International Journal of ASRO
Volume 12, Number 04, pp.106-116
Des 2021

DETERMINATION OF ALTERNATIVE MAIN ENGINE IN IMPLEMENTING RE-ENGINE (CASE STUDY: KRI XYZ)

Dedy Aryanto[1], Udisubakti Ciptomulyono[2], Sutrisno [3]

[1,3]*Indonesian Naval Technology College, Bumimoro-Morokrembangan,Surabaya 60187, Indonesia*
[2]*Industrial Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*

ABSTRACT

KRI XYZ is one of the Ocean tugboats owned by the Indonesian Navy under the Garuda Ship Unit, which has a tactical nature to provide tug assistance for elements that experience damage or accidents at sea. Based on the letter of the Garuda Utama Commander Number B/947/V/2021 dated 19 May 2021, regarding Appreciation for the Replacement of the KRI XYZ Main Engine, a re-engine is required for the KRI XYZ. This study aims to determine the criteria, methods used and choose the appropriate and best Alternative type of MAIN ENGINE. There are four MAIN ENGINE A, B, C, and D Alternative engines. There are ten selection criteria grouped into benefit and risk criteria groups. The Analytical Hierarchy Process (AHP) method is used to support the selection of the best Alternative based on the criteria of benefit and level of risk, and BCR analysis is carried out for benefits and costs. The results of this study indicate that with the AHP method and BCR analysis, the selected Alternative is the best and feasible engine A (BCR>1) and has a low risk meaning that the Alternative is the most profitable if it is chosen as a replacement engine for MAIN ENGINE KRI XYZ.

Keywords: *Benefit, Cost, Risk, Analytical Hierarchy Process, Benefit-Cost Ratio.*

1. INTRODUCTION

Threats and disturbances that come from certain parties and to maintain the security of Indonesia's marine territory, both from within and from outside, it is necessary to prepare elements of the KRI, including the readiness of the KRI to carry out delays when a KRI is damaged at sea or in the area of operation. KRI XYZ is one of the delayed-type KRIs for the middle of the sea.

The operational needs of KRI XYZ itself are very much needed, including:

a. Carry out assistance (pulling) to the ship that ran aground.
b. Providing tug assistance for friendly ships that cannot maneuver themselves from one place to another.
c. Provide fire fighting assistance to other ships.
d. Provide assistance in dealing with leakage of other vessels.
e. Provide limited logistical assistance (BBM and AT) to delayed vessels.
f. Drag or place shooting targets.
g. Provide relief assistance in oil or water pollution in the sea.

Based on the letter of the Commander of the Garuda Utama Number B/947/V/2021 dated 19 May 2021, regarding Appreciation for the Replacement of the KRI XYZ Main Engine and the existence of operational needs, the readiness of the KRI XYZ is necessary. Function as a tugboat.

Figure 1. Main Engine Performance Graph

A decrease in the propulsion performance of a ship due to its long service life is shown in Figure 1.1.. It could be that the expected results are better than the original condition. This effort is to implement what is known as the Re-Engine.

2. LITERATURE REVIEW

2.1 Main Engine

The main engine is the main system that is widely used for the main propulsion system on ships. The main propulsion engine on ships usually uses a diesel engine which is known as a type of ship propulsion engine that has high efficiency and power which is used to propel the ship.

2.2 Re-Engine

Replacing the engine is one of the efforts to regenerate the primary driving motor that has decreased in performance with a new MAIN ENGINE by considering the considerations that have been determined. Some of the main changes when replacing the main propulsion engine, among others:

a. Improve safety and reliability
b. Higher performance
c. Efficient use of fuel
d. Ease of finding spare parts.

2.3 MCDM with Analytical Hierarchy Process (AHP)

MCDM is an interactive computer-based system that helps decision-makers utilize data and models in solving unstructured and semi-structured problems. AHP is a fundamental approach in decision-making. Thomas L. Saaty, a mathematician, developed AHP. This method makes effective decisions on complex problems by simplifying and speeding up the decision-making process by breaking the problem into its parts in a hierarchical arrangement, assigning a numerical value to subjective judgments about the importance of each variable, and determining which variable has the highest priority and act to influence the outcome of the situation.

The rationale for the AHP method is forming a numerical score to rank each decision Alternative based on how best the Alternative should be matched with the decision maker's criteria. Criteria and Alternatives were assessed through pairwise comparisons. According to a study conducted by Saaty in 1988, for various problems, a scale of 1 to 9 is the best scale in expressing opinions. The value and definition of the qualitative opinion of the Saaty comparison scale can be seen in Table 1.

Table 1. AHP . Paired Comparative Rating Scale

Intensity of Interest	Information
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is of more critical importance than the other elements
9	One element is critical importance than the other elements
2,4,6,8	The values between two values of adjacent considerations

Each level in the hierarchy has a different character, both in terms of structure and function, which at a certain level will depend on the smoothness of the next level. The main problem with hierarchical arrangement is to create a fit at the highest level based on interactions at the lower levels. The arrangement of this hierarchy is very dependent on the experience and level of knowledge as well as the inter-achievements of the compilers of the actual problem situation. Therefore, the hierarchical arrangement in AHP is fundamental for individuals to describe a problem into stratified groups and existing sub-groups.

The relationship in a hierarchy is linear from one level to the next, but some of the advantages of this hierarchical model (Ciptomulyono, 2000) are:

a. Hierarchy is a system that can tell how changes in priorities at higher levels will affect priorities at lower levels.
b. The hierarchical model can express detailed information about structure and function at lower levels and provide a comprehensive picture of their implementation and use at higher levels. Constraints in the variables in one level are clearly described due to the above level.
c. The hierarchical model is not easy to change because of the influence that can bring a relatively small impact. However, it is flexible enough to accept changes without destroying the existing structure.
d. Naturally, the hierarchical structure and arrangement in modules (variables) are more efficient than the whole chain.

Hierarchical modeling is expected to reflect the actual situation. This model has selected the most important variables from the existing situations and conditions and their relationships.

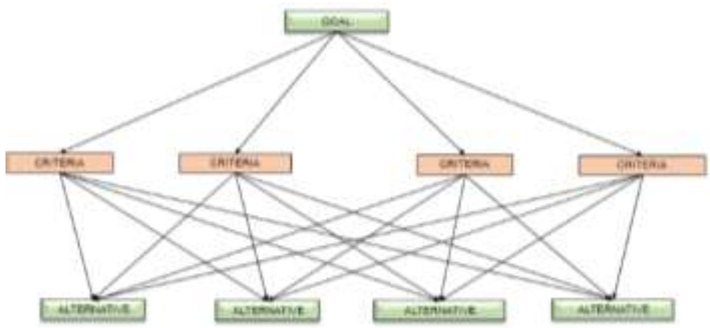

Figure 2. Hierarchical Structure in AHP (Saaty, 1993)

2.4 *Expert Choice*

Software Expert Choice version 11 program can combine the results of comparisons with more than 100 participants, namely by combining the average feature to average the results of individual paired assessments into a value. The method used to obtain the average value is calculating the geometric average.

Expert Choice software is used for decision-making problems with many Alternatives and a large hierarchy or a hierarchy with many levels. There is no need to calculate the weights manually. The error rate in calculating the weights is minimal. However, it depends on our accuracy in inputting data from respondent data.

Sensitivity Analysis was conducted to determine the variation of the priority criteria to observe the extent of its effect on Alternative priorities. Sensitivity Analysis is done with the Sensitivity-Graphs command in the main menu of the Software Expert Choice. We can change the priority of each criterion (by clicking and dragging the criteria bar) to see the sensitivity to Alternative priorities. Figure 2.2 shows the Sensitivity four graphs.

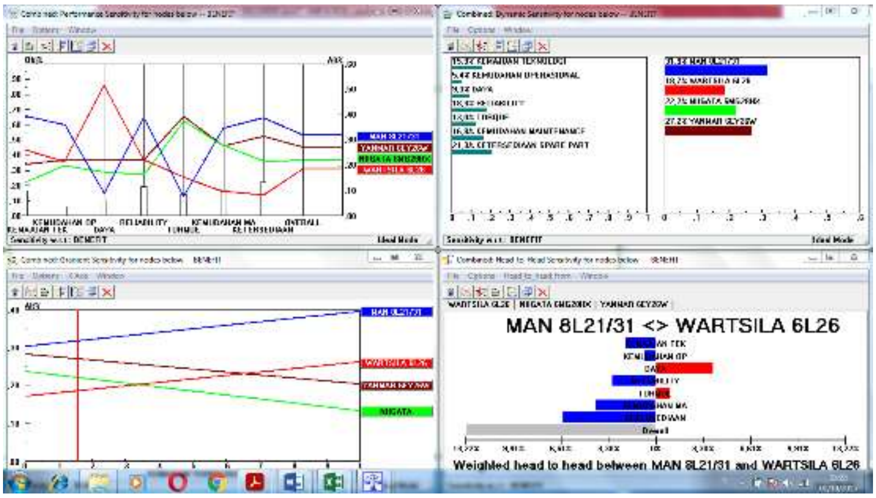

Figure 3. Four Graphs

2.5 *Analysis Benefit-Cost Ratio (BCR)*

Data collection is carried out in strategic analysis Benefits, Cost, and Risk Analysis strategic analysis; the calculation uses the Pairwise Comparison method. Structurally, a decision is divided into three parts, the first is the assessment system, the second is the matrix of the decision benefit-cost ratio (BCR) and risk as a consideration for making decisions, and the third is a hierarchy or network of linkages, facts (objectives) that make a decision Alternative more desirable than the desired one. Others (Saaty TL, 2001).

BCR analysis is usually done by looking at the ratio between the benefits of a project to the general public and the government's costs. Mathematically this is formulated as follows:

$$BCR = \frac{Benefit}{Cost}$$

a. If the result of the B/C comparison is > 1, and it has the highest value, it means it is profitable.

b. If the results of the B/C comparison <1, it is not profitable and does not deserve to be prioritized

3. ANALYSIS AND DISCUSSION

3.1 Data Retrieval

The research at this stage carried out data analysis and data processing on questionnaire data which was the expert's perception regarding the selection of Main engine KRI XYZ obtained by researchers. The aim is to get a more detailed description of the relationship between each criterion, Alternative Main engine in terms of benefits and risks for KRI XYZ with the help of Software Expert Choice Version 11.

After obtaining the Alternative weights of the Main engine KRI XYZ in the form of Benefit weights from the calculation results of Software Expert Choice Version 11, the next stage is BCR data processing to determine whether the Alternative chosen is feasible or not. Meanwhile, from the weighting of Alternative Risk with AHP, it can be used as an additional option for Indonesian Navy policymakers in selecting Main engine Alternatives for KRI XYZ.

a. Resource Determination

The resource persons are mid-level officers consisting of selected experts who have had more than adequate academic and service experience, especially in procurement, maintenance, and repair in the Koarmada II area and UPT Headquarters in the eastern region. They have served for more than 20 years. Data were obtained directly through interviews and filling out questionnaires to the experts. This data is qualitative in the form of opinions from the sources and subjective respondents. Acting as resource persons and respondents are as follows in Table 4.1.

Table 2. List of Experts/Informants

No	Respondents expert	Job unit	Amount
1	Kasatlaikmatim	Satlaikmatim	1
2	Kasatharmatim	Satharmatim	1
3	Aslog Garuda Utama	Slog Garuda Utama	1
4	Kadisharkap Garuda Utama	Disharkap Garuda Utama	1
5	Pabanhar Alut Slog	Slog Garuda Utama	1
6	Kasub PF Disharkap	Disharkap Garuda Utama	1
7	Kabag PF Satharmatim	Koharmatim	1
8	Kasubada Dismatbek Garuda Utama	Disharkap Garuda Utama	1

b. Criteria Data in each Alternative

The definition that the expert/Validator has agreed upon on the variable main engine election plan for KRI XYZ is set out in the following table:

Tabel 3. Main Engine Criteria Definition

No	Criteria	Definition	Nature	Category
1	Technology advances	Main Engine technology to be used in accordance with the latest scientific advances.	Qualitative	Benefit
2	Reliability	Main Engine Reliability is the probability of resistance of a Main Engine or system to perform a specified function well within a specified period under the conditions for which it is designed to operate properly.	Qualitative	Benefit
3	Operational Ease	Main Engine operation is easier because the start and stop controls already use electronic control.	Qualitative	Benefit
4	Automation	The main engines used on ships are now equipped with Automation with electronic systems so that the main engine security will be better if the Automation works well.	Qualitative	Risk
5	Power	In selecting the Main Engine to be installed on the ship, power must also be considered in choosing the Main Engine with greater power. This means that the Main Engine can serve the power needed to move the ship.	Quantitative	Benefit
6	Torque	Also called moment or moment of force, it is the rotational equivalent form of linear force. On tugboats, and ample torque is needed due to delaying other ships—the greater the Main Engine Torque, the better the ability to delay the ship.	Quantitative	Benefit
7	Security Features	A good Main Engine is undoubtedly equipped with safety features. The more complete the safety features of the Main Engine, the more guaranteed safety. Because if it is not equipped with safety features, it will lead to things that are not desirable and can endanger the crew	Qualitative	Risk
8	Ease of Maintenance	The selection of the Main Engine must be easier for maintenance so that if a problem occurs, the repair will be carried out quickly.	Qualitative	Benefit
9	Control System	The advanced Main Engine control system will provide reasonable security for Main Engine performance and make it easier to use. The main engine with complete control will be selected as the best Main Engine.	Qualitative	Risk
10	Availability of spare parts	Spare parts from the Main Engine are the most critical needs if one day the Main Engine is damaged/undergoing maintenance so that spare part replacement is needed. Therefore, the ease of obtaining spare parts is highly considered in selecting the Main Engine.	Qualitative	Benefit

c. Main Engine Alternative

In choosing an Alternative engine that can be used, the specifications for the ocean tug ship KRI XYZ are needed, so we get several types of brands and types of engines as shown in table 4.

Table 4. List of KRI XYZ Engine Alternatives

NO	DESKRIPSI	MPK BARU	MPK BARU	MPK BARU	MPK BARU	SATUAN
	Merk	A	B	C	D	
	Grade application					
1	Daya (Power)	2307	2708	2580	2610	hp
2	Putaran	1000	1000	750	750	rpm
3	Dimensi					
	Panjang	5254	4387	3704	4271	mm
	Lebar	1820	1882	1824	1804	mm
	tinggi	3267	2430	3142	3112	mm
4	Berat	19000	17000	16000	18500	kg
5	Torque	1642,48	1948,06	2415,34	2444,62	N.m
		1,64248	1,94806	2,41534	2,44462	kN.m
	Torque	3,28496	3,89611	4,83067	4,88924	2 Engine
6	Harga engine	1.553.077	1.823.031	1.736.861	1.757.057	$
7	Biaya HSD/Hari	144.425.600	169.521.000	152.653.600	156.186.800	Rp
8	Biaya pemeliharaan/TH	203.785.000	239.207.000	227.900.000	230.550.000	Rp
9	Biaya Overhaule (1x)	11.514.886.000	13.516.390.000	12.877.506.000	13.027.244.000	Rp

Source: Injasmar,Disadal,Dismatal,Progar Satban

3.2 Data Processing

The AHP (Analytical Hierarchy Process) method is a functional hierarchy with the primary input being human perception which is the research subject. AHP has many advantages in explaining the decision-making process. One of them is to describe it graphically so that it is easily understood by all parties involved in decision-making.

Data processing using the AHP method The data obtained from the previous stages will be processed in several sub-sections. The first part is a data processing to obtain Alternative weights based on the Benefit criteria group. The second part is data processing to obtain Alternative weights based on the Risk criteria group. Then the data is entered into Software Expert Choice, as shown below.

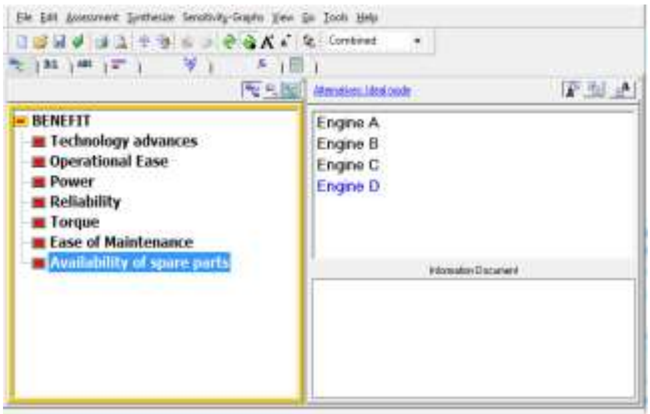

Figure 4. Determination of Benefit Criteria for Selection of Main Engine

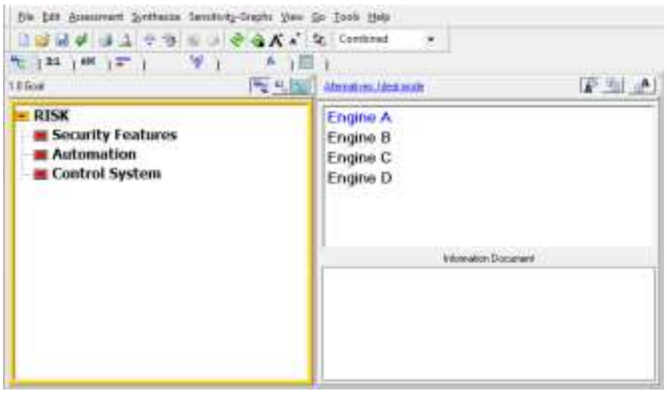

Figure 5. Determination of Risk Criteria for Selection of Main Engine

a. Pairwise Comparison

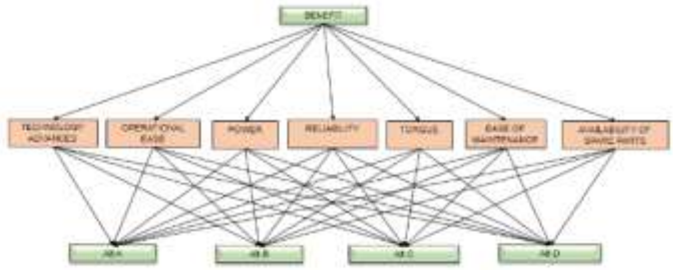

Figure 6. Hierarchy Criteria Benefit

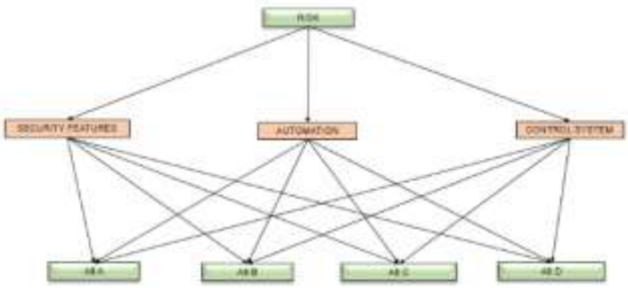

Figure 7. Hierarchy Criteria Risk

From the Benefit criteria there are seven criteria, and the Risk criteria are three criteria, using pairwise comparison.

In this research, the pairwise comparison process was carried out with the help of Software Expert Choice V.11. This software allows time in a relatively fast calculation. The assessment results processed in the AHP processing are the average (Geomean) of 8 (eight) respondents who are considered experts in their fields.

b. Consistency Ratio.

Based on the results of pairwise comparisons of all criteria and sub-criteria from 8 expert questionnaires, the results of the consistency ratio show that the overall CR value is 0.1. The Consistency Ratio value can be seen when inputting pairwise comparison data using Expert Choice Software V.11.

Figure 8. Inconsistent Value

After all the data is consistent with CR 0.1, the calculation can be continued using AHP.

c. Calculation of weight criteria Benefit.

The following are the results of the calculation of Software Expert Choice V.11, which is the weight of the first level criteria presented in tables and figures from the results of combining eight experts

Table 5. Weights of Benefit Criteria from Selection of Main Engine

No	Criteria	Weight
1	Technology advances	0,159
2	Operational Ease	0,054
3	Power	0,093
4	*Reliability*	0,183
5	*Torque*	0,130
6	Ease of Maintenance	0,168
7	Availability of spare parts	0,213
	Amount	1,000
	Inconsisten	0,00771

Table 6. Weights of Alternative Main Engine Benefit Criteria

No	Alternative Main Engine	Weight
1	Engine A (Alternatif I)	0,319
2	Engine B (Alternatif II)	0,187
3	Engine C (Alternatif III)	0,222
4	Engine D (Alternatif IV)	0,272
	Amount	1,000
	Inconsisten	0,01

d. Calculation of Weight Criteria Risk

The following are the results of the calculation of Software Expert Choice V.11 with pairwise comparisons of the criteria and alternatives, which are the weights/priorities of the Risk criteria presented in the table

Table 7. Weight of Risk Criteria from Main Engine Selection

No	Criteria	Weight
1	Security Features	0,251
2	Automation	0,312
3	Control System	0,438
	Amount	1,000
	Inconsisten	0,00401

Table 8. Weights of Alternative Main Engine Risk Criteria

No	Alternative Main Engine	Weight
1	Engine A (Alternatif I)	0,175
2	Engine B (Alternatif II)	0,187
3	Engine C (Alternatif III)	0,329
4	Engine D (Alternatif IV)	0,309
	Amount	1,000
	Inconsisten	0,00

3.3 Discussions

Based on the results obtained from data collection and processing, then proceed with analysis and discussion of these results, where the results of the analysis are the output of the AHP method and continue with BCR analysis and consider risk factors from the AHP Risk results. So from the model and analysis results show that the selected MAIN ENGINE Alternatives, which will be used as replacements for the KRI XYZ re-engine, are as follows:

a. Analysis of Alternative Types Main Engine Based on Benefit and Risk Criteria

The results of AHP data processing produce consistent weights between criteria. The results of data processing using the AHP method with Software Expert Choice V.11 produces the following data:

Table 9. Alternative Assessment Results for Benefit Criteria

Criteria	weight	Alt 1	Alt 2	Alt 3	Alt 4	Inconsistent
Technology advances	0,159	0,397	0,263	0,135	0,205	0,00927
Operational Ease	0,054	0,362	0,216	0.200	0,222	0,00343
Power	0,093	0,089	0,517	0,174	0,220	0,03
Reliability	0,183	0,389	0,222	0,165	0,224	0,00063
Torque	0,130	0,077	0,154	0,376	0,392	0,01
Ease of Maintenance	0,168	0,347	0,098	0,279	0,276	0,00183
Availability of spare parts	0,213	0,388	0,083	0,215	0,315	0,00257
weight Alternative		0,319	0,187	0,222	0,272	0,01

From the comparison of Alternatives for the benefit group, the first Alternative is engine A, which has the highest benefit, namely 0.319. The factor that dominates the Alternative weight value from engine A is because the Alternative weight value is very high for five criteria (Technology Advancement, Operational Ease, Reliability, Maintenance Ease, and Spare Part Availability) where the benefit criteria group has the highest weight. The second Alternative weight value is engine D has a weight value of 0.272, the third Alternative value is C has a weight value of 0.222, and the fourth Alternative weight value is engine B has a weight value of 0.187.

In this research, the Alternative sought is the Alternative that gives the highest benefit value weight so that in this case, engine A is the best, while engine B is the least good.

While the results of Alternative assessments for the Risk criteria are presented in Table 4.9 below:

Table 10. Alternative Assessment Results for Risk Criteria

Criteria	Weight	Alt 1	Alt 2	Alt 3	Alt 4	Inconsistent
Security Features	0,251	0,177	0,196	0,318	0,309	0,00168
Automation	0,312	0,180	0,226	0,310	0,284	0,00049
Control System	0,438	0,170	0,151	0,351	0,329	0,00312
Weight Alternative		0,175	0,187	0,329	0,309	0,00401

From the risk weight values results by looking at the risk level category table, Alternative engine A with a weight value of 0.175 and engine B with a weight value of 0.187 is considered to have Low Risk. In contrast, engine C has a risk value of 0.329, and engine D, a risk value of 0.309, has a Moderate Risk.

In this research, the expected Alternative is an Alternative with a low-risk weight, so it can be said that engines A and B have the best risk because they are at the Low-Risk level.

b. Sensitivity Analysis

Sensitivity analysis is carried out in identifying the impact of changes in the priority of the importance of one criterion on the priority of the interests of other criteria. Where can affect the results of the Alternative assessment of Main engine selection? Sensitivity analysis in this study was carried out with Software Expert Choice V.11.

The Performance Sensitivity of Expert Choice in Figure 9 shows the variation of the Alternative ranking of Main engine selection, which is different for each criterion in the benefit criteria group. On the Torque criteria, the selection of the Main from engine A has the lowest value, while the selection of the Main engine from B < C < D for engine D has the most considerable torque.

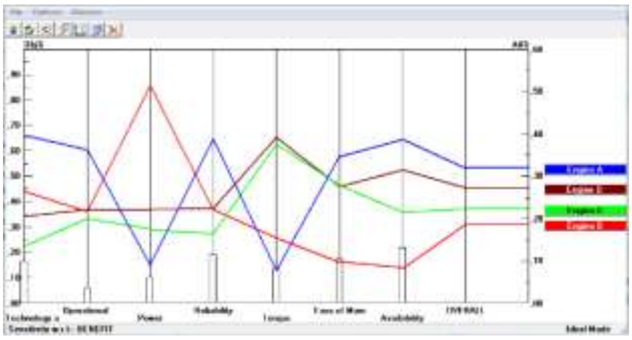

Figure 9. Diagram of Group Performance Sensitivity Benefit Criteria

This performance analysis tool can be adjusted with the assumption of changes in the level of importance of the existing criteria. For the benefit criteria, the most sensitive is the Torque criteria and the Power criteria, while the other five criteria have little effect on the engine Alternative priority level. For example, Figure 10 illustrates that if the Torque criterion weight is from 0.130 to 0.502, then the overall Alternative ranking results will change with the selection of Main engine from engine D to have the highest benefit weight value followed by engine C and engine C A and finally engine B.

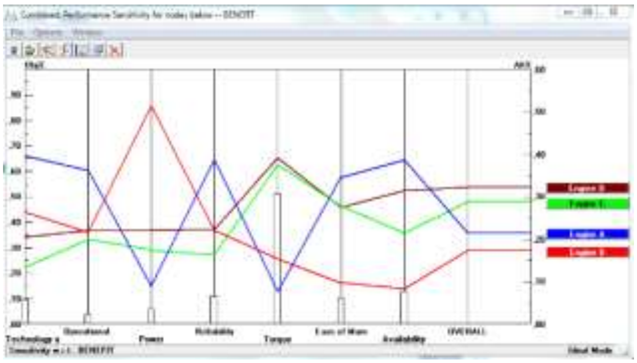

Figure 10. Diagram of Performance Sensitivity Torque Criteria

The sensitivity that has the second effect on the benefit criteria, namely power, which is shown in Figure 11, illustrates that if the weight of the Power criterion is from 0.093 to 0.610, then the overall Alternative ranking results will change with the selection of the main engine from engine B to have the highest benefit value followed by engine D and engine C. and lastly is engine A.

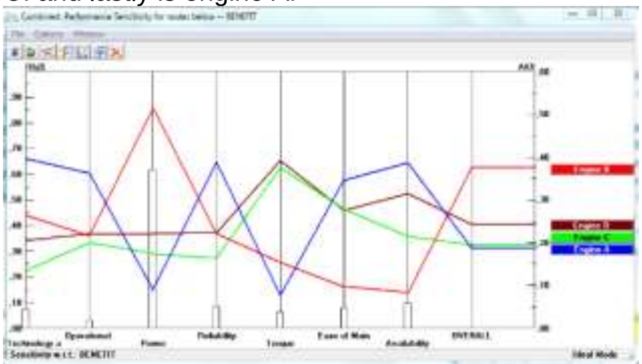

Figure 11. Diagram of Performance Sensitivity Power Criteria

3.4 Calculation Analysis BCR

With the Alternative priorities obtained previously, we can calculate the BCR value.

Table 11. Calculation Cost for BCR in main selection engine

	engine A	engine B	Engine C	Engine D
engine price	1.553.076,792	1.823.030,755	1.736.860,911	1.757.056,968
fuel price	0,730	0,730	0,730	0,730
lube oil price	2,050	2,050	2,050	2,050
comsumption fuel L/hour	248,667	291,875	262,833	268,917
comsumption lube oil L/hour	1,036	1,383	1,286	1,301
amount day 1 year	100,000	100,000	100,000	100,000
amount fuel/year	18.152,667	21.306,875	19.186,833	19.630,917
amount lube oil L/year	212,406	283,414	263,547	266,743
service OVERHAUL $ million/8 year	136.622,298	160.369,824	152.789,566	154.566,189
Maintenance /year	14.536,914	17.063,703	16.257,147	16.446,183
MATERIAL OVERHOULE/8 year	684.787,041	803.815,911	765.821,658	774.726,561
TOTAL COST ($)	854.311,326	1.002.839,727	954.318,752	965.636,593
NORMALIZATION COST	0,226	0,266	0,253	0,256

The following equation is used in the BCR calculation:

$$BCR = \frac{Benefit}{Cost}$$

Table 12. Calculation BCR Priority Selection of main engine

No	Type Engine	Benefit	Cost	B/C Ratio
1	Engine A	0,319	0,226	1,410372
2	Engine B	0,187	0,266	0,704319
3	Engine C	0,222	0,253	0,878656
4	Engine D	0,272	0,256	1,063933

On Table 12, the calculation of the BCR for the selection of MPK for KRI XYZ, the BCR value for engine A is 1.410372, the BCR Alternative for Engine B is 0.704319, the Alternative BCR value for engine C is 0.878656, and the Alternative BCR value for engine D is 1, 063933. This shows that Alternative engine A has the highest BCR value.

a. If the results of the B/C comparison > 1 have the highest value, it is profitable if it is used as an alternative to the Main engine KRI XYZ and deserves to be prioritized.

b. If the results of the B/C comparison < 1, it means that it is not profitable as an alternative to the Main engine KRI XYZ replacement and is not feasible to be prioritized.

3.5 Result in Analysis

After the risk level of each Alternative is known, the results are used to strengthen the arguments for the benefit and cost analysis that has been carried out. The chosen alternative has the highest benefit and cost ratio with the lowest level of risk. The mapping of the analysis results based on the ratio of benefits and costs with the analysis results based on the level of risk is summarized in Table 4.12.

Table 13. BCR and Level Risk

No	Engine type	*Benefit*	*Cost*	*B/C Ratio*	*Risk*	Information
1	Engine A	0,319	0,226	1,410372	0,175	*Low*
2	Engine B	0,187	0,266	0,704319	0,187	*Low*
3	Engine C	0,222	0,253	0,878656	0,329	*Moderat*
4	Engine D	0,272	0,256	1,063933	0,309	*Moderat*

Judging from the BCR and also considering the risk factors, the first choice of engine A has the most considerable BCR value with a value of 1.410372 > 1, which has the highest value, which means it is profitable when used as an Alternative to MPK KRI XYZ and deserves to be prioritized with low risk. The second option is engine D, which has a BCR value of 1.063933 > 1, which is still profitable if used as an Alternative to MPK KRI XYZ and deserves to be prioritized with moderate risk. In comparison, engine B and engine C have a BCR value with a BCR value of < 1. It is not profitable as an Alternative to MPK KRI XYZ replacement and is not feasible to be prioritized.

Table 14. Priority of Selected Main Engine Alternative.

Alternative	Priority	Information
Engine A	1	Best and feasible (BCR>1) and Low risk
Engine D	2	Eligible (BCR>1 for Moderate risk

The choice of an Alternative engine for KRI XYZ in addition to a higher and feasible BCR value (BCR>1) must also consider the lowest risk factor (low) so that the best MPK Alternative is engine type A with the highest BCR value and low-risk level. The second choice is engine D, while engines B and C are not feasible because the BCR value is <1. So that policymakers in the Navy can choose the best Alternative engine for KRI XYZ, using engine A where the Benefit-Cost Ratio is higher and feasible, and the risk is low.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusions

From the research that has been done, the following conclusions can be drawn:

a. The criteria and weights used in the selection of Main engine Alternatives to re-engine KRI XYZ are grouped into benefit categories, cost categories, and risk criteria groups, with each group of criteria as follows:

1) The benefit criteria group has seven criteria consisting of Technological Progress with a weight of 0.159, Operational Ease with a weight of 0.054, Power with a weight of 0.093, Reliability with a weight of 0.183, Torque with a weight of 0.130, Ease of Maintenance with a weight of 0.168 and Availability of Spare Parts with a weight of 0.213.

2) The Cost criteria group has four criteria consisting of Fuel Consumption with a weight of 0.396, Machine Price with a weight of 0.303, Overhoule Costs with a weight of 0.190, and Maintenance Costs with a weight of 0.111.

3) The Risk criteria group has three criteria consisting of Security Features with a weight of 0.251, Automation with a weight of 0.312, and Control Systems with a weight of 0.438.

b. In determining Alternative priorities for selecting the Main engine KRI XYZ in this study using the Analytical Hierarchy Process (AHP) method to obtain Alternative weights from the benefit criteria for engine A of 0.319, engine B of 0.187, engine C of 0.222, and engine D of 0.272 for the risk criteria for engine A is 0.175, engine B is 0.187, engine C is 0.329, and engine D is 0.309. Then from the cost normalization results, it is found that engine A is 0.226, engine B is 0.266, engine C is 0.253, and engine D is 0.256..

c. Based on data processing with AHP and BCR analysis and considering the level of risk, the selected Alternative is the best and feasible A engine (BCR>1) and low risk, meaning that it is most profitable to choose the engine as a replacement engine for Main engine KRI XYZ. Thus, it can be used as a guideline for the leadership of the Navy in determining engine type priority policies, paying attention to the BCR value, and considering the level of risk in the implementation of the KRI XYZ re-engine selection.

4.2 Suggestions

Some suggestions that can be given in this research are:

a. The priority of the Main engine type A that has been analyzed can be used as material for consideration and input to the leadership for selecting the appropriate Main engine type for the KRI XYZ re-engine.

b. Determining the priority of Alternative Main engine types and using the weight of the AHP method whereby separating the benefit criteria, cost criteria, and research criteria. BCR analysis from the Alternative weighting of benefit criteria and cost criteria, other researchers, can also be carried out using the ANP and Dematel methods to check the relationship between criteria.

c. If used as a policy from this research, the provider/procurement party needs to consider the Life Cycle Cost (LCC) of each type of the Main engine, which is an Alternative, so that the decision results will be more detailed.

ACKNOWLEDGEMENTS

The authors greatly acknowledge the support from Indonesia Naval Technology College STTAL Surabaya Indonesia for providing the necessary resources to carry out this research work. The authors are also grateful to the anonymous reviewers and journal editorial board for their many insightful comments, which have significantly improved this article.

REFERENCES

Abdulvahitoglu, A., & Kilic, M. (2021). A new approach for selecting the most suitable oilseed for biodiesel production; the integrated AHP-TOPSIS method. Ain Shams Engineering Journal. Turkey.

Al Mukharom, R.R. (2019). KRI Krait 827 Main Engine Selection Analysis in Implementing Re-engine With Fuzzy MCDM Method, Surabaya: STTAL.

Aoun, J., Quaglietta, E., Goverde, R. M., Scheidt, M., Blumenfeld, M., Jack, A., & Redfern, B. (2021). A hybrid Delphi-AHP multi-criteria analysis of Moving Block and Virtual Coupling railway signaling. Transportation Research Part C 129 (2021) 103250,Belanda.

Ciptomulyono. U, & Henry. (2000). Fuzzy goal programming model for determining priority weighting in the process hierarchy analysis (AHP) method. Science and Technology Journal, 19-29

Ciptomulyono. U. (1998). Integration of Analytical Hierarchy Process and Goal Programming Approach for Waste Management Strategy. The 3rd International Conference on Multi-Objective Programming and Goal Programming. Quebec, Canada.

Guchhait, A. (2017). Supplier Selection in A Supply Chain Using Multi-Criteria Decision Making Methods. American Journal of Engineering Research, 6(10), 338-345.

Hart, B. (2006). International Standards online at www.saiglobal.com/shop. Risk management AS/NZS 4360. Third edition 2004.

Hutabarat,D., Ciptomulyono,U., Ahmadi & Hartoko,P. (2020). Determining the Priority of Submarine Types as Archipelago War Defense Using the

Fuzzy AHP Method and BCR Analysis, Surabaya: STTAL.

Inggil,B. (2010), Final Project: Selection of New Submarine Alternatives for the Indonesian Navy by Using the Analytic Network Process (ANP) Method, Surabaya: STTAL.

Kepala Staf Angkatan Laut. 2016. Kasal Regulation number: Perkasal/5/ 2016 concerning the Basic Development Policy of the Navy towards Minimum Essential Force.

Kasal Decree No. Kep/1049/VI/2015 dated 16 June 2015 regarding the Manual for the Implementation of the Maintenance of Indonesian Navy Ships (PUM-7.101)

Kasal Decree No. Kep/1050/VI/2015 dated 16 June 2015 concerning Ship Repowering Field Manual in the Indonesian Navy (PUM-7.101.204)

Livret Platform (2019). KRI Soputan 923.

Mahmoudkelaye, S., Azari, K. T., Pourvaziri, M., & Asadian, E. (2018). Sustainable material selection for building enclosure through. Case Studies in Construction Materials, 2214-5095, Iran.

Engine, K. D. (t.thn.). Maintenance Journal Book. KRI Soputan 923.

Mulyono, S. (1996). Troubleshooting using the AHP Method. Jakarta: Publishing Institute, Faculty of Economics, University of Indonesia.

Najib, R. (2014). Selection of Air Attack Repellent Weapons for LPD Class KRI Makassar With Fuzzy MCDM ApproachSurabaya: STTAL.

Németh. I, et al.(2020). Maintenance schedule optimization for manufacturing systems IFAC Papers OnLine 53-3 (2020) 319–324.

Novirsal,R., & Tjakraatmadja, H. J. (2006). Benefit-Cost Analysis Using Analytic Hierarchy Process In Selecting Suitable Technology To Enhance Fleet Management System in PT PETROSEA Tbk. The 4th Indonesian Symposium on Analytic Hierarchy Process.

Presidential Regulation Number 70 of 2012 concerning the Procurement of Goods and Services

Regulation of the Minister of Defense number 17 of 2014 concerning the Procurement of ALUTSISTA within the Ministry of Defense and the TNI, pasal 1 ayat (1)

Ponidi. (2015). Optimalisasi Pola Perawatan Dan Perbaikan Yang Di Rencanakan Pada Mesin Utama KRI Sultan Nuku 873 Dengan Tipe Mesin Deutz AG 620 V 16. Surabaya: STTAL.

Rahmanita, P.E., Novi, I. J. (2017). Use of AHP and FAHP Methods in E-Commerce Website Security Quality Measurement. Journal of Information Technology and Computer Science (JTIIK), Vol. 5, No. 3, August 2018, p. 371-380

Richard. (2008). Analysis of Engine Replacement for Cargo Ships at One of the Shipping Companies in Indonesia.

Saaty, T. (1993). Decision Making for Leaders: Analytical Hierarchical Process for Decision Makers in Complex Situations. PT Pustaka Binaman Pressindo, Jakarta.

Saaty, T. (2008) ―Decision Making With The Analytic Hierarchy Process.‖ Int. J. Services Sciences, Vol. 1, No. 1.

Sennaroglua, B., & Celebia, G. V. (2018). A military airport location selection by AHP integrated PROMETHEE and VIKOR methods. Transportation Research Part D, 160-173.

Sonar,H.C., & Kulkarni, S.D (2021) An Integrated AHP-MABAC Approach for Electric Vehicle Selection. Research in Transportation Business & Management, India

Letter from the Commander of the Commander of the Military Command II Number B/947/V/2021 dated 19 May 2021 concerning Appreciation for the Replacement of the KRI Soputan-923 Main Engine.

Taha. HA (2007), Operations Research: An Introduction, Pearson Prentice Hall, New Jersey, USA.

Turan, O, et al. (2009). Maintenance/repair and production-oriented lifecycle cost/earning model for ship structural optimization during the conceptual design stage. Universities of Glasgow and Strathclyde.Scotland.

Wijnmalen, D. (2007). Analysis of benefits, opportunities, costs, and risks (BOCR) with the AHP–ANP: A critical validation, Belanda.

Wicaksana,J.M., Fathimahhayati, D. L, Sukmono,Y. (2020). Decision Making in Supplier Selection Using Analytical Hierarchy Process (AHP) and Technique For Others Reference by Similarity to Ideal Solution (TOPSIS) (Studi Kasus: M-Merchandise Universitas Mulawarman). (Civil Engineeering, Elektrical Engineeering and Industrial Engineeering) Vol. 17, No : 2, Oktober 2020 , p-ISSN:1907-5243, e-ISSN: 2655-8416, Samarinda:UNMUL.

Yogi,P., Rizal, O., Ahmadi, & Suharyo. S. O. (2017). Feasibility Analysis of Naval Base Relocation Using SWOT and AHP Method to Support Main Duties Operation. Journal of Defense Management, 7(1), 1-8.