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Article

Selection of Indonesian Navy Ship Maintenance and Repair Facilities for Modernization Using the Analytic Hierarchy Process (AHP)

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Abstract: Naval fleet operational readiness is strongly influenced by the effectiveness of ship maintenance and repair infrastructure. For the Indonesian Navy (TNI AL), the development of a modern Ship Maintenance and Repair Facility (Fasharkan) is essential to support fleet reliability, operational availability, and long-term defense capability. However, determining the most appropriate facility for modernization requires a systematic evaluation involving multiple strategic, technical, and organizational factors. This study aims to identify the most suitable Fasharkan to be developed into a modern naval maintenance facility using a structured multi-criteria decision-making approach. The research employs the Analytic Hierarchy Process (AHP) integrated with a SWOT-based evaluation framework to analyze five alternative facilities: Mentigi, Jakarta, Surabaya, Makassar, and Manokwari. Decision criteria were derived from expert assessments and literature on naval maintenance systems, covering strength, weakness, opportunity, and threat factors with multiple operational subcriteria. Pairwise comparison matrices were processed using Expert Choice 11 to obtain priority weights and evaluate consistency levels. The results indicate that the opportunity criterion has the highest priority weight (0.508), suggesting that external strategic opportunities, including technological advancement and defense industry policy support, play a dominant role in determining modernization priorities. Among the alternatives, Fasharkan Surabaya achieved the highest global priority score (0.373), significantly outperforming other facilities. This result reflects its superior infrastructure capacity, strategic geographic position, stronger industrial ecosystem, and greater readiness for technological modernization. Consistency ratio values below 0.1 confirm the reliability of expert judgments and the robustness of the analytical model. The findings provide a structured decision-support framework for naval infrastructure development and highlight the strategic importance of Surabaya as the most feasible candidate for transformation into a modern naval maintenance facility capable of enhancing Indonesia's maritime defense readiness.
Keywords: Analytic Hierarchy Process; Naval Maintenance Infrastructure; Ship Repair Facility; Multi-Criteria Decision Making; SWOT Analysis; Defense Infrastructure Development; Indonesian Navy; Maritime Defense Readiness

1. Introduction

The operational readiness of warships is one of the main factors in supporting a country's maritime defense capability. For the Indonesian Navy (TNI AL), the existence of ship maintenance and repair facilities, or Maintenance and Repair Facilities (Fasharkan), plays a strategic role in ensuring the operational readiness of the fleet. Fasharkan functions as a center for maintenance, repair, and enhancement of the technical capabilities of ships, allowing warships to maintain their reliability and operational availability. Previous research shows that an effective maintenance system significantly influences the reliability of the ship's system, operational safety, and cost efficiency of the military equipment's life cycle (Bevilacqua & Braglia, 2000; Karatuğ et al., 2023).

Along with the development of maritime technology and the demands for modernization of defense equipment, ship maintenance facilities also need to be upgraded to become more modern, integrated, and efficient. The modernization of ship maintenance facilities is not only related to the improvement of physical infrastructure such as dry docks and workshop equipment, but also includes aspects of maintenance management, availability of human resources, logistical support, and the integration of information technology into the maintenance system. Therefore, the selection of the most suitable maintenance facilities to be developed into modern ship repair facilities is a strategic decision that requires comprehensive analysis based on various technical and operational criteria (Goossens & Basten, 2015; Gualeni & Vairo, 2023).

In the organizational structure of the Indonesian Navy's maintenance, there are several Fasharkan spread across various strategic regions of Indonesia. This research considers five alternative Fasharkan that have the potential to be developed into modern ship maintenance facilities, namely Fasharkan Tanjung Uban, Fasharkan Jakarta, Fasharkan Surabaya, Fasharkan Makassar, and Fasharkan Manokwari. The five facilities have different characteristics in terms of dock capacity, repair facilities, geographical location, and logistical and operational support. These differences in characteristics make the process of selecting the best facility a complex multi-criteria decision-making problem (Saka & Cetin, 2020).

To solve the multi-criteria decision-making problem, this research uses the Analytic Hierarchy Process (AHP) method. The AHP method is one of the approaches widely used in strategic decision-making because it can break down complex problems into a hierarchical structure consisting of goals, criteria, sub-criteria, and decision alternatives. Thru the pairwise comparison process, this method can generate priority weights that reflect the relative importance of each criterion and alternative being analyzed (Saaty, 1990; Ho, 2008). The AHP approach has also been widely applied in the selection of maintenance strategies, facility locations, and decision-making in the industrial and transportation sectors (Vaidya & Kumar, 2006).

In this study, the data processing and analysis were carried out using Expert Choice version 11 software, which is specifically designed to support decision analysis based on the AHP method. This software allows for the systematic and accurate calculation of priority weights, evaluation of respondent judgment consistency, and sensitivity analysis. By using Expert Choice 11, the analysis results are expected to provide more objective recommendations in determining the most suitable Fasharkan to be developed into an effective and efficient modern ship maintenance facility for the Indonesian Navy (TNI AL) (Saaty & Vargas, 2001; Ishizaka & Labib, 2011).

2. Research Method

This research uses a quantitative approach with the Analytic Hierarchy Process (AHP) method to determine the priority of the Indonesian Navy's Maintenance and Repair Facilities (Fasharkan) that are most suitable to be developed into effective and efficient modern ship maintenance facilities. AHP is a multi-criteria decision-making method that can break down complex problems into a hierarchical structure consisting of goals, criteria, sub-criteria, and alternatives, thereby facilitating the evaluation and prioritization process systematically (Saaty, 1990; Vaidya & Kumar, 2006). This method is widely used in operations management research, system maintenance, and facility selection because it can combine quantitative and qualitative considerations in a structured manner (Ho, 2008).

The research stages begin with problem identification and the determination of research objectives, namely selecting the most potential Fasharkan to be developed into a modern ship maintenance facility. Next, criteria and sub-criteria are identified based on literature studies and expert opinions from the technical aspects of ship maintenance, logistics management, and policymakers within the TNI AL environment. This approach is commonly used in AHP research because expert involvement can enhance the validity of criteria determination and decision weight (Emrouznejad & Marra, 2017).

The next stage is the formulation of the decision hierarchy structure, which consists of three main levels: the research objective, assessment criteria, and the Fasharkan alternatives to be evaluated. After the hierarchy is formed, pairwise comparison is conducted using the Saaty importance scale with a value range of 1–9 to determine the relative importance between criteria and between alternatives (Saaty, 1990). The results of the assessment are then processed to obtain the priority weight values thru eigenvector calculations.

To ensure the consistency of respondent assessments, a Consistency Ratio (CR) test is conducted. The CR value must be less than 0.1 for the assessment to be considered consistent and usable in further analysis (Saaty, 1990). If the

CR value exceeds this limit, the assessment process needs to be revised until an acceptable level of consistency is achieved. This approach has been widely used in research on maintenance policy selection and strategic decision-making in various industrial sectors (Bevilacqua & Braglia, 2000).

The final stage of the research is the calculation of global priorities and the ranking of alternative Fasharkan that are most suitable for being developed into modern ship maintenance facilities. The results of this analysis are expected to provide data-based and scientific method recommendations to support strategic decision-making related to the development of TNI AL ship maintenance facilities to be more effective and efficient.

3. Research Results and Discussion

The Analytical Hierarchy Process (AHP) method is a decision-making technique used to determine priorities and select the best alternative based on predetermined criteria. In the AHP analysis calculation, the researcher uses Expert Choice 11 software to facilitate and enhance the accuracy of the calculations. There are stages and steps in the use of AHP (Marsono, 2020).

3.1 Research Results

From the AHP hierarchy structure chart, there are criteria (C), subcriteria (SC), and alternatives (A). The following are the explanations:

Table 3.1 Criteria Code

NO	CRITERIA	CODE
1	Strength Analysis	C1
2	Weakness Analysis	C2
3	Opportunity Analysis	C3
4	Threat Analysis	C4

Table 3.2 Subcriteria Codes

CRITERIA	SUBCRITERIA	CODE
Strength Analysis (C1)	Sufficiency of Technical Personnel	S.C 1.1
	Main Equipment is Sufficient	S.C 1.2
	SOP Maintenance & Repair Implemented Well	S.C 1.3
	Spare parts & Materials Are Sufficiently Available	S.C 1.4
	Sufficiency of Budget Allocation	S.C 1.5
Weakness Analysis (C2)	Lack of personnel training programs	S.C 2.1
	Lack of optimization in equipment modernization	S.C 2.2
	Lack of quality management system	S.C 2.3
	Lack of inventory management system	S.C 2.4
	Lack of efficiency in budget utilization	S.C 2.5
Opportunity Analysis (C3)	Government policy supports	S.C 3.1
	Opportunities for collaboration with the local maritime industry	S.C 3.2
	The public perception of fashion is very good	S.C 3.3

	The development of maritime technology has a positive impact	S.C 3.4
	Defense industry policy is very supportive	S.C 3.5
	The implementation of environmental standards is very effective	S.C 3.6
Threat Analysis (C4)	Regional political dynamics toward policy changes	S.C 4.1
	Budget allocation limitations & fluctuations in spare part prices	S.C 4.2
	The lack of availability of quality Human Resources from the community	S.C 4.3
	Lack of technology transfer opportunities from international partners	S.C 4.4
	Lack of defense regulatory support	S.C 4.5
	The impact of climate change can affect operations	S.C 4.6

Table 3.3 Alternative Code

NO	ALTERNATIVE	CODE
1	FASHARKAN MENTIGI	A1
2	FASHARKAN JAKARTA	A2
3	FASHARKAN SURABAYA	A3
4	FASHARKAN MAKASSAR	A4
5	FASHARKAN MANOKWARI	A5

3.1.1 Setting the priority weights of Criteria and Subcriteria by determining the eigenvector

Eigenvector in AHP functions as a mathematical representation of priority weights obtained from pairwise comparison consensus. The larger the eigenvector value of a criterion, the higher its level of importance in decision-making. This process also applies to sub-criteria at each level of the hierarchy separately. In the calculation to obtain the priority weights of criteria and sub-criteria, the researchers used expert choice software.

Table 3.4 Weights Criteria-Subcriteria Priority

CRITERIA-SUBCRITERIA	WEIGHT
C3	0,508
C1 - S.C 1.5	0,495
C2 – S.C 2.2	0,460
C3 – S.C 3.4	0,444
C4 – S,C 4.2	0,370

3.1.2 Mengukur Konsistensi logis dengan menguji Indeks Konsistensi (Consistency Index/CI) dan Konsistensi Rasio (Ratio Consistency/RC) Kriteria

IR is a predetermined value based on the number of elements. This can be seen in the table below:

Table 3.5 Index Ratio

n	1	2	3	4	5	6	7	8	9	10
IR	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

The following is a table of the Consistency Index obtained from using expert choice software.

Table 3.6 Consistency Index (CI)

C – S.C - A	CI
C	0,07
C1	0,09
C2	0,08
C3	0,09
C4	0,08
S.C 1.1	0,09
S.C 1.2	0,08
S.C 1.3	0,09
S.C 1.4	0,09
S,C 1.5	0,09
S.C 2.1	0,09
S.C 2.2	0,09
S.C 2.3	0,09
S.C 2.4	0,09
S.C 2.5	0,09
S.C 3.1	0,08
S,C 3.2	0,08
S.C 3.3	0,09
S.C 3.4	0,08
S.C 3.5	0,08
S.C 3.6	0,06
S.C 4.1	0,08
S.C 4.2	0,07
S.C 4.3	0,07
S.C 4.4	0,04
S.C 4.5	0,04
S.C 4.6	0,03

To calculate the Consistency Ratio (CR), divide the Consistency Index (CI) by the Ratio Index (RI). The RI or IR divisor value depends on the number of elements (n). The number of elements in this calculation is 1 because the data from several respondents is first taken to a geometric mean or average value.

So because the number of elements (n) is 1, it means that the value of the Consistency Ratio (CR) is the same as the value of the Consistency Index (CI) or can be written as CR = CI. The condition of the Consistency Ratio (CR) is that the value must not be more or less than 0.1, or can be written as CR < 0.1. From the table, the numerical values obtained are all less than 0.1, meaning that the data obtained from respondents is consistent and logical.

3.1.3 Determine the weight of each sub-criteria and alternative

From the determination of the weight of each sub-criteria and alternative, the weights can be taken as a priority or eigenvector as follows:

Table 3.7 Weight of Priority Subcriteria-Alternatives

SUBCRITERIA	ALTERNATIVE	WEIGHT
S.C 1.1	A3	0,540
S.C 1.2	A3	0,544
S.C 1.3	A3	0,540
S.C 1.4	A3	0,531
S.C 1.5	A3	0,509
S.C 2.1	A3	0,446
S.C 2.2	A5	0,405
S.C 2.3	A5	0,405
S.C 2.4	A5	0,405
S.C 2.5	A5	0,405
S.C 3.1	A3	0,491
S.C 3.2	A3	0,502
S.C 3.3	A1	0,425
S.C 3.4	A3	0,498
S.C 3.5	A3	0,494
S.C 3.6	A3	0,461
S.C 4.1	A3	0,455
S.C 4.2	A3	0,409
S.C 4.3	A3	0,409
S.C 4.4	A5	0,385
S.C 4.5	A5	0,385
S.C 4.6	A2	0,356

3.1.4 Creating global priorities

The results of the global priorities are as follows:

Table 3.8 Global Priorities

PRIORITY	VALUE
C1	0,151

C2	0,256
C3	0,508
C4	0,075
S.C 1.1	0,232
S.C1.2	0,154
S.C 1.3	0,079
S.C 1.4	0,040
S.C 1.5	0,495
S.C 2.1	0,275
S,C 2.2	0,460
S.C 2.3	0,078
S.C 2.4	0,050
S.C 2.5	0,136
S.C 3.1	0,137
S.C 3.2	0,090
S.C 3.3	0,034
S.C 3.4	0,444
S.C 3.5	0,239
S.C 3.6	0,056
S.C 4.1	0,107
S.C 4.2	0,370
S.C 4.3	0,068
S.C 4.4	0,249
S.C 4.5	0,163
S.C 4.6	0,043

3.1.5 Chart the hierarchical structure and write the calculation results in the respective boxes for Criteria and Alternatives.

Writing the calculation results into the AHP hierarchical structure is a very important step because you can find out the calculation results for each criterion and sub-criteria and can read directly between the values of each level in the AHP hierarchical structure chart.

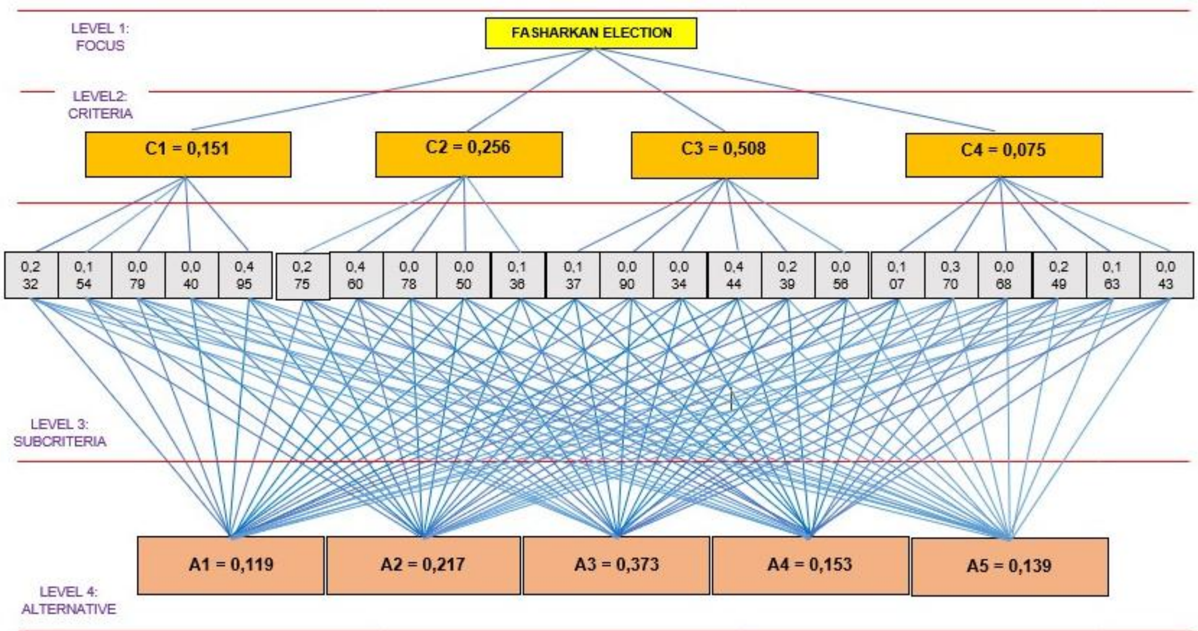

Figure 3.1 Hierarchical Structure Weight Value

3.1.6 Making decisions

The final step in the AHP process is decision-making based on the calculation results by ranking the Vi values from highest to lowest. The alternative with the highest value is the best choice. The calculated values are obtained using Expert Choice software. The table below shows the calculation results.

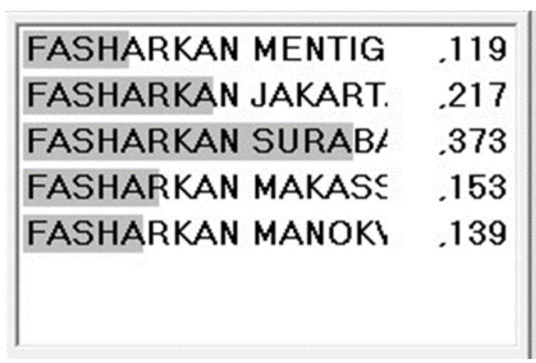

Figure 3.2 Alternative calculation results

From the results of alternative calculations using the expert choice software, the alternatives can be sorted from largest to smallest as follows:

Table 3.9 Alternative Sequences

NO	ALTERNATIVE	VALUE
1	FASHARKAN SURABAYA	0,373
2	FASHARKAN JAKARTA	0,217
3	FASHARKAN MAKASSAR	0,153
4	FASHARKAN MANOKWARI	0,139

5	FASHARKAN MENTIGI	0,119

Based on the ranking results in the table, the highest ranking is **Fasharkan Surabaya**, with a **weighting value of 0.373**. Therefore, Fasharkan Surabaya was selected. Fasharkan Surabaya, one of the Class A Fasharkans selected, will be transformed into **Fasharkan Modern**.

3.2 Research Discussion

3.2.1 Criteria Priority Analysis

Based on the results of data processing using the Analytical Hierarchy Process (AHP) method, the following criteria priority weights were obtained:

1) C3 (Opportunity Analysis) = 0,508
2) C2 (Weakness Analysis) = 0,256
3) C1 (Strength Analysis) = 0,151
4) C4 (Threat Analysis) = 0,075

These results show that Opportunity Analysis (C3) is the most dominant criterion in determining which Fasharkan will be developed into a Modern Fasharkan.

Interpretation:

The dominance of opportunity factors indicates that decision making is more oriented towards:

a. Government political support
b. Development of maritime technology
c. Defense industry policy
d. Industrial collaboration opportunities

This indicates that the direction of Fasharkan's development policy takes into account external factors that are strategic and prospective rather than solely internal factors.

3.2.2 Dominant Subcriteria Analysis

Based on the priority weight of the sub-criteria, several factors that have the greatest influence are:

Subcriteria with the highest weight:

1) S.C 1.5 (Adequacy of Budget Allocation) = 0,495
2) S.C 2.2 (Lack of optimization of equipment modernization) = 0,460
3) S.C 3.4 (The development of maritime technology has a positive impact) = 0,444
4) S.C 4.2 (Limited budget allocation & fluctuations in spare part prices) = 0,370

Interpretation:

a) The budget factor is the most crucial variable, both in terms of strength and threat.
b) Modernization of equipment is an important concern in organizational weaknesses.
c) The development of maritime technology is a very decisive strategic opportunity.

This means that the success of the transformation towards Modern Fasharkan is highly dependent on:

1) Adequate budget support

2) Modernization of infrastructure

3) Adaptability to technological developments

3.2.3. Alternative Priority Analysis for Each Subcriteria

From the results of the alternative priority weights for each sub-criteria:

1) Fasharkan Surabaya (A3) dominates almost all the main sub-criteria, especially:

- S.C 1.1 – S.C 1.5 (internal strength)
- S.C 3.1, 3.2, 3.4, 3.5, 3.6 (external opportunities)
- S.C 4.1, 4.2, 4.3 (threat)

2) Fasharkan Manokwari (A5) excels in several aspects of certain weaknesses and threats.

3) Fasharkan Jakarta (A2) excels in S.C 4.6 (impact of climate change).

This shows that comprehensively, Surabaya has the best combination of internal strengths and external opportunities compared to other alternatives.

3.2.4. Global Priorities Analysis

Based on the results of the global priority calculation, the alternative order is:

Rating	Alternative	Weight
1	**Fasharkan Surabaya**	**0,373**
2	Fasharkan Jakarta	0,217
3	Fasharkan Makassar	0,153
4	Fasharkan Manokwari	0,139
5	Fasharkan Mentigi	0,119

Interpretation:

Fasharkan Surabaya's weight value (0.373) is significantly higher than the other alternatives. This indicates:

a) Surabaya has better technical resource readiness.

b) Relatively stronger infrastructure and industrial support.

c) Strategic position to support defense industry policy.

d) Higher potential for adaptation to modernization.

Thus, quantitatively and objectively, Surabaya is the most rational alternative to be developed into a Modern Fasharkan.

3.2.5. Test Consistency

The Consistency Ratio (CR) value for all criteria and sub-criteria is <0.1.

Artinya:

a) The expert respondents' assessments are consistent

b) There are no logical inconsistencies in the pairwise comparisons

c) The decision results can be declared methodologically valid

3.2.6. Strategic Implications

Based on the results of this study, several strategic implications can be concluded:

a) An external opportunity-based approach (opportunity driven strategy) is the main strategy in Fasharkan's transformation.

b) Modernization of Fasharkan must be supported by:

- Budget management reform
- Optimization of equipment modernization
- Integration with maritime technology developments

c) Fasharkan Surabaya has the highest readiness to become a pilot project for Fasharkan Modern.

Discussion Conclusion

Based on the results of AHP processing:

1) The most dominant criterion is Opportunity Analysis (C3)
2) Budget and modernization factors are the primary determinants.
3) The best alternative is Fasharkan Surabaya (0.373).
4) The data is stated to be consistent and scientifically accountable.

Thus, analytically and objectively, Fasharkan Surabaya deserves to be prioritized as a class A Fasharkan which will be developed into a Modern Fasharkan.

4. Conclusion

Fasharkan Alternative Selection Results based on global priority calculations, the alternative order is:

1) Fasharkan Surabaya = 0,373
2) Fasharkan Jakarta = 0,217
3) Fasharkan Makassar = 0,153
4) Fasharkan Manokwari = 0,139
5) Fasharkan Mentigi = 0,119

Fasharkan Surabaya's value is significantly higher than other alternatives, indicating that:

a. Possesses the most stable internal strength
b. Superiority in strategic external opportunities
c. Better prepared in terms of modernization and industrial support
d. Strategically positioned to support national defense industrial policy

Thus, objectively and quantitatively, Fasharkan Surabaya was selected as the most rational and worthy alternative to be developed into a Modern Fasharkan.

Decision Validity, all Consistency Ratio (CR) values < 0.1, which indicates that:

a. The expert respondents' assessments are consistent
b. There are no logical inconsistencies

c. The decision results are valid and methodologically accountable

The formulation for selecting the Indonesian Navy's Fasharkan ship to be developed into an effective and efficient modern Fasharkan ship was carried out using an AHP approach based on a structured SWOT analysis, with an emphasis on:

a. Dominance of external strategic opportunity factors,

b. Prioritizing budget adequacy and equipment modernization,

c. Integration of maritime technology developments, and

d. Selection of alternatives based on quantitative global priorities.

The research results determined Fasharkan Surabaya as a class A Fasharkan that is most suitable to be developed into a Modern Fasharkan because it has **the highest priority score (0.373)** and the most comprehensive strategic readiness.

Scientifically, systematically, and objectively, the selection of effective and efficient Modern Fasharkan must be oriented towards national strategic opportunities, supported by adequate budget and modernization of facilities, and determined through structured decision-making methods such as AHP.

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