ANALYTICAL HIERARCHY PROCESS AND TOPSIS APPROACH TO STRATEGY DETERMINATION OF DEPO LEVEL MAINTENANCE FOR SUBMARINE

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Defense Industry Policy Committee (DIPC) and PT.PAL Indonesia projects have not yet determined a strategy in determining the implementation of submarine maintenance. Availability of the budget in carrying out maintenance and repair of submarines is one of the obstacles that is quite difficult in carrying out scheduled and planned maintenance of the defense equipment. On the other hand, if a policy is implemented to carry out continuous maintenance, it will result in a very high maintenance budget burden. Based on the current conditions and several previous studies, this study aims to provide an analysis of development strategy priorities in determining submarine maintenance. This study uses the MCDM Hybrid Technique approach combining the Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. While the AHP method is applied in screening decision criteria and determining the weight of each decision criterion, the TOPSIS method is used in ranking alternative maintenance strategies. Based on the results of the study, the criteria for the maintenance strategy on the Submarine showed that the safety level criterion (C4) had the highest weight of 0.201 with a CR of 0.097. Then the Technology Use criterion (C3) weights 0.143 as the second criterion. The resource availability criterion (C7) is the third criterion with a weight of 0.135. While the Operational Time criterion (C5) weights 0.056 as the criterion with the smallest weight. Submarine-02 with the Medium category maintenance strategy. Submarine-03 with a medium-level maintenance strategy weight 0.633. Furthermore, Submarine-01 and Submarine-04 are currently still in the Corrective level maintenance category with respective weights of 0.279 and 0.344.

Key words: *Maintenance Level, Submarine, TOPSIS (Technique for Others Reference by Similarity to Ideal Solution), Analytical Hierarchy Process (AHP).*

1. INTRODUCTION

The availability of the budget for carrying out the maintenance and repair of the warship is one of the obstacles that are quite difficult for the Indonesian Navy to carry out scheduled and planned maintenance of its defense equipment. This is because the Plan Maintenance System (PMS) requires a relatively large amount of money and a long enough time to support its programs. So that in practice the PMS schedule that has been set is often missed and what happens next is that as long as a system/part has not been damaged, the component will continue to operate. The period on the submarine is determined by the implementation of the maintenance and repairs carried out. Thus operational demands and expectations change both strategically and tactically over their lifetime (Muinde et al., 2014). Submarine maintenance is carried out at three separate levels based on the resources and capabilities required to perform maintenance: Organizational, Intermediate, and Depot levels (Saravanan & Kumar, 2020).

Lifecycle maintenance includes depot maintenance, intermediate maintenance, and organizational-level maintenance. Depot maintenance, or D-level, includes "overhaul or complete rebuild of parts, assemblies, subassemblies, and final goods, including the manufacture of parts. This level of complex repairs is carried out in a depot-level facility, such as a shipyard. Any work that requires the boat to be out of the water (e.g. in drydock) is typically D-grade maintenance (Goossens & Basten, 2015). This study aims to provide an analysis of depot-level maintenance determination to support the readiness of sea operations for submarine. This study used the Analytical Hierarchy Process (AHP) and TOPSIS method approach. The AHP method is used to determine the selected criteria for carrying out maintenance at the depot level. The TOPSIS method is used to analyze the priority of the Submarine class in determining Depo level maintenance.

2. LITERATURE REVIEW

Onboard maintenance systems as described by Seiti et al. (2017), it is necessary to use risk evaluation in the maintenance selection strategy for ship engine systems. Desember et al. (2020), in their research also suggested the need for a prioritization process in the Submarine Maintenance, Repair, and Overhaul (MRO) development strategy. Resobowo et al. (2014), in their research also explained the selection of variables that affect the maintenance of Submarine. Asuquo et al. (2019), also proposed strategic multi-attribute group decision-making (MAGDM) for selection of appropriate and concise maintenance strategies using qualitative and quantitative integrative approaches. Jimenez et al. (2020), proposed the development of predictive maintenance solutions in the shipping industry based on computational artificial intelligence models using real-time data. Kimera & Nangolo (2020), propose a review of maintenance practices, tools, and parameters for marine mechanical systems that can be classified as plant, machine, and equipment (PME). Jeong et al. (2018), proposed a new decision-making process used to compare the performance of ships with diesel-electric hybrid propulsion or conventional propulsion systems with an analytical hierarchical method approach. Animah & Shafiee (2021), proposes choosing the right maintenance strategy for various critical engines found in the ship's engine room. Emovon (2016), describes the use of hybrid MCDM techniques in prioritizing maintenance strategies for ship systems with the analytical methods used, namely Delphi, AHP and TOPSIS methods. Goossens & Basten (2015), in his research, investigated the maintenance of policy selection (MPS) through the use of the Analytic Hierarchy Process (AHP). Emovon et al. (2018), in their research presents the selection of appropriate maintenance strategies for ship engine systems and other related ship systems with the MCDM model. However, several previous studies have not discussed specifically related maintenance strategies for this type of submarine, where the condition of existing submarine systems and buildings is different from ships on water.

2.1. Maintenance Theory

Maintenance is most commonly defined as all activities aimed at maintaining a system or returning it to the condition deemed necessary for it to function as intended. Other definitions include maintenance objectives such as providing services to enable an organization to achieve its goals and maintain the ability of the system to provide services. Although the definition is quite broad, five specific maintenance responsibilities are generally recognized:

a. Maintain assets and equipment in good condition, properly configured, and safe to perform their intended function;
b. Perform all maintenance activities including preventive, predictive, and corrective maintenance, repairs, design modifications, and emergency maintenance efficiently and effectively;
c. Preserving and controlling the use of spare parts and materials;
d. Commissioning of new plants and factory expansion;
e. Operate utilities and save energy

Technical maintenance can be divided into several levels, starting from the strategic level to the operational level. At each level, decisions are made about, for example, what the maintenance objectives are, which maintenance concept to apply, which maintenance policy to choose, and so on.

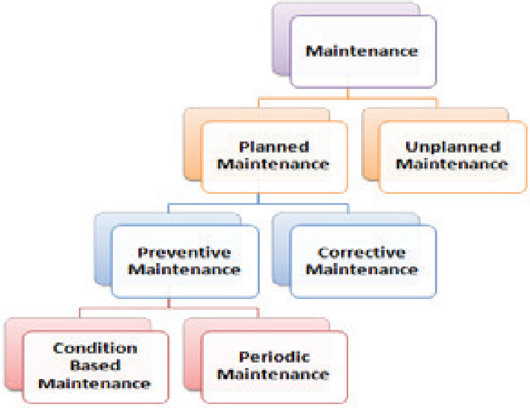

Fig. 1 Maintenance Philosophy. Source: Goossens & Basten (2015)

2.2. Ship Maintenance

Maintenance is considered at the early stages of ship design. Each component in the ship is scheduled to be maintained separately in the maintenance scheduling plan to maximize the function of the ship. A ship can be ready if all of its main components are operational, such as propulsion, power, air conditioning, and cargo engines. If any of the major components are not operational, the ship will be classified as not ready, and maintenance will be required. In the marine industry, ship maintenance and ship repair can be completed in two different ways. First, it can be done at a ship repair site when the ship is scheduled for dry dock to survey underwater passages. Second, when is the time for the classification survey (Goossens & Basten, 2015).

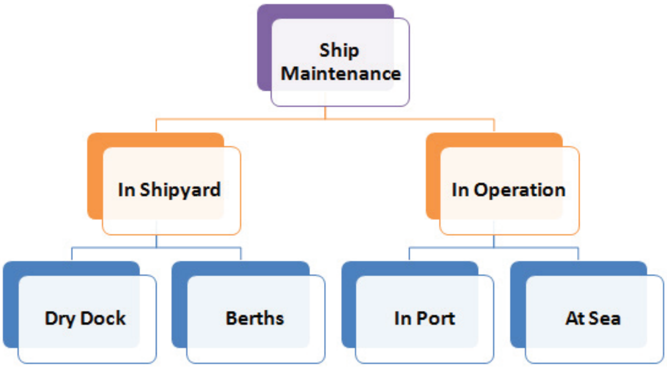

Fig. 2 Ship Maintenance. Source: Alhouli (2011)

Ship maintenance, like maintenance in other industries, usually uses two types of policies, namely corrective maintenance policies and preventive maintenance policies. A fault maintenance policy is usually done without preventive maintenance, except for essential lubrication and making minor adjustments. Preventive maintenance involves maintenance to reduce the number of breakdowns and can be either time- or condition-based maintenance (Alhouli et al., 2017).

2.3. Analytical Hierarchy Process (AHP)

AHP describes complex multi-factor or multi-criteria problems into a hierarchy, according to Saaty, a hierarchy is defined as a representation of a complex problem in a multi-level structure, where the first level is the goal, followed by the factor level, criteria, sub-criteria, and so on down to the next level. the last of the alternatives with a hierarchy of a complex problem can be described in groups which are then arranged into a hierarchy as the problem will appear more structured and systematic. One of the main advantages of AHP that differentiates it from other decision-making models is that there is no absolute consistency requirement. So that the existing problems can be felt and observed, but the completeness of the numerical data does not support the modeling of problems quantitatively (Saaty, 1990).

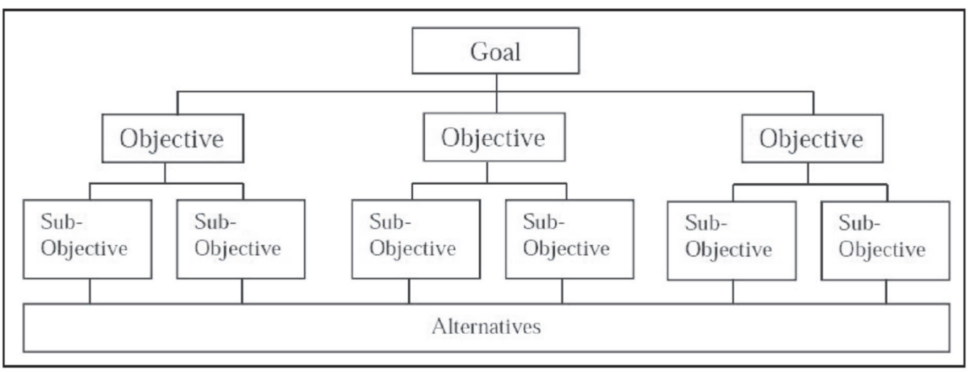

Fig. 3 AHP Structure.
Source: Saaty (1990)

7 pillars that are used and must be considered in AHP modeling (Saaty, 2012), including:

a. The ratio scale is a comparison of two values (a/b) where the values a and b are the same type (unit). The ratio scale is a set of consistent ratios in the same transformation (multiplication with positive constants). A set of values (in the same units) can be standardized by normalizing so that units are no longer needed and these objects can be more easily distinguished from one another.
b. Pairwise comparisons. Pairwise comparisons are made to provide relative weights between criteria and/or alternatives, so that the priority of those criteria and/or alternatives will be obtained. There are three approaches to sorting alternatives or criteria, namely relative, absolute, and benchmarking. The approach is used for critical general criteria. The absolute approach is used at the lower level of the hierarchy where there is usually a quantifiable detailed description of each criterion. In the benchmarking approach, the alternatives are compared with known reference alternatives, then the alternatives are sorted according to the results of the comparison.
c. Conditions for the sensitivity of the eigenvectors. The sensitivity of the eigenvectors to changing criteria limits the number of elements in each comparison set. This requires homogeneity of the elements concerned. Change must be by selecting a small element as a unit and asking what effect it has on the larger element.
d. Homogeneity and clustering. Clustering is used when the differences between elements are more than one degree, to slowly widen the fundamental scale, eventually increasing the scale from 1 to 9 to infinity. This is especially true for relative measurements.
e. Synthesis. Synthesis is applied to a ratio scale to create a unidimensional scale to represent the overall output, using additional weighting.
f. Maintaining and reversing the order of weighting and order in the hierarchy is affected by the addition or change of criteria or alternatives. Often there is a phenomenon of order reversal (rank reversal), especially in relative measurements. Sequence reversal is intrinsic

to decision making as is the order-preserving condition.

g. Group consideration. Group judgments must be carefully and mathematically integrated. With AHP, it is possible to take into account the experience, knowledge, and strengths of the individuals involved.

TOPSIS (Technique for Others Reference by Similarity to Ideal Solution)

TOPSIS (Technique For Others Reference by Similarity to Ideal Solution) is a multi-criteria decision-making method introduced by Yoon and Hwang (1981) in Do et al. (2020). This method uses the principle that the chosen alternative must have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution from a geometric point of view (Do et al., 2020). Determining the relative proximity of an alternative to the optimal solution is done by calculating the Euclidean distance. The TOPSIS method considers the distance between the positive ideal solution and the negative ideal solution by taking the relative closeness value to the positive ideal solution (Teniwut et al., 2019). The steps of the TOPSIS method are as follows (Chen, 2019):

a. Define the problem to be solved with the TOPSIS method.

b. Make a decision matrix according to the problem to be solved, then normalize the matrix with the equation.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad [1]$$

Where rij is the normalized matrix of the problem base matrix, with i = 1,2,3,....m, and j = 1,2,3 ... n. While xij is the basic matrix to be normalized. For each i denotes a row of the matrix, and for each j denotes a column of each matrix.

c. Normalize the rij matrix using weight ratings so that a normalized weight rating matrix is obtained, the equation used is as follows y ij = w i xr ij ……………………..………(2) where y ij is the weighted rating matrix, wi is the i weighted rating , and rij is the normalized result matrix in the second step. For i = 1,2,..., m, and j = 1,2, .., n. In this case, the rating weight must be determined based on the number of decision variables being resolved.

d. Determine the positive ideal solution (A+) and Negative Ideal Solution (A-) based on the weighted rating matrix values in step 3. The following equation is used to find positive ideal solution values $A+ = (y\ 1+, y\ 2+, \ldots, yn+)$..(3) and to find negative ideal solution values use the following equation $A -=(y\ 1-, y\ 2-, \ldots, yn -)$ under the condition:

$$y_i^+ = \begin{cases} \max y_{ij} : \text{if } j \text{ is cost attribute} \\ \min y_{ij} : \text{if } i \text{ is profit attribute} \end{cases} \quad [2]$$

$$y_i^- = \begin{cases} \max y_{ij} : \text{if } j \text{ is the profit attribute} \\ \min y_{ij} : \text{if } i \text{ is the cost attribute} \end{cases}$$

e. Determine the distance between the weighted values of each alternative to the positive ideal solution and the negative ideal solution. To determine the distance between the weighted values of each alternative to the positive ideal solution, the following equation is used:

$$D_i^- = \sqrt{\sum_{i=1}^{n} (y_{ij} - y_i^-)^2} \quad [3]$$

While to calculate the distance between the weighted values of each alternative to the negative ideal solution, the following equation is used:

$$D_i^+ = \sqrt{\sum_{i=1}^{n} (y_i^+ - y_{ij})^2} \quad [4]$$

f. The last step is to calculate the preference value for each alternative with the equation:

$$V_i = \frac{D_I^-}{D_I^- + D_I^+} \quad [5]$$

3. METHODS

Based on the type classification and analysis, this research is qualitative research with descriptive statistics. A descriptive statistical approach is used in providing an assessment in the form of numbers from research observations and testing of research objects of people or observable behavior (Filimonau & Perez, 2019). Data processing is a process consisting of input activities, process activities, and output activities (Samrin et al., 2021). In this study, data processing was assisted by Microsoft Excel and Expert Choice software. The steps in this research for data analysis include defining the problem and determining the desired solution. In this stage determine the problem to be solved in a clear, detailed, and easy to understand manner. Determine the criteria related to the determination of maintenance on the submarine, create a hierarchical structure starting with the main goal. After compiling the main goal as the top level, the hierarchical level below it will be arranged and creating a pairwise comparison matrix that describes the relative contribution or influence of each element on the goals or criteria at the level above it. There is a flow chart in this research as shown in Fig. **4**.

4. RESULTS

4.1. Determination and weighting of the strategy criteria

At this stage, the weighting of the criteria is used to provide ranking to the criteria used. Giving a value to each criterion followed by pairwise comparisons to find out the priority weight of each criterion. This criterion was obtained from the results of content analysis of some of the previous literature which was supported by expert opinion. In determining the weight of the criteria, namely calculating the total value of the overall criteria for each criterion as shown in **Table 1** below.

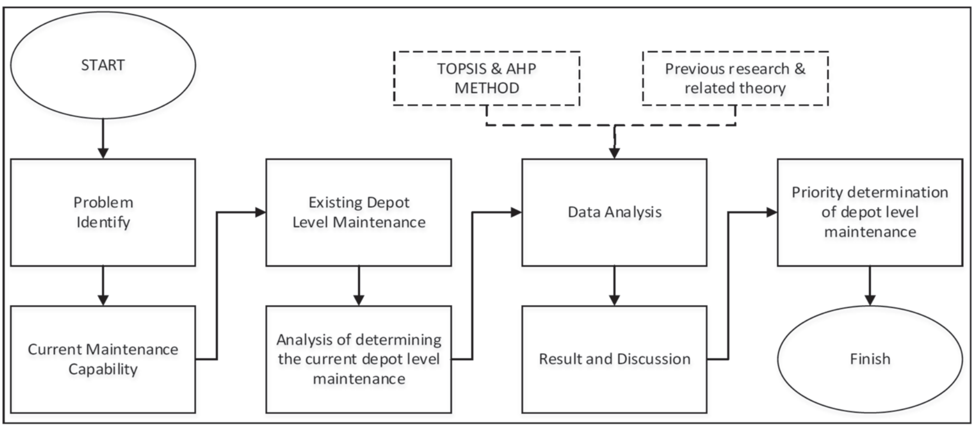

Fig. 4 Research Flowchart

Table 1. Submarine Maintenance Level Criteria Data

CODE	CRITERIA	CODE	CRITERIA
C-1	Characteristics	C-5	Operational time
C-2	reliability	C-6	Cost
C-3	Technology use	C-7	Availability of resources
C-4	Security level	C-8	Human Resources

The next step is to calculate the weight of the criteria from the pairwise comparison matrix between criteria. The form of

Table **2** pairwise comparison assessment.

Table 2. Pairwise comparison matrix for each criterion of the experts

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	1	1/3	1/2	2	3	1	1/2
C2	1	1	1	1	3	2	1/3	1/2
C3	2	1	1	1/2	2	2	1	2
C4	2	1	2	1	2	2	3	2
C5	1/2	1/3	1/2	1/2	1	1/3	1/2	1/2
C6	1/3	1/2	1/2	1/2	3	1	2	2
C7	1	3	1	1/3	2	1/2	1	2
C8	2	2	1/2	1/2	2	1/2	1/2	1

Table 3. The value of the weight of the criteria for the maintenance level of the submarine

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	Weight
C1	1	1	1/3	1/2	2	3	1	1/2	0.112
C2	1	1	1	1	3	2	1/3	1/2	0.124
C3	2	1	1	1/2	2	2	1	2	0.143
C4	2	1	2	1	2	2	3	2	0.201
C5	1/2	1/3	1/2	1/2	1	1/3	1/2	1/2	0.056
C6	1/3	1/2	1/2	1/2	3	1	2	2	0.116
C7	1	3	1	1/3	2	1/2	1	2	0.135
C8	2	2	1/2	1/2	2	1/2		1	0.112
CR = 0.097									1,000

Table 4. The value of weight and ranking on the submarine maintenance level criteria

NO	Criteria	Weight	rank
1	Characteristics	0.112	7
2	Reliability	0.124	4
3	Technology use	0.143	2
4	Security level	0.201	1
5	Operational time	0.056	8
6	Cost	0.116	5
7	Availability of resources	0.135	3
8	Human Resources	0.112	6

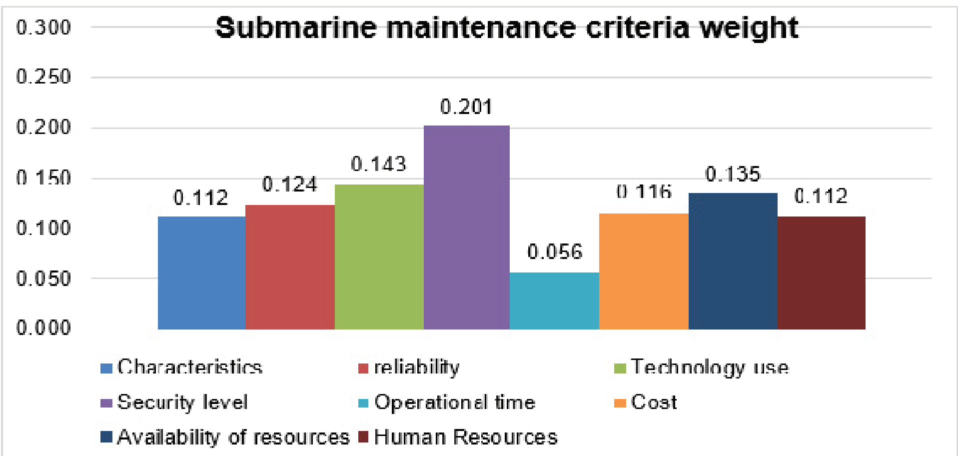

Fig. 5 Histogram of the weight value of the criteria

Analysis of the Priority Strategy for Submarine Maintenance Strategy

In this case the determination of the level of maintenance of the submarine was carried out using a random survey of related stakeholders. From the results of the survey, seven criteria were obtained which were taken into consideration in the strategy for selecting the improvement level which would later be used as calculations using the TOPSIS method.

The TOPSIS calculation steps in this study are as follows:

a. Build a decision matrix.

In the decision matrix, the matrix column states the attributes, namely the existing criteria, while the matrix rows state the alternatives. The decision matrix design can be seen in Table 5.

Table 5. Paired Decision Matrix

Criteria Weight	**0.112**	**0.124**	**0.143**	**0.201**	**0.056**	**0.116**	**0.135**	**0.112**
alternatives / criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Submarine-01	4.5	4.0	4.0	3.6	4.3	3.9	4.8	3.1
Submarine-02	4.2	3.8	3.8	3.1	4.4	4.0	4.5	3.2
Submarine-03	4.2	3.7	4.0	3.3	4.1	3.8	4.6	3.4
Submarine-04	3.9	3.7	3.9	3.7	4.0	3.9	4.4	3.0

The next step is to determine the preference weight of each criterion used in the TOPSIS method. The preference weight is obtained from the results of the analysis of how important these criteria affect the results. The greater the influence, the greater or vice versa, the smaller, the smaller the value.

Table 6. Criteria Preference Weight

Alternative / criterion	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Divider	8,892	8,885	8,885	5,545	8,000	9021	9,634

b. Normalized matrix calculation.

Calculation results based on Table 5 and Table 6 are then used to obtain the results of the decision matrix normalization by calculating the performance rating of each Ai alternative on each Ci criterion. The results of normalization (R) can be seen in

Table 7. Normalization Matrix, which has been calculated according to the normalized performance of each alternative on the criteria.

Table 7. Normalized Decision Matrix Calculation

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
Submarine-01	0.506	0.506	0.478	0.496	0.500	0.499	0.519	0.577
Submarine-02	0.450	0.478	0.478	0.586	0.500	0.554	0.519	0.433

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
Submarine-03	0.506	0.478	0.506	0.406	0.500	0.471	0.467	0.577
Submarine-04	0.534	0.535	0.535	0.496	0.500	0.471	0.493	0.384

c. Weighted normalized matrix calculation.

This step is carried out by multiplying each row of the matrix from each coordinate matrix with the importance weight of each selection criterion or determining the level of repair of the submarine. The result of the multiplication will be the value of the weighted normalized decision matrix in Table 8.

Table 8. Weighted Normalized Decision Matrix Calculation

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8
Submarine-01	0.056	0.063	0.069	0.100	0.028	0.058	0.070	0.064
Submarine-02	0.050	0.059	0.069	0.118	0.028	0.064	0.070	0.048
Submarine-03	0.056	0.059	0.073	0.082	0.028	0.055	0.063	0.064
Submarine-04	0.060	0.066	0.077	0.100	0.028	0.055	0.067	0.043

d. Determine the Positive Ideal Solution Matrix (A+) and Negative Ideal Solution (A-).

Positive ideal solutions (A+) and negative ideal solutions (A-) can be determined based on the normalized weight rating. The positive ideal solution (A+) can be calculated as follows. This step is carried out by finding the smallest and largest values of each matrix column in Table 9.

Table 9. Distance Between Positive and Negative Ideal Solutions

	C1	C2	C3	C4	C5	C6	C7	C8
A+	0.050	0.066	0.069	0.082	0.028	0.064	0.063	0.064
A-	0.060	0.059	0.077	0.118	0.028	0.055	0.070	0.043

e. Calculating the Distance of Positive Ideal Solution (D+) and Negative Ideal Solution (D-).

Table 10. Preference Weight of Each Alternative

NO	D+	D-
1	0.022	0.030
2	0.041	0.017
3	0.014	0.043
4	0.032	0.020

a. Perform weighting and ranking.

After getting the relative closeness value, the final step is to rank the alternatives that have been calculated. As Tabel 11 below.

Table 11. Alternative Ranking and Determination of Maintenance Strategy.

NO	RESULTS	WEIGHT	RANK	MAINTENANCE LEVEL
1	Submarine-01	0.279	4	CORRECTIVE
2	Submarine-02	0.776	1	MEDIUM
3	Submarine-03	0.633	2	MEDIUM
4	Submarine-04	0.334	3	CORRECTIVE

Based on Table 11 be concluded that the results of calculations using the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method it is obtained that the first rank with a weight of 0.776 is Submarine-02 with the Medium category maintenance strategy. Submarine-03 with medium level maintenance strategy weights 0.633.

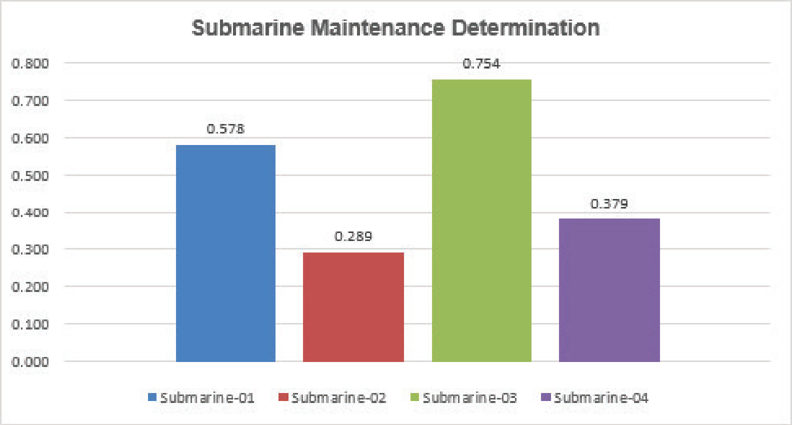

Fig. 6 Histogram of Submarine maintenance strategy determination

Based on the results in Table 11 and Fig. **6**, it can be identified that Submarine-01 and Submarine-04 are currently still in the Corrective level maintenance category with respective weights of 0.279 and 0.344.

5. DISCUSSIONS

Based on the research results, the criterion for the level of safety (C5) in determining the maintenance strategy is the criterion with the highest weight, namely 0.201. Security can be defined as a state of risk that is acceptable to society. In this regard, to assess the current level of ship safety, it is necessary to measure the risk level of the world's fleet of operations, thereby estimating and assessing the basic risk contributors, namely the frequency of maritime accidents and the extent of their consequences (Elefttheria et al., 2016). The safety level of the ship is greatly influenced by the age, size, and type, at the very time of carrying out the maintenance. When data on ship characteristics is available, the possibility of the ship being involved in an accident while carrying out maintenance can be predicted (Li et al., 2014). The criterion with the second largest weight is the use of technology (C3) in maintenance of 0.143. The nature of the industry makes integration of the latest technological advances complicated. This is due to the very high adjustment needs because each ship meets very specific requirements (Zacharaki et al., 2022). Availability of resources (C7) is the factor with the third highest weight of 0.135. According to Ren et al. (2021), maintenance scheduling refers to the detailed arrangement of maintenance tasks during the recommended period while considering environmental conditions, availability of resources.

Types of submarine that have to carry out mid-level repairs, namely Submarine-02 and Submarine-03. Treatment strategy evaluation includes identifying the most appropriate treatment strategy for different machines with maximizing importance through consideration of a set of constraints. A suitable maintenance strategy not only enhances the organization to compete with others but also leads to maximum profit (Seiti et al., 2017). In the corrective level maintenance strategy, there are two types of submarine, namely Submarine-01 and Submarine-04. Preventive and corrective maintenance costs are estimated to optimize maintenance. The output is a maintenance plan that will aim to reduce ship operating costs. It should be noted that maintenance planning can result in redesign of ship structures (Garbatov et al., 2018).

6. CONCLUSIONS

The research results show that, safety level criteria (C4) has the highest weight of 0.201 with a CR of 0.097. Then the Technology Use criterion (C3) weights 0.143 as the second criterion. The resource availability criterion (C7) is the third criterion with a weight of 0.135. While the Operational Time criterion (C5) weights 0.056 as the criterion with the smallest weight. Second, Submarine-02 with the Medium category maintenance strategy. Submarine-03 with a medium-level maintenance strategy weight 0.633. Furthermore, Submarine-01 and Submarine-04 are currently still in the Corrective level maintenance category with respective weights of 0.279 and 0.344.

6.1. Future Work

In the final stage of the research, several suggestions can be given for further research, namely: a) Subsequent research can propose how the level of consistency of decisions when decisions are taken; b) research can consider an analysis of the risk calculation of the maintenance strategy and propose alternative strategies to be used if the main strategy cannot be implemented.

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