

FAILURE MODE EFFECT AND CRITICALITY ANALYSIS (FMECA) FOR DETERMINATION TIME INTERVAL REPLACEMENT OF CRITICAL COMPONENTS IN WARSHIPS RADAR

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ABSTRACT

Using of radar navigation in Indonesian Warships, specialty in Patrol Boats Unit of Indonesian Eastern Fleet is very vital as remote sensing devices in navigation. It's using must exist absolutely at the time of Indonesian Warships carry out operations, so the readiness of radar navigation will greatly affect the implementation of the tasks performed. This study aims to obtain critical components on navigation radars on warships and also aims to obtain a critical time interval for replacing critical components of the navigation radar so that warships are ready to operate. In the next stage this research also aims to calculate the cost of critical component replacement components based on the Cost Benefit Ratio (CBR) method.

In this paper proposed FMECA models in determining the critical components of Navigation Radar. Failure Mode Effect and Criticality Analysis (FMECA) is used as a methodology to identify and analyze all potential failure modes of various parts of the system, the effects of the failure of the system, how to avoid failure and to reduce the impact of failure on the system. Based on the model is obtained Risk Priority Number (RPN) that is used as a reference value in determining the critical components. RPN value of each component is analyzed by Risk Matrix, from 27 (twenty-seven) components that have been identified, There are obtained seven (7) components that are considered critical: Modulator, Power Supply Scanner, Diodes Limiter, Magnetron, Receiver, Motor, and Circulator. The modulator has the highest RPN value, 24180 and Plotter Control Circuit has the lowest RPN value, 3289.

Determining the time interval replacement of critical components that have been obtained using the approach Reliability and Cost Benefit Ratio (CBR). Results indicate that the component replacement Diode Limiter has the fastest time, 152 days. While the replacement of components with the longest time are Motor and Circulator, 458 days. CBR value for all of the critical components are less than 1 ($CBR < 1$), it shows the recommendation of replacement cost was efficient. Diode Limiter has CBR value that is the most efficient, namely 0.57572. From sensitivity analysis is obtained that Reliability $R(t)$ variable greatly affects the determination of the change in the time interval replacement of critical components, in which there are parameter β (slope), Y parameter (location), and the parameter η (scale). Parameter β more influence on changes in the value of Reliability $R(t)$.

Keywords: FMECA, Risk Priority Number (RPN), Reliability, Time Interval of Replacement, CBR.

1. INTRODUCTION

Patrol Boats Unit fleet command is commander for Development which has the principal task of the strength and capacity to implement the combat elements of the organic conform their basic function, namely in the field of anti-ship warfare surface and anti-air warfare in order to improve the combat capability of the Fleet command East Region. With one of its functions preparing and controlling the plans and programs

in the field of maintenance carried out by vessels in units according to the cycle system planned maintenance in order to improve the technical readiness elements according to plan and program Fleet Command, is no exception in this case the maintenance of navigation equipment as well as radar navigation.

Use of radar navigation in Warships, his specialty in Unit Patrol Boats Fleet Command very vital as remote sensing devices in navigation. Its use is an absolute must exist at the time of Warships carry

out operations so that the readiness of radar navigation will greatly affect the implementation of the tasks performed by the operation of the Elements. Often by the time of the Elements will carry out the task of operations have constraints on the readiness of radar navigation, and of course will affect the overall readiness of Warships. To prevent the occurrence of these conditions, we need a proper step to correct or eliminate the damage so that system performance is not decreased.

Navigation Radar JRC JMA 5310 in Warships of 4 pieces radar, owned by Warships Sura-802, Warships Kakap-811, Warships Kerapu-812, and Warships Tongkol-813. Navigation radar at this time is about 7.5 years old with hours of operation that exceeds 10,000 hours of operation, thus the inspection of technical conditions to be increasingly frequent. According [21], inspection (inspection) is an act directed against a system to prevent sudden breakdown, and to see whether the system works properly in accordance with its function.

From the condition of Radar JRC JMA 5310 in Warships, in need of a proper maintenance planning for improvement priority. To prevent or avoid various forms of damage, predict and find an easy step to prevent damage. Determining the appropriate measures to prevent damage. The combines technical requirements and management strategies, [25]. The incidence of damage to the components studied to determine which solution will be taken based on the form of damage, effects, and costs of all systems. Data information about the crash will assist personnel to determine the appropriate corrective action and determine the different priorities of each component are experiencing failure.

Another work [1], proposed the application method and TOPSIS in Fuzzy FMEA to determine the critical components and priorities of various alternative repair elected to damage the components applied to the radar system Sperry Marine Navigation, which is expected by the application of this method can improve operational performance Warships. In these studies do not consider the determination of the time interval replacement of critical components and optimal cost of maintenance/care.

In this research plan proposed model of Failure Mode Effects and Criticality Analysis (FMECA) in determining the time interval

replacement of critical components Navigation Radar JRC JMA 5310 taking into account the optimization of maintenance costs increase the value of reliability. Another work [2], FMECA is a methodology to identify and analyze all potential failure modes of various parts of the system, the effects of the failure of the system, how to avoid failure and or reduce the impact of failure on the system. The problem statements in this study are as follows:

1. How to determine the physical components of the warship navigation radar
2. How to determine the time interval for replacing critical components based on the reliability of the system on warship navigation radars
3. How to calculate the cost of replacing the critical component with the Cost Benefit Ratio (CBR) method

The motivation of this research is to be able to do better management on the maintenance of warship navigation radar so that the ship is ready to operate whenever and wherever

2. MATERIAL AND METHODS

2.1 Radar (Radio Detection and Ranging)

According [3], Radar is a code that used the United States Navy in 1940 during World War II, which stands for radio detection and ranging. Radar is an active remote sensing system, which provides its own illumination source. The radio waves are transmitted as pulses with high energy microwave energy. Pulse interacts with the atmosphere and the target. A portion of the energy is radiated back, received by the target is then measured intensity and time delay between transmission and reception of signals back. Radar signals can be displayed on a Plan Position Indicator (PPI) radar systems or other display.

Since the discovery of Radar by Sir Robert Watson Wat (the Father of Radar) in 1932 until today has undergone very rapid development in the field of technology. This development is aimed at the effective use of the addition and the added efficiency of deployment and maintenance as well as increased reliability of the system. As an illustration, the first radar target is only capable of capturing and showing the only sector where the target is located. While the modern generation Radar is able to capture the target with accurately determine target coordinates, altitude, distance, speed, and other benefits information. In the era of globalization, the role and functions of Radar in everyday human life are very important, visible indication of how urgent the lives of the civilian population and military interests are supported by the device Radar.

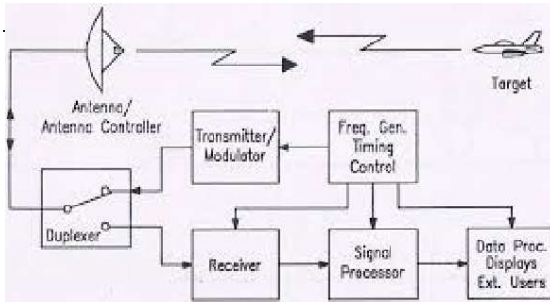


Figure 1. Block Diagram of Radar Working Principle [4]

2.2 Failure Modes Effects and Criticality Analysis (FMECA)

FMECA was originally developed by the National Aeronautics and Space Administration (NASA), which aims to improve and verify the reliability Hardware space program MIL-STD-785, entitled the Reliability Program for Systems and Equipment Development and Production to review the procedures for conducting FMECA on the equipment or system or. The MIL-STD-1629 is a military standard that establishes the requirements and procedures for FMECA, to evaluate and document the potential impact of any functional failure or hardware on mission success, security personnel and systems, maintenance and system performance.

According [2], defines FMEA is a methodology to identify and analyze:

- All potential failure modes of various parts of the system
- The effect of the failure of the system How to avoid failure and or reduce the impact of failure on the system.

Procedure Failure Modes Effects and Criticality Analysis (FMECA) outline can include several steps systematically include [5]:

- Identify all potential failure modes and their causes.
- Evaluation of the impact on each failure modes in the system.
- Identify methods in detecting damage/failure.
- Identify corrective measurements to failure modes.
- Access the frequency and significance of the damage are important for critical analysis, which can be applied.

Meanwhile, according to [6], the basic steps in the conventional FMECA include:

- Defining the system, which includes the identification of internal functions and interfaces, the expected performance in various levels of complexity, restrictions, and definitions of system failure.
- Perform functional analysis, illustrating the operation of linkage, and the dependence of functional entities.
- Identifying failure modes and effects, all potential failure modes of the items and interfaces are identified and their impact on the function directly, item and the system must be clearly defined.
- Determine the severity rating (S) of the failure mode, which refers to how serious the impact or effect of the failure mode.
- Determining occurrence rating (O) of the frequency of occurrence of failure mode and failure mode analysis. Assuming that the system components tend to fail in many ways, this information is used to describe the most critical aspects of the system Desain.
- Detection determines to rate (D) from control design criteria, the failure mode.
- Risk Priority Number (RPN) Represents the weighted multiplication result Severity, occurrence, and Detection. These results will be able to determine the critical components.

$$\text{RPN} = \text{Severity (S)} \times \text{Occurrence (O)} \times \text{Detection (D)}$$

Table 1: Severity Index

| Rating | Effect | Severity Effect |
|--------|----------------------------------|---|
| 10 | Hazardous without warning (HWOW) | Very high severity ranking when a potential failure mode affects safe system operation without warning |
| 9 | Hazardous with warning (HWW) | Very high severity ranking when a potential failure mode affects safe system operation with the warning |
| 8 | Very High (VH) | System inoperable with destructive failure without compromising safety |
| 7 | High (H) | System inoperable with equipment damage |
| 6 | Moderate (M) | System inoperable with minor damage |
| 5 | Low (L) | System inoperable without damage |
| 4 | Very Low (VL) | |

| | | |
|---|------------------|---|
| 3 | Minor (MR) | A system operable with significant degradation of performance |
| 2 | Very Minor (VMR) | A system operable with some degradation of Performance |
| 1 | None (N) | A system operable with minimal interference No effect |

[7]

Table 2: Occurrence Index

| Rating | Probability of occurrence | Failure probability |
|--------|--|---------------------|
| 10 | <i>Very High (VH)</i> : failure is almost inevitable | > 1 in 2 |
| 9 | <i>High (H)</i> : repeated failures | 1 in 3 |
| 8 | | 1 in 8 |
| 7 | | 1 in 20 |
| 6 | <i>Moderate (M)</i> : occasional failures | 1 in 80 |
| 5 | | 1 in 400 |
| 4 | | 1 in 8000 |
| 3 | <i>Low (L)</i> : relatively few failures | 1 in 15000 |
| 2 | | 1 in 150000 |
| 1 | | < 1 in 150000 |

[7]

Table 3: Detection Index

| Rating | Detection | The possibility of the detection by the controller |
|--------|--------------------------|---|
| 10 | Absolute Uncertainty(AU) | Design control cannot detect potential cause/mechanism and subsequent failure mode. |
| 9 | Very remote (VR) | Very remote chance the design control will detect potential cause/mechanism and subsequent failure mode |
| 8 | Remote (R) | Remote chance the design control will detect potential cause/mechanism and subsequent failure mode. |
| 7 | Very Low (VL) | Very low chance the design control will detect potential cause/mechanism and subsequent failure mode. |
| 6 | Low (L) | Low chance the design control will detect potential cause/mechanism and subsequent failure mode. |
| 5 | Moderate (M) | Moderate chance the design control will detect potential cause/mechanism and subsequent failure mode. |
| 4 | Moderately High (MH) | Moderately high chance the design control will |

| | | |
|---|---------------------|--|
| 3 | High (H) | detect potential cause/mechanism and subsequent failure mode. |
| 2 | Very High (VH) | High chance the design control will detect potential cause/mechanism and subsequent failure mode. |
| 1 | Almost Certain (AC) | Very high chance the design control will detect potential cause/mechanism and subsequent failure mode. Design control will detect potential cause/mechanism and subsequent failure mode.. |

[7]

2.3 Probability Distributions

2.3.1 Weibull Distribution

Weibull distribution is widely used in the reliability analysis, especially to perform calculations component life. This type of distribution is also one of the most widely used distributions fields of engineering, reliability, this is because the distribution has the ability to model the data differently and more by setting the value of shape parameter β . According [8], Weibull distribution can be presented in the form of two or three parameters.

$$MRL(t) = \frac{1}{R(t)} \left[MTTF - \int_0^t R(t) dt \right] \quad (1)$$

Where:

β = parameter form, $\beta > 0$

η = Parameter Scale, $\eta > 0$

γ = location parameter, $\gamma < \infty$ when damage first.

Weibull distribution reliability function can be expressed by:

$$f(t) = \frac{\beta}{\eta} \left(\frac{t - \gamma}{\eta} \right)^{\beta-1} e^{-\left(\frac{t - \gamma}{\eta} \right)^{\beta}} \quad (2)$$

Weibull reliability distribution function can be expressed by:

$$R(t) = e^{-\left(\frac{t - \gamma}{\eta} \right)^{\beta}} \quad (3)$$

Value rate can be expressed by:

$$\lambda(t) = \frac{\beta}{\eta} \left(\frac{t - \gamma}{\eta} \right)^{\beta-1} \quad (4)$$

If $\gamma = 0$ then obtained a Weibull distribution with two parameters.

If $\beta > 1$, then at $t = \text{large}$ pdf equal to zero as well as the rate of destruction is equal to zero, consequently the value of reliability $R(t) = 1$, see equation (15) to pdf and equation (16) $R(t)$ and the equation (17) to $\lambda(t)$. The larger the value η a component, then the probability of broken components will be smaller (equation 16). If the value η component A is greater than component B, then the value of the reliability of components and a faster decline than the component A.

2.3.2 Exponential Distribution

The exponential distribution is widely used in engineering reliability because it can present the distribution of the time distribution phenomenon that failure of a component/system. According [9], the exponential distribution density function is expressed in the equation:

$$f(t) = \lambda e^{-\lambda t}; t > 0, \lambda > 0 \quad (5)$$

And the cumulative distribution function is:

$$F(t) = 1 - e^{-\lambda t} \quad (6)$$

Where:

t = Time

λ = Constan failure rate

Reliability function is:

$$R(t) = 1 - F(t) = e^{-\lambda t} \quad (7)$$

Failure Rate:

$$\lambda(t) = \frac{f(T)}{R(t)} = \lambda \quad (8)$$

$$MTTF = \int_0^{\infty} R(t) dt = \frac{1}{\lambda} \quad (9)$$

2.3.3 Normal Distribution

According [8], the normal distribution (Gaussian) is useful for describing the influence of accretion can specify the time when the time between failures associated with the uncertainty, the normal distribution has the following formula:

$$f(t) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left[-\frac{(t - \mu)^2}{2\sigma^2} \right] \quad (10)$$

For $-\infty \leq t \leq \infty$

Where:

σ = the standard deviation of the random variable T

μ = the average of the random variable T

And the cumulative distribution function is:

$$F(t) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left[-\frac{(t - \mu)^2}{2\sigma^2} \right] dt \quad (11)$$

Reliability function of the normal distribution is:

$$R(t) = \int_t^{\infty} \frac{1}{\sigma \sqrt{2\pi}} \exp \left[-\frac{(t - \mu)^2}{2\sigma^2} \right] dt \quad (12)$$

The rate of destruction of the normal distribution can be obtained using the equation:

$$\lambda(t) = \frac{\exp \left[-\frac{(t - \mu)^2}{2\sigma^2} \right]}{\int_t^{\infty} \exp \left[-\frac{(t - \mu)^2}{2\sigma^2} \right] dt} \quad (13)$$

2.4 FMECA Model on Determination Critical Components

Steps Failure Mode Effects and Criticality Analysis (FMECA) model are adjusted to the flow chart of research as follows:

- Identifying the JRC JMA 5310 radar system, which includes the identification of internal functions and interfaces, the expected

- performance in various levels of complexity, restrictions, and definitions of system failure.
- Identifying potential damage mode, all potential failure modes of the items and interfaces are identified and their impact on the function directly, item and the system must be clearly defined.
 - Determine the severity rating (S) of the failure mode, referring to how serious the impact or effect of the failure mode.
 - Determining accuracy rating (O) of the frequency of occurrence of failure mode and failure mode analysis keWarshipstisan. Assuming that the system components tend to fail in many ways, this information is used to describe the most critical aspects of the system design.
 - Determining the detection rating (D) from control design criteria, the failure mode.
 - Calculated Risk Priority Number (RPN) to identify critical components determining Radar JRC JMA 5310.

| Rating | Definition |
|--------|---|
| High | Requiring repairs to eliminate the danger |
| Medium | Require a review of the acceptability of risk |
| Accept | An acceptable risk to be reviewed as a draft that has been cooked |

$$RPN = \text{Severity (S)} \times \text{occurrence (O)} \times \text{Detection (D)}$$

- The cumulative results of components that have a high RPN value selected as a candidate for critical components.

2.5 Risk Matrix

The next step to implement criticality analysis using a risk matrix components corresponding predefined criteria. The final results obtained are the items included in the rating of risk "high" based on the risk matrix. Overall results FMECA analysis models and risk matrix will then be presented in the form FMECA Worksheet. Table 4. Shows the categories of damage based on the level of influence on the system or personnel, Table 5. Shows Severity of Frequency, and Table 6. Shows Rating of Risk.

Table 4 : Severity of Consequences

| Severity of Consequences | |
|--------------------------|--|
| Category | Definition |
| Catastrophic (I) | Cause a system shutdown |
| Critical (II) | The system can not function according to the specified |
| Marginal (III) | System decreased performance function |
| Negligible (IV) | The system can function with little risk |

Table 5 : Severity of Frequency

| Severity of Frequency | | |
|-----------------------|-------------------|------------------------------|
| Frequency of Events | Definition | |
| | qualitative | quantitative |
| Frequent | Often occur | $\geq 1 \times 10^{-3}$ hour |
| Probable | Very likely occur | $\geq 1 \times 10^{-4}$ hour |
| Occasional | Common occur | $\geq 1 \times 10^{-5}$ hour |
| Remote | Seldom occur | $\geq 1 \times 10^{-6}$ hour |
| Improbable | Imposable occur | $< 1 \times 10^{-7}$ hour |

Table 6 : Rating of Risk

2.6 Cost Benefit Ratio (CBR) Model of Replacement Critical Components

Cost Benefit Ratio (CBR) is lower than 1 (CBR <1), the activities are profitable, in other words, Benefit must be greater than the cost, as an illustration, if the replacement is done before the failure, the benefits obtained will be maximized and the cost can be reduced will certainly benefit. To get a replacement cost of each component by (Knight, 2012) can be described in the form of the following equation:

$$CBR = \frac{R_{(T)} \cdot [C_K + (t_{BF} \cdot C_{PN})] + [(1 - R_{(T)}) \cdot \{C_K + (t_{AF} \cdot C_{PE}) + (t_{AF} \cdot C_{BD})\}]}{C_K + (t_{AF} \cdot C_{PE}) + (t_{AF} \cdot C_{BD})}$$

CBR : Cost Benefit Ratio

C_K : Cost of Component

$R_{(T)}$: Reliability

$1 - R_{(T)}$: Probability of failure

T_{BF} : Time of repair before the damaged component

T_{AF} : Time of repair after the damaged component

C_{PN}: Cost of labor in normal condition /plannedC_{PE}: Cost of labor in the emergency conditionC_{BD}: Cost when breakdown happened

| | | | |
|----|-------------------------------|------|----|
| 26 | UPS (K27) | 3640 | 26 |
| 27 | Plotter Control Circuit (K14) | 3289 | 27 |

3. RESULT AND DISCUSSION

3.1 Questionnaire Results of FMECA Application

To obtain questionnaire data, the authors create a concept that is not independent of the choice of terminology FMECA, which contains the component failure mode risk identification and risk assessment criteria for identification of component failure mode. Furthermore, from the data obtained by the results of the questionnaire rating severity, occurrence, and the detection of each of the components gathered from the experts. From the values of severity, occurrence, and detection can be calculated the score of RPN components. RPN value obtained from all subsequent components is sorted from largest to smallest value, as the ranking of priority/criticality level components. Recapitulation and ranking the results of calculation of RPN values shown in Table 7.

Table 7 : Risk Priority Number (RPN) Values

| No | Components | RPN | Ranking |
|----|---------------------------|-------|---------|
| 1 | Modulator (K1) | 24180 | 1 |
| 2 | Power Supply Scanner (K9) | 23040 | 2 |
| 3 | Diode Limiter (K8) | 20280 | 3 |
| 4 | Magnetron (K6) | 16800 | 4 |
| 5 | Receiver (K2) | 15950 | 5 |
| 6 | Motor (K3) | 13500 | 6 |
| 7 | Radar Processor (K10) | 11648 | 7 |
| 8 | Circulator (K7) | 11220 | 8 |
| 9 | Rotary Joint (K4) | 8602 | 9 |
| 10 | Track Ball (K22) | 7524 | 10 |
| 11 | Power Supply CPU (K18) | 7500 | 11 |
| 12 | Transformer (K23) | 7475 | 12 |
| 13 | Monitor Fan (K20) | 7452 | 13 |
| 14 | Bridge Diode (K24) | 7140 | 14 |
| 15 | Keyboard Matrix (K21) | 7106 | 15 |
| 16 | Condensator (K25) | 6804 | 16 |
| 17 | Radiator / Antena (K5) | 6336 | 17 |
| 18 | LCD Monitor (K19) | 6072 | 18 |
| 19 | I/F Chassis (K16) | 5750 | 19 |
| 20 | Filter (K26) | 5187 | 20 |
| 21 | Terminal Board (K12) | 4840 | 21 |
| 22 | NSK Circuit (K13) | 4620 | 22 |
| 23 | ARPA (K11) | 4488 | 23 |
| 24 | I/O Circuit (K15) | 4095 | 24 |
| 25 | AIS Interface (K17) | 3822 | 25 |

3.2 Determination of Critical Components

Data analysis results severity of consequence frequency and severity of each of the above components further processed into a risk matrix to classify the rating of risk components to the criteria specified in Table 3.3 to the combination of the level of damage and the potential consequences of the level of frequency of occurrence. So that component is included in the severity of consequence "catastrophic" or "critical" is not necessarily included in the classification of critical components in question. Similarly, the frequency components with very high damage (probably) could not be ascertained included in the category of critical components. Critical components are referred to in this paper is a component of the rating category of risk "high" risk matrix based on the analysis of the method FMECA. This is because the component with the high level of risk that have an average level of frequency of occurrence and severity of impact damage higher than other components are included in the rating category of risk "medium" and "unacceptable". The results of the risk analysis matrix for each component are presented in Table 8.

Table 8 : Risk Rating of Components

| No | Components | Rating of Risk |
|----|---------------------------|----------------|
| 1 | Modulator (K1) | High |
| 2 | Power Supply Scanner (K9) | High |
| 3 | Diode Limiter (K8) | High |
| 4 | Magnetron (K6) | High |
| 5 | Receiver (K2) | High |
| 6 | Motor (K3) | High |
| 7 | Radar Processor (K10) | Medium |
| 8 | Circulator (K7) | High |
| 9 | Rotary Joint (K4) | Accept |
| 10 | Track Ball (K22) | Accept |
| 11 | Power Supply CPU (K18) | Accept |
| 12 | Transformer (K23) | Accept |
| 13 | Monitor Fan (K20) | Accept |
| 14 | Bridge Diode (K24) | Accept |
| 15 | Keyboard Matrix (K21) | Accept |
| 16 | Condensator (K25) | Accept |
| 17 | Radiator / Antena (K5) | Accept |
| 18 | LCD Monitor (K19) | Accept |
| 19 | I/F Chassis (K16) | Accept |
| 20 | Filter (K26) | Accept |
| 21 | Terminal Board (K12) | Accept |
| 22 | NSK Circuit (K13) | Accept |

| | | |
|----|-------------------------------|--------|
| 23 | ARPA (K11) | Accept |
| 24 | I/O Circuit (K15) | Accept |
| 25 | AIS Interface (K17) | Accept |
| 26 | UPS (K27) | Accept |
| 27 | Plotter Control Circuit (K14) | Accept |

Based on the rating of risk, of the 27 components were analyzed gained critical components that have high risks and RPN are shown in Table 9.

Table 9 : Critical Components

| No | Components | Category | | Risk Matrix | RPN |
|----|---------------|--------------|------------|-------------|-------|
| 1 | Modulator | Critical | Probable | High | 24180 |
| 2 | P.S Scanner | Catastrophic | Probable | High | 23040 |
| 3 | Diode Limiter | Critical | Probable | High | 20280 |
| 4 | Magnetron | Critical | Probable | High | 16800 |
| 5 | Receiver | Catastrophic | Occasional | High | 15950 |
| 6 | Motor | Catastrophic | Occasional | High | 13500 |
| 7 | Circulator | Critical | Probable | High | 11220 |

3.3 Analysis of Reliability Value Before Time Interval Replacement

Prior to the calculation of the time interval of replacement parts so that the value of reliability in accordance with the desired, first performed reliability value calculation before optimization.

Table 10 : Reliability Value of Components Before Optimization

| No | Components | MTBF (Day) | Reliability |
|----|----------------------|------------|-------------|
| 1 | Modulator | 274 | 0,537901 |
| 2 | Power Supply Scanner | 273 | 0,551594 |
| 3 | Diode Limiter | 162 | 0,486821 |
| 4 | Magnetron | 177 | 0,482604 |
| 5 | Receiver | 166 | 0,499164 |
| 6 | Motor | 464 | 0,442824 |
| 7 | Circulator | 463 | 0,433815 |

From the calculation results are shown in Table 10 can be seen that the scanner has a power supply component reliability scores the highest of 0.551594, but still not meet the target that is above 0.95 in accordance with the provisions of section minimal instrumentation. While most low-value component reliability is a component circulator that is 0.433815. Based on data reliability scores above components, necessary to determine the appropriate time intervals so that the reliability value of these components can be increased as desired.

3.4 Analysis of Reliability Value After Time Interval Replacement

After calculating the time interval determining replacement values obtained new reliability. The calculation inputting replacement intervals and was calculated using the results of parameter tables corresponding distribution (Weibull 3). The minimum limit of reliability required for a component to operate the 0.95. Table 11. The results of the calculation of critical component replacement intervals.

Table 11 : Reliability Value of Components After Optimization

| No | Components | MTBF (Day) | Time Interval Replacement (Day) | Reliability |
|----|----------------------|------------|---------------------------------|-------------|
| 1 | Modulator | 274 | 234 | 0,953037 |
| 2 | Power Supply Scanner | 273 | 232 | 0,951484 |
| 3 | Diode Limiter | 162 | 152 | 0,958165 |
| 4 | Magnetron | 177 | 157 | 0,957328 |
| 5 | Receiver | 166 | 157 | 0,952719 |
| 6 | Motor | 464 | 458 | 0,980802 |
| 7 | Circulator | 463 | 458 | 0,970894 |

From the calculation results are shown in Table 11. above shows that all the components already meet the target level of reliability that is above 0.95 in accordance with the minimum provisions of the instrument parts, component replacement diode limiter had the fastest time, which is 152 days, whereas the replacement of components with the longest time, ie 458 days is a component of the motor and the circulator.

3.5 Analysis of Component Replacement Cost

In the previous chapter has presented the costs if the replacement part before the condition is broken and after damage. The data on the calculation of replacement parts after the damage occurred, if applied in accordance with the method of component replacement intervals have been proposed/recommended for each critical component, then the cost will be a benefit or a benefit for the maintenance budget savings Radar JRC JMA 5310.

To see if the replacement of critical components has been effective in terms of cost will be explained by calculating the Cost Benefit Ratio (CBR) it. 5.3 Table 12. Shows the calculation of the replacement process CBR critical components:

Table 12 : Cost Benefit Ratio (CBR)

| No | Components | Time Interval Replacement (Day) | Benefit When Implement Recommendation (IDR) | CBR |
|----|---------------|---------------------------------|---|---------|
| 1 | Modulator | 234 | 33.240.000,- | 0,86481 |
| 2 | P.S. Scanner | 232 | 29.890.000,- | 0,84991 |
| 3 | Diode Limiter | 152 | 7.780.000,- | 0,57572 |
| 4 | Magnetron | 157 | 8.990.000,- | 0,78276 |
| 5 | Receiver | 157 | 27.980.000,- | 0,88729 |
| 6 | Motor | 458 | 34.375.000,- | 0,84735 |
| 7 | Circulator | 458 | 9.410.000,- | 0,65848 |

In Table 12. Explains the results of any replacement of critical components have been effective if it is seen from the cost side, it is seen from the CBR for each critical component, which is less than 1 (CBR <1).

4. CONCLUSIONS

From the analysis and discussion that has been done in the previous chapter, we can make some conclusions as follows:

1. Based on the steps Failure Mode Effects and Criticality Analysis (FMECA) through the calculation of Risk Priority Number (RPN) and the Risk Matrix, it can be determined from the 27 components gained 7 components that have the highest RPN value and the value of Risk Matrix "high", they are modulator, power supply scanner, limiter diode, magnetron, receiver, motors and circulator. The modulator has the highest RPN value, namely 24180 and Plotter Control Circuit has the lowest RPN, namely 3289.

2. In the calculation of the time interval replacement of all critical components obtained the shortest time interval is limiter diode, ie 152 days and components with the longest time interval are motor and circulator, ie 458 days. As for the other components, modulator 234 days, power supply scanner 232 days, magnetron and receiver 157 days.

3. Based on the analysis it can be seen that the cost of component replacement has been concluded efficiently, where the value of Benefit Cost Ratio (CBR) is less than 1 (CBR <1)., It is seen from the CBR value of each critical component, ie 0.86481 modulators, power supply scanner 0.84991, 0.57572 limiter diode, magnetron 0.78276, 0.88729 receivers, motors 0.84735 and 0.65848 circulator.

5. FUTURE WORK

Based on the efforts that have been made in this study, the author felt the need to give suggestions for future work:

a. Need for follow-up research that method of determining the time interval of replacement parts will contribute to the maintenance of Navigation Radar JRC JMA 5310.

b. Need for an evaluation of the methods of treatment primarily Navigation Radar JRC JMA 5310 that have been implemented over the years, in order to support operational readiness of the main tasks of the Navy, namely to maintain the sovereignty of the Homeland sea.

c. Recording of the damaged journal that better fits with the hours of operation that will ease in prioritizing improvements to be implemented.

d. This research is very useful in the development of science and technology in the maintenance of components on warship navigation radars. In the future, the development of radar technology will be indispensable, as a principal component of warships, so that the application of the FMECA method for determining critical components based on system reliability is needed in the future trends.

6. ACKNOWLEDGEMENT

The authors greatly acknowledge the support from Indonesian Naval Technology College STTAL and Indonesian Navy Institution for providing necessary resources to carry out this research work. This paper is the result of the author research for the purposes of education only because the data used is confidential, without reducing the substance of study interests.

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