 4 No.1 probability plot TTF of weibull distribution of PMCM module results in Anderson Darling value 0.540 and p-value 0.131, No.2 probability plot TTF of lognormal distribution of PMCM module results in Anderson Darling value 0.450 and p-value 0.078, No.3 probability plot TTF of exponential distribution of PMCM module results in Anderson Darling value 0.913 and p-value 0.092 and No.4 probability plot TTF of normal distribution of PMCM module. probability plot TTF exponential distribution of PMCM module results in Anderson Darling value 0.913 and p-value 0.092 and No.4 probability plot TTF normal distribution of PMCM module results in Anderson Darling value 0.458 and p-value 0.073.

Based on Figure 4.12, it can be seen that the data tends to follow the lognormal distribution pattern. This can be concluded based on the distribution of data close to the lognormal distribution straight line plot. To determine the appropriate distribution, statistical testing is carried out using the Anderson Darling value. In this context, the data is said to follow a certain distribution if the Anderson Darling value obtained is the smallest compared to the Anderson Darling values of the other distributions tested. In addition, the p-value is also used as a reference, where a p-value greater than 0.05 indicates the suitability of the distribution to the data. Based on the test results, the lognormal distribution has the lowest Anderson Darling value of 0.450. Therefore, the lognormal distribution can be said to fit the data in the figure because it meets the criteria. After the appropriate distribution type for the PMCM module is determined, the next step is to determine the parameters of the selected distribution. The location value and scale value will be used in the process of calculating the MTTF value at the next stage.

Table 2. MTTF parameter values of PMCM modules

Component	**TTF Distribution Type**	**Parameters**	
		Scale (σ)	Location (μ)
PMCM Module	*Lognormal*	0,230232	13,0379

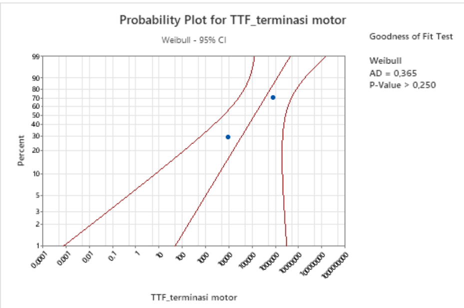
After determining the type of distribution and parameters of TTF, the next step is to calculate MTTF. Calculating the MTTF value uses the parameter values σ and μ. The results of the MTTF calculation show that the greater the MTTF value, the component has a longer damage time span. The MTTF of the termination motor is 471843.8516 minutes or 327 days, indicating that the PMCM Module will be damaged again after 327 days from the last damage.

4.2.3 Calculating Reliability of PMCM Module

After obtaining the MTTF value, the reliability value of this component can be known. Calculating the reliability value of the PMCM Module with the parameters of the location value and the Lognormal distribution scale. Then the reliability value obtained on the PMCM Module component at this time is 60.369%.

4.2.4 Calculating MTTF of Motor Vessel Termination

From the TTF data that has been obtained, a suitability test is carried out to determine the Anderson Darling value and p-value using Minitab software to find out what distribution will be used to obtain the reliability value of the motor termination.



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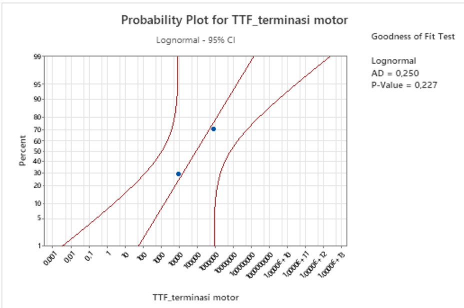

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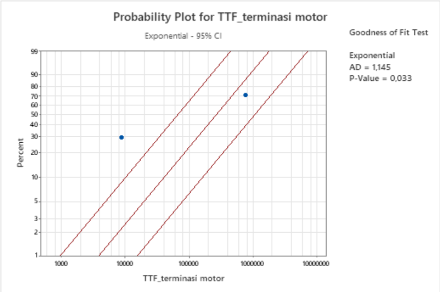

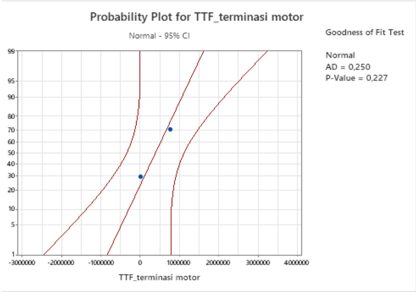

Fig 5. No. 1 Test results of determining the weibull distribution of TTF of motorcycle initiation, No. 2 Test results of determining the lognormal distribution of TTF of motorcycle initiation, No. 3 Test results of determining the exponential distribution of TTF of motorcycle initiation, and No. 4 Test results of determining the normal distribution of TTF of motorcycle initiation.

In Figure 5. No. 1 probability plot TTF weibull distribution of termination of motorized buses produces Anderson Darling value 0.365 and p-value >0.25, No. 2 probability plot TTF lognormal distribution of termination of motorized buses produces Anderson Darling value 0.250 and p-value 0.227, No. 3 probability plot TTF exponential distribution of termination of motorized buses produces Anderson Darling value 1.145 and p-value 0.033 and No. 4 probability plot TTF normal distribution of termination of motorized buses. 3 probability plot TTF of exponential distribution of motorcycle terminations results in Anderson Darling value of 1.145 and p-value of 0.033 and No. 4 probability plot TTF of normal distribution of motorcycle terminations results in Anderson Darling value of 0.250 and p-value of 0.227.

Based on Figure 5, it can be seen that the data tends to follow a lognormal distribution pattern. This can be concluded based on the distribution of data close to the lognormal distribution straight line plot. To determine the appropriate distribution, statistical testing is carried out using the Anderson Darling value. In this context, the data is said to follow a certain distribution if the Anderson Darling value obtained is the smallest compared to the Anderson Darling values of the other distributions tested. In addition, the p-value is also used as a reference, where a p-value greater than 0.05 indicates the suitability of the distribution to the data. Based on the test results, the lognormal distribution has the lowest Anderson Darling value of 0.250. Therefore, the lognormal distribution can be said to fit the data in the figure because it meets the criteria. After the type of distribution that is suitable for the termination of the motor wesel is determined, the next step is to determine the parameters of the selected distribution. The location value and scale value will be used in the MTTF value calculation process at the next stage.

Table 3. MTTF parameter values of the motor termination vane

Component	TTF Distribution Type	Parameters	
		Scale (σ)	Location (μ)
Wesel Motor Termination	*Lognormal*	2,23421	11,29837

After determining the type of distribution and parameters of TTF, the next step is to calculate MTTF. Calculating the MTTF value uses the parameter values σ and μ. The results of the MTTF calculation show that the greater the MTTF value, the component has a longer damage time span. The MTTF of the termination motor is 978931.7 minutes or 679 days, indicating that the PMCM Module will be damaged again after 679 days from the last damage.

After obtaining the MTTF value, the reliability value of this component can be known. Calculating the reliability value of the termination motor wessel with parameters Location value and Lognormal distribution scale. Then the reliability value obtained on the current motor termination component is 98.22%.

5 Conclusion

Based on the results of the research that has been done, it can be concluded that the calculation of MTTF and reliability can determine the reliability value of the BSG-9 wessel drive component which is often damaged as follows:

a. The reliability value of the landing plate is 19.69%
b. The reliability value of the detection handlebar is 21.78%
c. PMCM module reliability value of 60.36%
d. The reliability value of the window motor termination is 98.22%

Based on the above conclusions, it is recommended that the maintenance of the BSG-9 relay drive on critical components that have the lowest reliability based on RCM (Reliability Centered Maintenance). It is hoped that the company can increase the reliability of the critical components of the BSG-9 wessel drive by implementing maintenance activities based on the RCM method.

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