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SELECTION OF ALTERNATIVE ENERGY SOURCES INDONESIAN WARSHIP PATROL CRAFT 36 CLASS USING LIFE CYCLE COST (LCC) AND TOPSIS (TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION)

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ABSTRACT

Indonesia has abundant natural resources of oil and gas energy. Domestic fuel supply is not entirely fulfilled by domestic oil refineries, almost 20% -30% of domestic oil demand must be imported from abroad. This has an impact on the Navy. Steps to address this problem through switching to the use of alternative energy fuels for the Indonesian warship class Patrol Craft 36. The selection of appropriate alternatives requires analysis of information and identification of alternative fuel requirements to be selected. The approach in this study uses Life Cycle Cost method to see the life cycle cost of alternative and combined TOPSIS (Technique For Order Preference By Similarity To Ideal Solution) approach to other than cost factor, and Benefit Cost Ratio. The result of data processing of alternative energy sources selected is gas, CNG (Compressed Natural Gas) with the value of Benefit Cost Ratio 53,7051 Life Cycle Cost IDR 14,168,302,864.

Keywords: *Alternative Energy, Life Cycle Cost, TOPSIS.*

1. INTRODUCTION.

Geographically, Indonesia is an archipelago (archipelagic state) which is the largest total area, occupying nearly two-thirds of the Southeast Asian region (Adisasmita, 2006). The geographical position is located at the intersection of the world between the Indian Ocean and the Pacific Ocean as well as between Asia and Australia (UNCLOS , 1982). Based on this geographical location, Indonesia has abundant natural resources (Beatly, et al., 1994).

One of the abundant natural resources of oil and gas is the energy that becomes the mainstay of the Indonesian economy, both as a producer and supplier of foreign exchange in the country's energy needs. But in fact, the level of consumption of petroleum (oil) in the country has exceeded production capacity. In recent years, the supply of domestic fuel cannot be entirely met by domestic oil refineries, nearly 20% -30% of domestic oil needs had to be imported from abroad (LM FEUI Research Bureau, 2011).

The decrease in oil production was due to the decline in production from existing fields more quickly than expected. About 90 percent of Indonesia's total oil production is produced from the field whose age more than 30 years (MIGAS, 2016). So, it takes a considerable investment to curb the natural decrease. While oil reserves held generally categorized into groups unproven (believed to exist but have not been found) and proven (shown to be present and can be explored) with a certain degree of confidence.

Based on the above data source, even though Indonesia is one of the oil-producing countries, it still has not been able to meet domestic demand and this is a very big impact in Indonesia especially in the field of defense. Based on (The

Law of The Republic of Indonesia No.34, 2004) explains that ' the duty of the maritime security forces in the field of defense and law enforcement and to protect the maritime territories of national jurisdiction in accordance with the provisions of national law and ratified international law ' reinforced by national defense policy determined by the Ministry of Defense related to the Minimum Essential Force (MEF).

The Navy also feels the impact of fuel shortages. This is because most of the platforms (primary equipment, weapon system) that is possessed particularly Indonesian Warship Class Patrol Craft 36 that uses diesel fuel energy sources as the main motor drive. Looking for the main task, Indonesian Warship Class Patrol Craft 36 is a fast patrol fleet in the shallow marine waters that require a high level of mobility (Naval Headquarters, 2000).

Due to the needs for high fuel consumption for Indonesian Warship Class Patrol Craft 36 and the dependence on the availability of diesel fuel source, it requires the implementation of source selection for alternative waterwheel Indonesian Warship Class Patrol Craft 36. The selection of alternative energy source is also considered in terms of cost, both initial costs, operational and maintenance, and the risks of the alternative energy sources. To analyze the cost aspects, it has conducted research using Life Cycle Cost (LCC) method to measure the extent of the benefits and costs of each alternative. After knowing and evaluating the cost of each alternative, the weighting of selected alternatives is also done using TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method, resulting in a ranking of each alternative for selecting.

1.1 Related Works

(Burhanudin, 2002) explains the review of gas fuel development as an alternative fuel. Based on data sources predicted that the next 10 years will decrease crude oil production. Therefore, it is necessary to develop alternative energy sources, since 1987 the government has utilized gas fuel, which in terms of cheaper cost of fuel, lighter than air, machine age can last long, cheaper maintenance, and environmentally friendly. A study of (Dale, 2013) shows the development of renewable energy technologies. The energy sources studied are solar photovoltaic (PV), CSP (Concentrating Solar Power), and wind. This study is a comparative analysis of the three energy sources and calculate the energy cost used. Where seen from the Life Cycle Assessment aspect of each energy source. The results of this study found that the energy sourced from the wind has the cheapest energy costs followed by CSP, and then solar photovoltaic (PV). A study of raw material composite gear selection using MCDM method and Life Cycle Assessment. Selection of this composite raw material by considering from the aspect or criteria of mechanical, electrical, chemical cost, recycling process, and disposal. The result of this research is comparing gear making from pure PET raw material compared to PET composite / aluminum powder (A.S.Milani, et al., 2011). In a study (Firsani & Utomo, 2012) conducted using Life Cycle Cost (LCC) method in analyzing the construction of Diamond Building in Malaysia using the green building concept. Based on the concept required an analysis that sees how much the cost incurred. LCC analysis requires relevant costs, including initial costs, operational and maintenance costs, energy costs, replacement costs, and residual value. The analysis was performed by researchers using Present Worth Method, where the analysis period was determined for 10 years. (Mulyatno, 2010) conducted a technical study of the ship propulsion system using biodiesel fuel on Laboar vessels. This research is based on the study of fishermen's problems on the price of fuel which is increasingly expensive. So, developed alternative driving energy sources using biodiesel. Based on the results of the analysis and empirical calculations, the results show that efficiency when using diesel fuel when the ship is currently sailing is 23.2%, while the efficiency for B20 biodiesel fuel is 22.3%, B30 type is 23.2%, and type B50 is 22.1%. A comparative study of the use of emulsions of biodiesel mixed with DEE (Diethyl Ether) to produce an appropriate mixture of diesel engine performance. In addition, exhaust emissions produced by diesel engines can be reduced or reduced. The results of this study that the level of exhaust emissions specifically of NO can be reduced by up to 20%. Where the NO content is the most percentage of gas in air pollution (Kannan & R., 2011). (Wibawa & Alam, 2013) researchers conducted research on the use of alternative gas energy sources for driving traditional fishing vessels. Seeing the situation and conditions of rising unstable fuel supply prices. This study tried to use a dual fuel system that was applied to fishing boat engines. (Bakar, et al., 2009) conducts research on the application of environmentally friendly machines using alternative CNG (Compressed Natural Gas) fuels. The research was carried out on diesel engines that were used as a means of transportation. The results of this study that exhaust emissions from CNG are very low and far above the machines that use gasoline or diesel fuel.

2. METHODOLOGY.

2.1. Life Cycle Cost

Life Cycle Cost procedures based on (G. Woodward, 1997) is as follows: (1) Considered elements of cost are all cash flows that occur during the life cycle of an asset. From the previous definition, LCC includes all expenses incurred, from acquisition to disposal at the end of his life.

(2) Defining cost structure involves grouping costs so as to define the potential trade-offs, to achieve optimum LCC. Properties set fee structure will depend on the depth and the extent of the LCC study. (3) Estimating the cost relationship is a mathematical expression that describes the approximate cost of an item or activity as a function of one or more independent variables. (4) The establishing LCC formulation method involves the selection of an appropriate methodology for evaluating the asset of LCC. According to the literature life cycle costs are all the expenditure related to the items since it is designed until it is no longer usable. Then the life-cycle costs can be combined into Eq. (1).

Life Cycle Cost = Initial Cost + Operating Costs + Maintenance Cost + Disposal Cost (1)

One of the indicators used as a decision making basis to analyze the cash flow is a method of NPW (Net Present Worth). NPW is the present value of all cash flows from now until the end. Some calculations in the NPW method (Net Present Worth), namely:

The present value factors of uniform sequence (look for the value of P if the value of A is known) can be obtained by using Eq. (2).

= (/ , %,) (2)

(P; current equivalent value, A; cash flow in period-N, i; interest rate, N; period). The capital recovery factor of a uniform series (look for an A if the value of P is known) by using Eq. (3).

=(/ , %,) (3)

(A; current cash flow of period to-N, P; Present value at period-N, i; interest rate, N; period). To obtain the value of NPW (Net Present Worth) can be obtained by using Eq. (4).

= Σ h −
Σ h (4)

2.2 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS is based on the concept where the best selected alternative not only has the shortest distance from the positive ideal solution, but it also has the longest distance from the negative ideal solution (Hwang & Yoon, 1981). This concept is widely used in several Multi Criteria Decision Making models to solve problems in a practical decision. This is due to the concept is simple and easy to understand, efficient computing and has the ability to measure the relative performance of the alternatives in the decision of a simple mathematical form.

In general, the procedures of TOPSIS follow the steps as follows (Lai, et al., 1994): (1) Make a normalized decision matrix. (2) Make a weighted, normalized decision matrix. (3) Determine positive ideal solution matrix and negative ideal solution matrix. (4) Determine the distance between the value of each alternative with a positive ideal solution matrix and negative ideal solution matrix. (5) Determine the value of preference for each alternative.

TOPSIS requires a work rating of each alternative A_i for each of the normalized C_j criteria, as shown in the Eq. (5).

(5)

(i=1,2,...,m; j= 1,2,...,n)

The ideal A^+ positive solution and the ideal A^- negative solution can be determined based on the normalized weighted (y_{ij}) rating as Eq. (6) and Eq. (7).

(6)

(7)

(i=1,2,...,m;j=1,2,...,n)

The distance between alternative A with the ideal solution can be seen in the Eq. (8).

$^+ = \sqrt{\Sigma\ (^+ -)^2}$ (8)

(i=1,2,...,m)

The distance between alternative A with the ideal negative solution can be seen in the Eq. (9).

$^- = \sqrt{\Sigma\ (- ^-)^2}$ (9)

(i=1,2,...,m)

The proximity value of each alternative (V_i) can be seen in the Eq. (10).

(10)

(i=1,2,...,m)

3. RESULT AND DISCUSION.

The alternative object offered in this study is: (a) High Solid Diesel (b) Biodiesel (c) Compressed Natural Gas (CNG). The judges used in determining the sample to an expert in this study are those who have positions which can influence in the selection of alternative energy sources Indonesian Warship Patrol Craft Class 36, as Units of eligibility, Department of maintenance and repair, and Department of materials and supplies as consideration in the determination of the expert, and the recent experienced personnel type Patrol Craf Class 36. The calculation of Life Cycle Cost from each alternative is obtained based on total expenses incurred during 1 (one) year. The life cycle is calculated over a period of 25 (twenty five) years of age from Patrol Craft Class 36. The analysis used is a technical analysis of technical methods of Present Worth, then conducted an NPV analysis (Net Present Value). The criteria generated for the selection of alternative energy sources can be seen in Table 1.

Table 1. Criteria for Energy Sources Selections

Criteria	Understanding / Parameter
Efficiency	The level of fuel consumption used.
The Main Machine	Type MAN machine with type D 282 LE 410.
Diesel Generator	Type Perkins type 4 TGM that produces a power of 50 KVA.
Fuel System	Fuel flow from the storage tank to machine and burning process.
Tank Capacity	The amount of fuel charge capacity to be stored at Patrol Craft 36 is 30,000 liters.
Budget Limitations	Ability to support in conducting operations.
Security	Impacts that can trigger an explosion or fire for Patrol Craft Class 36.
Transfer of Fuel.	Fueling process at Indonesian Warship. Current condition of fuel transfer through among others bunker service, ground pipe Pertamina limited company , fuel trucks, and through Indonesian Warship (Assist Liquid Oil) Class while at sea.
Exhaust gas emissions	The remaining fuel combustion inside is discharged through the engine exhaust system.
Machine Room Temperature	Indicators during the combustion process that affect the temperature of the warship engine room.

3.1 Life Cycle Cost Analysis Using Fuel HSD (Existing)

The use of HSD fuel is a current condition that does not require a current or initial investment cost. The costs consist of maintenance cost for replacement filters (fuel, air and oil), and the cost of fuel consumption. The estimated costs, which incurred using Eq. 1 for 1 (one) year in conducting the operations can be seen in Table 2.

Table 2. Estimated Cost of PC 36 Using Fuel HSD Over One Year

Types of Costs			Total Cost
Investment Costs			
Operating Costs	IDR 6.500.000		IDR 26.000.000
Maintenance Costs			
Fuel Filters	IDR 882.500	30	IDR 26.475.000
Air Filter	IDR 4.800.000	14	IDR 67.200.000
Oil Filter	IDR 482.500	14	IDR 6. 755.000
Fuel Costs	IDR 11.900	551.000 Ltr	IDR 6.556.900.000
Total			**IDR 6.683.330.000**

The calculation results of Life Cycle Cost using HSD fuel are of IDR 909.188.428.625, then to get the value of Net Present Worth (NPW) based on Eq. 4 can be seen in Table 3.

Table 3. Life Cycle Cost Use of HSD Fuel

Year	Investment Cost	Operating Costs	Maintenance costs	Fuel costs	Total Present Cost	Total Annual Cost
0						
1		IDR 26.000.000	IDR 100.450.000	IDR 6.556.900.000	IDR 6.683.330.000	IDR 7.552.162.900
2		IDR 43.370.663	IDR 167.557.328	IDR 10.937.580.860	IDR 11.148.479.055	IDR 6.683.330.000
3		IDR 61.389.968	IDR 237.138.555	IDR 15.481.841.469	IDR 15.780.361.992	IDR 6.683.330.000
4		IDR 77.336.254	IDR 298.728.155	IDR 19.503.311.034	IDR 19.879.371.444	IDR 6.683.330.000
5		IDR 91.448.303	IDR 353.295.538	IDR 23.062.133.659	IDR 23.506.817.207	IDR 6.683.330.000
6		IDR 103.936.295	IDR 401.473.925	IDR 26.211.534.211	IDR 26.716.944.431	IDR 6.683.330.000
7		IDR 114.987.871	IDR 444.182.798	IDR 28.998.614.346	IDR 29.557.784.980	IDR 6.683.330.000
8		IDR 124.768.023	IDR 481.948.501	IDR 31.465.058.944	IDR 32.071.765.472	IDR 6.683.330.000
9		IDR 133.423.055	IDR 515.372.124	IDR 33.647.749.508	IDR 34.296.544.665	IDR 6.683.330.000
10		IDR 141.082.358	IDR 544.957.602	IDR 35.579.335.847	IDR 36.265.375.818	IDR 6.683.330.000
11		IDR 147.860.469	IDR 571.139.448	IDR 37.288.764.290	IDR 38.007.764.257	IDR 6.683.330.000
12		IDR 153.858.822	IDR 594.308.290	IDR 38.801.459.725	IDR 39.549.597.838	IDR 6.683.330.000
13		IDR 159.167.108	IDR 614.813.531	IDR 40.140.105.952	IDR 40.914.086.582	IDR 6.683.330.000
14		IDR 163.864.696	IDR 632.958.877	IDR 41.324.784.023	IDR 42.121.607.595	IDR 6.683.330.000
15		IDR 168.021.849	IDR 649.016.705	IDR 42.373.171.706	IDR 43.190.210.260	IDR 6.683.330.000
16		IDR 171.700.752	IDR 663.227.179	IDR 43.300.948.415	IDR 44.135.876.337	IDR 6.683.330.000
17		IDR 174.956.407	IDR 675.802.808	IDR 44.121.989.746	IDR 44.972.748.971	IDR 6.683.330.000
18		IDR 177.837.538	IDR 686.931.488	IDR 44.848.574.996	IDR 45.713.344.222	IDR 6.683.330.000
19		IDR 180.387.201	IDR 696.780.225	IDR 45.491.570.793	IDR 46.368.738.219	IDR 6.683.330.000
20		IDR 182.643.541	IDR 705.495.801	IDR 46.060.593.422	IDR 46.948.732.964	IDR 6.683.330.000
21		IDR 184.640.302	IDR 713.208.673	IDR 46.564.153.648	IDR 47.462.002.623	IDR 6.683.330.000
22		IDR 186.407.347	IDR 720.034.224	IDR 47.009.781.989	IDR 47.916.223.560	IDR 6.683.330.000
23		IDR 187.971.100	IDR 726.074.555	IDR 47.404.140.335	IDR 48.318.186.990	IDR 6.683.330.000
24		IDR 189.354.959	IDR 731.419.962	IDR 47.753.135.711	IDR 48.673.910.632	IDR 6.683.330.000
25		IDR 190.579.609	IDR 736.150.591	IDR 48.061.978.505	IDR 48.988.708.506	IDR 6.683.330.000
				TOTAL	IDR 909.188.428.625	IDR 167.952.082.900

3.2 Life Cycle Cost Analysis Using Biodiesel Fuel

Based on the analysis of the characteristics and fuel systems for the use of biodiesel fuel for PC 36, it does not need a change of engine and fuel system. The operating and maintenance costs of PC 36 using HSD fuel are the same as using Biodiesel fuel due to the same fuel system. But differ in the calculation of fuel consumption costs. Thus, estimates of the costs incurred when using biodiesel fuel for 1 (one) year can be seen in the Table 4.

Table 4. Estimated Cost of PC 36 Using Fuel Biodiesel Over One Year

Types of Costs			Total Cost
Investment Costs			
Operating Costs	IDR 6.500.000		IDR 26.000.000
Maintenance Costs			
Fuel Filters	IDR 882.500	30	IDR 26.475.000
Air Filter	IDR 4.800.000	14	IDR 67.200.000
Oil Filter	IDR 482.500	14	IDR 6. 755.000
Fuel Costs	IDR 9.250	551.000 Ltr	IDR 5.096.750.000
Total			**IDR 5.223.180.000**

Obtained cost estimates using biodiesel fuel for the Life Cycle Cost above are IDR 710.552 .197.277, then to get the value of Net Present Worth can be seen in Table 5.

Table 5. Life Cycle Cost Using Biodiesel Fuel

Year	Investment Cost	Operating Costs	Maintenance costs	Fuel costs	Total Present Cost	Total Annual Equivalent Cost
0						
1		IDR 26.000.000	IDR 108.450.000	IDR 5.096.750.000	IDR 5.223.180.000	IDR 5.902.195.400
2		IDR 45.370.665	IDR 187.557.530	IDR 8.591.901.089	IDR 8.712.798.280	IDR 5.223.180.000
3		IDR 61.389.968	IDR 237.130.595	IDR 12.034.204.565	IDR 12.332.725.026	IDR 5.223.180.000
4		IDR 77.336.234	IDR 298.726.155	IDR 15.160.136.720	IDR 15.536.199.138	IDR 5.223.180.000
5		IDR 91.448.013	IDR 353.235.556	IDR 17.926.448.452	IDR 18.371.131.981	IDR 5.223.180.000
6		IDR 105.894.298	IDR 401.471.925	IDR 20.374.511.107	IDR 20.879.822.107	IDR 5.223.180.000
7		IDR 114.987.071	IDR 444.162.766	IDR 22.540.939.723	IDR 23.100.090.560	IDR 5.223.180.000
8		IDR 124.768.023	IDR 481.940.581	IDR 24.458.132.480	IDR 25.064.841.027	IDR 5.223.180.000
9		IDR 133.425.033	IDR 515.372.134	IDR 26.154.760.273	IDR 26.803.558.431	IDR 5.223.180.000
10		IDR 141.082.330	IDR 544.957.652	IDR 27.656.206.438	IDR 28.342.246.399	IDR 5.223.180.000
11		IDR 147.860.469	IDR 571.139.486	IDR 28.984.917.200	IDR 29.703.917.167	IDR 5.223.180.000
12		IDR 153.859.022	IDR 594.309.286	IDR 30.160.787.454	IDR 30.908.935.546	IDR 5.223.180.000
13		IDR 159.167.100	IDR 614.811.531	IDR 31.201.342.862	IDR 31.975.321.492	IDR 5.223.180.000
14		IDR 163.864.690	IDR 632.958.877	IDR 32.122.206.072	IDR 32.918.029.639	IDR 5.223.180.000
15		IDR 168.021.569	IDR 649.016.785	IDR 32.937.129.267	IDR 33.754.167.822	IDR 5.223.180.000
16		IDR 171.700.752	IDR 663.227.175	IDR 33.658.300.257	IDR 34.493.228.165	IDR 5.223.180.000
17		IDR 174.956.417	IDR 675.902.188	IDR 34.296.504.654	IDR 35.147.363.259	IDR 5.223.180.000
18		IDR 177.837.558	IDR 686.911.680	IDR 34.861.207.257	IDR 35.726.036.513	IDR 5.223.180.000
19		IDR 180.387.201	IDR 696.760.255	IDR 35.361.004.944	IDR 36.238.262.481	IDR 5.223.180.000
20		IDR 182.643.541	IDR 705.495.801	IDR 35.803.402.605	IDR 36.691.541.948	IDR 5.223.180.000
21		IDR 184.640.302	IDR 713.208.673	IDR 36.194.825.315	IDR 37.092.674.290	IDR 5.223.180.000
22		IDR 186.407.347	IDR 720.034.224	IDR 36.541.217.093	IDR 37.447.658.664	IDR 5.223.180.000
23		IDR 187.971.105	IDR 726.074.558	IDR 36.847.758.469	IDR 37.761.804.127	IDR 5.223.180.000
24		IDR 188.354.959	IDR 731.419.942	IDR 37.119.034.060	IDR 38.039.808.962	IDR 5.223.180.000
25		IDR 190.579.606	IDR 736.150.391	IDR 37.359.100.959	IDR 38.285.830.946	IDR 5.223.180.000
				TOTAL	IDR 710.552.197.277	IDR 131.258.513.400

3.3 Life Cycle Cost Analysis Using Compressed Natural Gas Fuel

The use of CNG fuel of PC 36 is based on the analysis of the characteristics and fuel systems, so a change of system flow of fuel and fuel tank design is needed. The CNG fuel system does not require the use of the fuel filter resulting the replacement costs nothing. The overall cost of installation of conversion kits in the fuel system of PC 36 is IDR 80.000.000. The Cost of 1 (one) CNG tube is 300 USD and the lifetime for 6 (six) years with the exchange rate IDR 12.156. These costs represent the investment costs to be incurred, so that the estimated costs of PC 36 using CNG fuel for 1 (one) year can be seen in the following Table 6.

Table 6. Estimated Cost of PC 36 Using Fuel CNG Over One (1) Year

Types of Costs			Total Cost
Investment Costs			
Kit Converter	IDR 80.000.000		
CNG Tube	IDR 18.234.000		IDR 98.234.000
Operating Costs	IDR 6.500.000		IDR 26.000.000
Maintenance Costs			
Fuel Filters			
Air Filter	IDR 4.800.000	14	IDR 67.200.000
Oil Filter	IDR 482.500	14	IDR 6. 755.000
Fuel Costs	IDR 3.100	551.000 Ltr (551 m^{3})	IDR 1.708.100.000
Total			**IDR 1.906.289.000**

The calculation results of Life Cycle Cost above obtained results of IDR 14.163.302.864, so to get the value of Net Present Worth (NPW) can be seen in Table 7.

Table 7. Life Cycle Cost Using CNG Fuel

Year	Investment Cost	Operating Costs	Maintenance costs	Fuel costs	Total Present Cost	Total Annual Equivalent Cost
0	IDR 98.234.000				IDR 98.234.000	
1		IDR 26.000.000	IDR 71.955.000	IDR 1.700.300	IDR 101.661.100	IDR 114.879.505
2		IDR 43.370.665	IDR 123.364.516	IDR 2.349.264	IDR 169.594.445	IDR 101.661.100
3		IDR 61.389.960	IDR 174.619.540	IDR 4.033.085	IDR 240.042.085	IDR 101.661.100
4		IDR 77.336.254	IDR 219.977.027	IDR 5.086.694	IDR 302.399.976	IDR 101.661.100
5		IDR 91.448.015	IDR 260.116.838	IDR 6.007.710	IDR 357.572.563	IDR 101.661.100
6		IDR 103.904.295	IDR 295.688.795	IDR 6.832.215	IDR 406.425.304	IDR 101.661.100
7	IDR 80.000.000	IDR 114.987.871	IDR 327.074.155	IDR 7.594.281	IDR 529.656.307	IDR 119.731.964
8		IDR 124.768.023	IDR 354.889.087	IDR 8.196.760	IDR 487.857.864	IDR 101.661.100
9		IDR 133.423.035	IDR 379.511.555	IDR 8.765.380	IDR 521.699.968	IDR 101.661.100
10		IDR 141.082.530	IDR 401.297.534	IDR 9.268.564	IDR 551.648.733	IDR 101.661.100
11		IDR 147.860.469	IDR 420.577.731	IDR 9.713.964	IDR 578.152.065	IDR 101.661.100
12		IDR 153.859.022	IDR 437.639.905	IDR 10.107.933	IDR 601.606.340	IDR 101.661.100
13		IDR 159.167.100	IDR 452.738.571	IDR 10.456.666	IDR 622.362.337	IDR 101.661.100
14	IDR 80.000.000	IDR 163.864.690	IDR 466.100.599	IDR 10.765.200	IDR 720.730.475	IDR 114.398.550
15		IDR 168.021.849	IDR 477.925.226	IDR 11.038.396	IDR 656.985.465	IDR 101.661.100
16		IDR 171.700.752	IDR 488.389.580	IDR 11.280.079	IDR 671.370.411	IDR 101.661.100
17		IDR 174.956.437	IDR 497.650.071	IDR 11.493.964	IDR 684.100.452	IDR 101.661.100
18		IDR 177.837.518	IDR 505.845.186	IDR 11.683.242	IDR 695.365.975	IDR 101.661.100
19		IDR 180.387.261	IDR 513.097.518	IDR 11.850.748	IDR 705.335.465	IDR 101.661.100
20	IDR 80.000.000	IDR 182.643.541	IDR 519.515.580	IDR 11.998.975	IDR 794.158.022	IDR 113.185.483
21		IDR 184.640.302	IDR 525.195.135	IDR 12.130.158	IDR 721.965.595	IDR 101.661.100
22		IDR 186.407.347	IDR 530.221.299	IDR 12.246.246	IDR 728.874.951	IDR 101.661.100
23		IDR 187.971.105	IDR 534.669.344	IDR 12.348.976	IDR 734.989.426	IDR 101.661.100
24		IDR 189.354.959	IDR 538.605.614	IDR 12.439.892	IDR 740.400.465	IDR 101.661.100
25		IDR 190.579.609	IDR 542.089.039	IDR 12.520.347	IDR 745.188.996	IDR 101.661.100
				TOTAL	IDR 14.168.302.064	IDR 2.596.964.270

3.4 Saving Total Annual Equivalent Cost Each Alternative

Saving Calculation Total Annual Equivalent Fuel cost is derived from the delta (Δ) saving Total Annual Equivalent Cost from the comparison of each fuel usage seen in the figure 1.

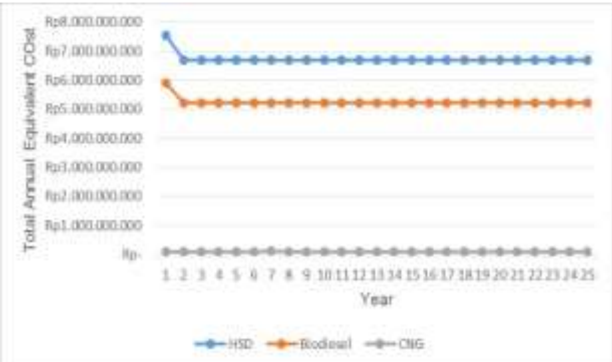

Fig. 1 Comparison Charts Total Annual Equivalent Costs Each Alternative

From the calculation of (delta) Total Annual Equivalent Cost savings above, it is explained that annual equivalent cost of the largest fuel if the fuel utilization ratio HSD was used CNG gas fuel in the amount of IDR 165.355.118.630. It can be seen in Table 8.

Table 8. Delta (Δ) Total Annual Equivalent Cost Saving Fuel

Fuel	*Total Annual Cost*	*(Δ) Saving*
HSD – Biodiesel	IDR 167.952.082.900 – IDR 131.258.513.400	IDR 36.693.569.500
HSD – CNG	IDR 167.952.082.900 – IDR 2.596.964.270	IDR 165.355.118.630
Biodiesel – CNG	IDR 131.258.513.400 – IDR 2.596.964.270	IDR 128.661.549.130

3.5 Sensitivity Analysis

This sensitivity analysis is a change of Life Cycle Cost to the interest rate (i) with the range of ± 30%. Then the Life Cycle Cost sensitivity to interest rate changes (i) can be seen in the Table 9.

Table 9. LCC Sensitivity to Interest Rate Changes

Interest rate (i)	Percentage of Cumulative Changes (i)	Fuel		
		HSD	Biodiesel	CNG
16,90%	30%	IDR 760.341.592.242	IDR 594.224.884.566	IDR 11.904.127.548
15,60%	20%	IDR 804.645.911.085	IDR 628.849.754.518	IDR 12.578.060.213
14,30%	10%	IDR 853.986.815.531	IDR 667.410.834.890	IDR 13.328.606.618
13%	0%	IDR 909.188.428.625	IDR 710.552.197.277	IDR 14.168.302.864
11,70%	-10%	IDR 971.246.548.361	IDR 759.052.081.293	IDR 15.112.296.476
10,40%	-20%	IDR 1.041.371.280.878	IDR 813.856.213.423	IDR 16.178.994.918
9,10%	-30%	IDR 1.121.041.808.105	IDR 876.120.609.226	IDR 17.390.898.681

The result of the LCC's sensitivity analysis of interest rate changes is found that with the change of interest rate increases up to 30% obtained the smaller LCC results for each fuel and vice versa if the change of interest rate is reduced to 30%, the LCC result of each fuel will get bigger.

3.6 Processing TOPSIS Analysis

Collecting data to calculate by using TOPSIS method is derived from expert interviews and a literature study for the selection of an alternative energy source for the Indonesian Warship PC 36 class that has been implemented. The results of the data obtained by the raised criteria in the selection of alternative energy sources for the PC 36 class. The initial form matrix can be seen in the Table 10.

Table 10. Matrix Initial Formation

NO.	CRITERIA	HSD	BIODIESEL	CNG	SCORE	
1.	Efficiency	2,2000	3,9000	4,4000	X1	6,2777
2.	The Main Machine	3,5000	3,2000	3,2000	X2	5,7210
3.	Diesel Generator	3,6000	3,2000	3,3000	X3	5,8387
4.	Fuel System	4,5000	4,4000	1,9000	X4	6,5742
5.	Tank Capacity	4,5000	4,5000	1,8000	X5	6,6136
6.	Budget Limitations	2,9000	3,8000	4,9000	X6	6,8454
7.	Security	4,4000	4,4000	1,8000	X7	6,4777
8.	Transfer of Fuel	3,8333	3,3333	4,5000	X8	6,7864
9.	Exhaust gas emissions	2,8333	4,0000	4,5000	X9	6,6542
10.	Machine Room Temperature	2,8333	4,1667	4,6667	X10	6,8678

This was followed by finding a normalized decision matrix of the initial matrix by using the Equation (5). The normalized decision matrix is at the following Table 11.

Table 11. Normalized Decision Matriks

HSD	BIODIESEL	CNG
0,3504	0,6212	0,7009
0,6118	0,5593	0,5593
0,6166	0,5481	0,5652
0,6845	0,6693	0,2890
0,6804	0,6804	0,2722
0,4236	0,5551	0,7158
0,6793	0,6793	0,2779
0,5649	0,4912	0,6631
0,4258	0,6011	0,6763
0,4126	0,6067	0,6795

The next is determining the positive ideal solution and negative ideal solution. The positive ideal solution is according to the Eq. (6) and the negative ideal solution is according to the Eq. (7). As a result, the positive and negative ideal solution is in the following Table 12.

Table 12. Positive and Negative Ideal Solution

Positive Ideal Solution (A+)	0,7009	0,6118	0,6166	0,6845	0,6804	0,7158	0,6793	0,6631	0,6763	0,6795
Negative Ideal Solution (A-)	0,3504	0,5593	0,5481	0,289	0,2722	0,4236	0,2779	0,4912	0,4258	0,4126

Calculate the alternate distances. Alternative distance with positive ideal solution is according to the Eq. (8) and the distance alternative to the negative ideal solution is according to the formula (9). Therefore, we get an alternative distance with a positive ideal solution and alternative distance with negative ideal solution at the following table 13.

Table 13. Positive and Negative Alternative Distance

Alternative Distance With Positive Ideal Solution		
(D1+)	0,5931	HSD
(D2+)	0,2834	BIODIESEL
(D3+)	0,6997	CNG
Alternative Distance With Negative Ideal Solution		
(D1-)	0,705	HSD
(D2-)	0,7946	BIODIESEL
(D3-)	0,6099	CNG

Calculate the closeness of each alternative against the ideal solution, using the Eq. (10). So the proximity of each alternative is obtained as a Table. 14. **Table 14.** Proximity of Each Alternative

	HSD	Biodiesel	CNG
Vi	0,5431	0,7371	0,4657

Eventually gained alternative ranking based on the relative closeness as follows: Biodiesel: 0.7371, HSD: 0.5431, CNG: 0.4657.

4. CONCLUSION.

From the results of data collection and processing, and analysis of data processing, Based on research by the method of Life Cycle Cost for the selection of an alternative energy source for the KRI Class PC 36, it can be concluded as follows: (a) Category costs contained in the selection of alternative energy sources for KRI Class PC 36, which are the initial cost (investment), operating costs, maintenance costs, and the cost of fuel (fuel cost). (b) Total Life Cycle Cost of each alternative, namely, for HSD fuel IDR 909,188,428,625, while for biodiesel fuel IDR 710,552,197,277, and for the use of CNG fuel is IDR 14,168,302,864. (c) Priority selection of alternative energy sources using the Life Cycle Cost is the use of CNG gas type fuel, biodiesel fuel, and the last HSD fuel (existing).

Selection of alternative fuels for KRI Class PC 36 with TOPSIS approach derived criteria for the selection of alternative fuels. These criteria are efficient, MPK machine, DG (Diesel Generator), fuel system, tank capacity, budget constraints, safety, fuel transfer, emissions, and the temperature of the engine room, and the next election results obtained from respondents in a sequence are biodiesel fuel, HSD fuel (existing), and CNG gas fuel.

Selection using TOPSIS approach that given to the respondents has no influence on the cost factor. Hence, to see the effect of the cost factor or Life Cycle Cost on the results of the calculation processing TOPSIS Benefit Cost Ratio, the results of calculations use the Benefit Cost Ratio which gets the greatest value is the chosen alternative. Sequentially, alternative priorities chosen by the Benefit Cost Ratio that is the fuel type with a value of 53.7051 CNG gas, biodiesel fuel with a value of 1.6949, and last priority is HSD fuel with a value of 0.9760.

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