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THE ANALYSIS OF THE DEVELOPMENT ALTERNATIVE ENERGY RESOURCES ON MARITIME SECTOR USING FUZZY MCDM METHODS

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ABSTRACT

The energy crisis has required the government to develop and utilize a renewable energy. Indonesia has a national jurisdiction area of ± 7.8 million km² with 2/3 of its territory being the sea of ± 5.9 million km². With this large sea area, it is a great potential for Indonesia to be able to develop alternative energy resources in the maritime sector amid the problem of fossil energy resources whose capacity is decreasing. Alternative energy in the maritime sector that can be developed include energy that utilizes ocean waves, ocean currents, tides, and ocean temperature differences. This study aims to determine the alternative energy of the maritime sector by reviewing from technical and financial aspects, political, economic, social and technological aspects. The method used is technical analysis, financial analysis, PEST analysis, and Fuzzy MCDM. The first step in this process is the mapping of the technical, financial, political, economic, social and technological aspects of each energy alternative with technical, financial and PEST analysis. Furthermore, with the Fuzzy MCDM method an alternative energy development selection model was made by assessing the performance of each. Based on the results of data processing shows the ranking of determining the alternative energy of the maritime sector with the first is the source of ocean current energy, the second is tidal energy, the third is wave energy and the last is Ocean Thermal Energy Conversion (OTEC).

Keywords: Alternative Energy Resources, PEST, Fuzzy MCDM

1. INTRODUCTION

Indonesia has a national jurisdiction area of ± 7.8 million km² with 2/3 of its territory is the sea of ± 5.9 million km², which covers the Indonesian Exclusive Economic Zone (EEZ) of ± 2.7 million km² and the Regional Sea, Aquatic Islands and Inland waters covering ± 3.2 million km². In addition, it has a coastline length of ± 81,000 km, and has 17,499 islands consisting of 5,698 islands named and 11,801 islands that are not / have not been named (Marsetio, 2017). The use of energy in Indonesia is still dominated by the use of non-renewable energy derived from fossils, especially petroleum and coal. Current conditions, the availability of fossil energy are running low (Azhar M. , 2018). To anticipate the limitations of fossil energy, new renewable energy is an alternative that can be developed to meet Indonesia's energy needs. This condition encourages the government to use new and renewable energy to meet energy needs. With the condition of Indonesia's marine waters 2/3 of the total area, Indonesia has the potential to overcome the problem of the fossil energy crisis by developing alternative energy resources in the maritime sector such as current, wave, tidal or ocean thermal energy.

The energy resource sector is a critical sector because it is related to the livelihoods of the people of Indonesia and affects the country's macroeconomy. The development of alternative energy resources requires enormous resources. Therefore, we need a calculation and strategic consideration to decide on a choice in the development of the maritime sector energy resources. Important factors in this development are influenced by considerations from financial, political, economic, social and technological aspects.

This research has some literature which is used as a support in conducting research such as research with the title Potential Of Sea Flow Energy As A Renewable Energy Source (Renewable Energy) On The Capalulu Holiday, North Maluku (Widjayanto, Bandono, Astika, & Tresnadi, 2020). Renewable energy production in the Łódzkie Voivodeship. The PEST analysis of the RES in the voivodeship and in Poland (Igliński, 2016). PEST Analysis of Green Jobs in Bulgaria (Harizanova & Stoyanova, 2017). Indonesia Sea Power and Regional Maritime Security Challenges (Marsetio, 2017). Determination Of Maintenance Priority Indonesian Navy Ship Depo Level Using Fuzzy MCDM (Kartiko, Suparno, Suharyo, Ahmadi, & Arica, 2018). Ocean Energy - A Clean Renewable Energy Source (Nguyen & Dong, 2019). Urban expansion induced vulnerability assessment of East Kolkata Wetland using Fuzzy MCDM method (SasankaGhosh, 2018). Analysis Financial and Development Ocean Energy in Indonesia (Estu Sri Luhur, 2013). Renewable Energy Development in Indonesia: Policy and Strategy (Arifin, 2019). The Impact of Renewable Energy on Employment in Indonesia (Elfani, 2011). Analysis of the socio-economic impact of renewable energy hybrid electricity utilization for rural community development (case study: Pantai Anyar, Yogyakarta special region, Indonesia) (Rachmawatie, Rustiadi, Fauzi, & Juanda, 2019). Establishing the Location of Naval Base Using Fuzzy MCDM and Covering Technique Methods: A Case Study (Okol S Suharyo, 2017).

Renewable Energy Developments in Indonesia (Zulkifli, Tohyama, Tohyama, & Maeda, 2019). In this research, the writer uses Fuzzy MCDM analysis to determine the potential of alternative energy resources that can be considered by the government to be developed. The first step in this process is the mapping of the political, economic, social and technological sectors of each alternative energy with a PEST analysis. Furthermore, with the application of the Fuzzy MCDM method, alternative energy development selection models are made by assessing the performance of each. The results of this study can be used as a reference for developing the potential of alternative energy resources in the maritime sector. This paper is divided into several parts, namely the second part of the Material and Methodology, the third part of the results of research and discussion and the fourth section of conclusions.

2. MATERIAL AND METHODS

2.1 Potential Alternative Sources of Energy in the Maritime Sector

In a simple, energy can be divided into two, namely renewable energy and non-renewable energy. Renewable energy is energy that utilizes renewable resources such as wind power, solar power, tides and biofuels. Non-renewable energy is energy that has a time-limited supply such as energy derived from fossils such as petroleum. Until now, petroleum is still the main source of energy in meeting domestic needs. However, the availability of energy derived from fossils is an important issue because of the depletion of petroleum reserves which can directly threaten the supply of fuel and electricity for the community. The maritime sector is very interested in this energy issue because the sea holds great potential as an alternative energy source so it is very potential to be developed. Marine energy is a term used to describe all forms of renewable energy that can be generated from the utilization of marine resources, including wave energy, tidal energy, river currents, ocean current energy, offshore wind, salinity gradient energy and thermal gradient sea energy (Busaeri, 2012). Technically, sea energy is energy that can be produced from kinetic energy of mechanical movement of sea water, potential energy from differences in sea level and sea water temperature. Marine energy can be converted into electrical energy by using technology that has developed rapidly in the international world. These energies are renewable energy because they come from sustainable natural processes (ESDM, 2012). Based on the review of various scientific reports, a number of potential sources of energy from the sea can be identified to support the electrical energy needs of coastal communities.

The energy sources are wind, ocean currents, tidal currents, ocean waves, differences in salinity, differences in sea water temperatures on the surface and on the seabed and sea plants that can be converted into biofuels. This resource is technically an alternative to conventional energy in meeting the electrical energy needs of the community which continues to increase along with population growth. For the maritime sector, marine energy provides hope especially for solving the energy problem in remote islands that have not been reached by electricity. The energies mentioned above are forms of renewable energy that can be produced from the use of marine resources. According to the results of a review of the report on the development of energy sources mentioned above (Busaeri, 2012). technically, the marine energies mentioned above can be converted from forms of kinetic energy, potential energy and the temperature difference in sea water. The potential use of sea energy that can be used technology to produce new electrical energy is limited to four types of energy, namely:

a. Sea wave electrical energy, which is converted from the kinetic power of the vertical movement of sea levels (ocean waves) through the parameters of height, length and wave period.

b. Tidal electrical energy, which is converted from the potential power of sea level differences.

c. The electrical energy of ocean currents, which is converted from the kinetic power of the mass movement of sea water that passes through the strait due to tidal cycle movements.

d. Electric energy difference in temperature of sea water or OTEC (Ocean Thermal Energy Conversion), which is converted from the power contained in the difference in temperature of sea water on the surface and in the deep sea. The potential of electricity generated from marine energy in Indonesia has been widely studied and calculated by various parties, one of which is a calculation issued by the Indonesian Ocean Energy Association - ASELI (Estu Sri Luhur, 2013). These potentials are grouped into theoretical potentials, technical potentials, and practical potentials for types of marine energy conversion technologies namely tidal currents, ocean waves and energy temperature differences in the ocean as shown in Figure 1.

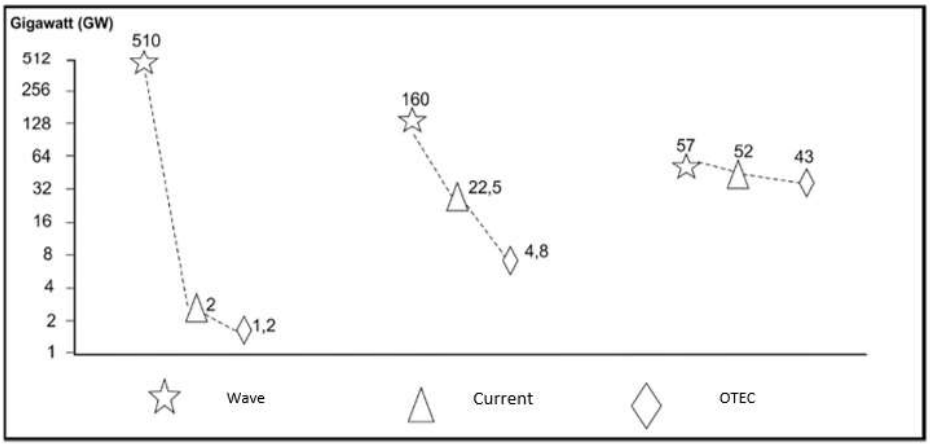

Figure 1. Potential Alternative Sources of Energy in the Maritime Sector

As shown in Figure 1, the maritime resource that has the most opportunity to be developed is the sea water temperature difference (OTEC) because its practical potential is highest compared to other marine energy sources. Based on data released by P3GL and ESDM, the potential of OTEC in Indonesian waters reaches 2.5 x 1023 Joules. With an efficiency of sea heat energy conversion of 3%, it can produce around 240,000 MW of power (Estu Sri Luhur, 2013). If seen from the natural conditions and geographical location of Indonesia which has many islands and straits, sea energy that has prospects to be developed is ocean current energy. Furthermore, the position of the Indonesian sea which lies between the Pacific Ocean and the Indian Ocean causes currents to move at high speeds. In addition to the large current strength, the Indonesian sea is also very rich in current energy sources tides which are expected to produce tidal current energy of 4.8 GW (Estu Sri Luhur, 2013).

The four potential types of marine energy along with generating capacity, potential locations and electricity needs are shown in Figure 2.

DETAIL	RESOURCE ENERGY			
	WAVE	CURRENT	TIDAL	OTEC
Potency of Energy	1.200 MW	4.800 MW	6.000 MW	220.000 MW
Plant Capacity	0,5 - 2 MW	10 - 200 MW	10 - 200 MW	5 - 100 MW
Location	Small Island and Littoral Area	East Area	Bali - NTT	Small Island and Littoral Area
Electrical Requirement	100 kW - 1,5 mW	> 10 MW	1-20 MW	> 5 MW

Figure 2. Maritime Sector Potential and Energy Types

Ocean energy from waves, currents, and differences in seawater temperature (OTEC) have the potential to produce electrical energy. Ocean wave energy is an energy that is produced from the movement of ocean waves towards the mainland and vice versa. Indonesia's vast sea area has great potential in producing electricity, but its utilization is not yet optimal. The advantage of this power plant is that it does not cause pollution because the driving source uses renewable natural energy, even though the installation and maintenance costs are expensive.

To realize this, a deeper study needs to be done. Measurement and mapping of potential ocean currents have been carried out by the Center for Marine Geology Study and Development (P3GL), while the energy potential from temperature differences is still in the process of being tested for eligibility by BPPT and Dharma Persada University. Energy difference in seawater temperature is the development of energy for the medium and long term by using OTEC technology which functions as a multipurpose such as for electricity, aquaculture businesses, a supply of fresh and mineral water, studies, and tourism (Estu Sri Luhur, 2013). OTEC power plants are used by utilizing the difference between surface water temperature and temperature in the sea so that it can produce electricity that can be enjoyed by households and businesses in the community economy.

2.2 PEST Analysis Method

PEST analysis is an analysis of business external environmental factors that include the political, economic, social and technological fields (Ward & Peppard, 2002). The PEST analysis model is carried out by collecting and describing information about external factors that have the potential to affect the business. PEST is a useful way or tool to summarize the external environment in business operations. PEST is used to assess the market of a business unit or organizational unit. The PEST analysis direction is a framework for assessing a situation, and assessing the strategy or position, the direction of the company, the marketing plan or idea. Where this analysis can be taken a new opportunity or threat to the company.

2.2.1 Factor PEST Analysis

These factors include the fields of Political, Economic, Social, Technological, Legal, and Environment.

a. Political

Political factors include the applicable law, government policies, and formal or informal rules in the corporate environment (Example: tax policies and local regulations).

b. Economic

Economic factors include all factors that affect the purchasing power of customers and affect the business climate of a company (Example: exchange rate standards, interest rates, and economic growth).

c. Social

Social factors include all factors that can affect the needs of customers and affect the size of the existing market share (Example: level of public education, level of population growth, social and work environment conditions).

d. Technological

Technological factors include all things that can help in facing business challenges and support the efficiency of a company's business processes (Example: discoveries and developments, costs and uses of technology, changes in science, and the impact of technological changes).

2.2.2. Benefits of PEST Analysis

PEST analysis has several benefits including:

a. It is a very useful tool in understanding the overall picture of the environment in which the business operates and the opportunities and threats that surround it. So that opportunities can be taken and minimize risks or threats.

b. It is a tool to understand all risks associated with the growth or decline in business, and also the position, potential and strategic direction for business and organizations.

c. It is a generic orientation tool to find out whether an organization in an environmental context with everything happening out there at the same time influences the organization.

2.2.3 Purpose of PEST Analysis

PEST analysis is a simple and effective tool for identifying which external forces might affect your business. This power needs to be identified because it can create an opportunity or a threat. Therefore the purpose of doing PEST is to:

a. Find out current external factors that can affect the organization

b. Identify external factors that might change in the future

c. Take advantage of opportunities or avoid threats from external factors

2.2.4 Results of PEST Analysis

The result of the PEST Analysis is an understanding of the whole picture of the company. This analysis can also be used to assess new market potential. The more negative forces that affect the market, the more difficult it is to do business in that market. Difficulties encountered in these markets can reduce the company's profit potential and limit the company's business movements in the market.

2.3 Fuzzy MCDM Analysis Method

2.3.1 Concept of Fuzzy Theory

The concept of fuzzy theory was initiated by Lotfi A. Zadeh in 1965 with his seminal paper "Fuzzy Sets" (Zadeh, 1974). Before working with fuzzy theory, Zadeh used control theory. He developed the concept of "state", which is the basic form of modern control theory. With fuzzy theory shows that all theories can be used as a basic concept of fuzzy or continues membership function. Broadly speaking, fuzzy theory can be classified into five main areas, namely:

a. Fuzzy Mathematics, where the concept of classical mathematics is expanded by changing the classical set with the fuzzy set;
b. Fuzzy Logic & Artificial Intelligence, where estimates for classical logic are introduced and expert systems are developed based on fuzzy information and thought estimates;
c. Fuzzy System, which includes fuzzy control and fuzzy approaches with signal processing and communication;
d. Uncertainty and Information, where differences from uncertainty are analyzed;
e. Fuzzy Decision Making, where consideration exists for optimization problems.

2.3.2 Membership Functions

The membership function is a curve that shows the mapping of data input points into the value of membership (often also called the degree of membership) which has an interval between 0 to 1. One way that can be used to obtain membership values is through function approach. There are several functions that can be used:

a. Linear Represeniation

In linear representations, mapping the input to the degree of membership is drawn as a straight line. This form is the simplest and is a good choice for approaching a concept that is less clear. There are 2 states of linear fuzzy sets, the first is the increase in the set starts at the domain value that has a zero membership degree [0] moves right to the domain value that has higher degree of membership.

Membership Function:

$$\mu[x] = \begin{cases} 0; & x \le a \\ (x-a)/(b-a); & a \le x \le b \\ 1; & x \ge b \end{cases}$$

Second, it is the opposite of the first. The straight line starts from the value of the domain with the highest degree of membership on the left, then moves down to the value of the domain that has a lower membership.

Membership Function:

$$\mu[x] = \begin{cases} (b-x)/(b-a); & a \le x \le b \\ 0; & x \ge b \end{cases}$$

b. Representation of Triangle Curves

A triangle curve is basically a combination of two lines (linear).

Membership function:

$$\mu[x] = \begin{cases} 0; & x \le a \ atau \ x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(c-b); & b \le x \le c \end{cases}$$

c. Representation of the Trapezoid Curve

Trapezoid curves are basically like triangles, it's just that there's a point that has a membership value of 1.

Membership function:

$$\mu[x] = \begin{cases} 0; & x \le a \text{ atau } x \ge d \\ (x-a)/(b-a); & a \le x \le b \\ 1; & b \le x \le c \\ (d-x)/(d-c); & c \le x \le d \end{cases}$$

2.3.3 Triangular Fuzzy Number (TFN)

In TFN, every single value (crisp) has a membership function consisting of three values, each of which represents the bottom value, middle value and top value.

A = (a1, a2, a3)

The membership function for TFN in the picture above is as follows:

$$\mu[x] = 0 \quad \text{for } x < a_1$$

$$= \frac{x - a_1}{a_2 - a_1} \quad \text{for } a_1 < x < a_2$$

$$= \frac{a_3 - x}{a_3 - a_2} \quad \text{for } a_2 < x < a_3$$

2.3.4 Defuzzification Value

Defuzzification is a process of conversion and a quantity of fuzzy into a definite quantity, where the output and the fuzzy process can be a combination of logic from two or more fuzzy membership functions that are defined according to the universe of speech. Defuzzy input and process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. There are several methods of defuzzification commonly used are as follows:

a. Centroid Method (Center of Gravity / COG)

In this method, a crisp solution is obtained by taking the center point (z) of the fuzzy region.

b. Bisector Method In this method, crisp solution is obtained by taking a value in the fuzzy domain that has a membership value of half of the total membership value in the fuzzy area.

c. Mean of Maximum (MOM) Method

In this method crisp solution is obtained by taking the average value of the domain that has a maximum membership value.

d. Largest of Maximum (LUM) Method

In this method crisp solution is obtained by taking the largest value from a domain that has a maximum membership value.

e. The Smallest Method of Maximun (SOM)

In this method, crisp solution is obtained by taking the smallest value from the domain that has the maximum membership value.

2.3.5 Linguistic Variables

Linguistic variable is a variable that has a description in the form of fuzzy numbers and more generally a word that is represented by a fuzzy set. For example, descriptions of linguistic variables for temperature can be LOW, MEDIUM and HIGH where the description is expressed as a fuzzy value. Like algebraic variables that use numbers as their values while linguistic variables use words or sentences as their values that form a set called "terms", each value of the "terms" is a fuzzy variable that is defined based on the base variable. Whereas the base variable defines the universe of speech for all fuzzy variables in the set of "terms".

2.3.5 Multiple Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is a decision-making method consisting of theories, processes, and analytical methods for decision making that involve uncertainty, dynamics, and multi-criteria aspects of decision. Multi-Criteria Decision Making (MCDM) is the terminology used in solving problems where the MCDM approach is expected to get the best alternative.

2.4 Flow Chart Mindset

The mindset of completing this research follows the system thinking of the research flow shown in Figure 3:

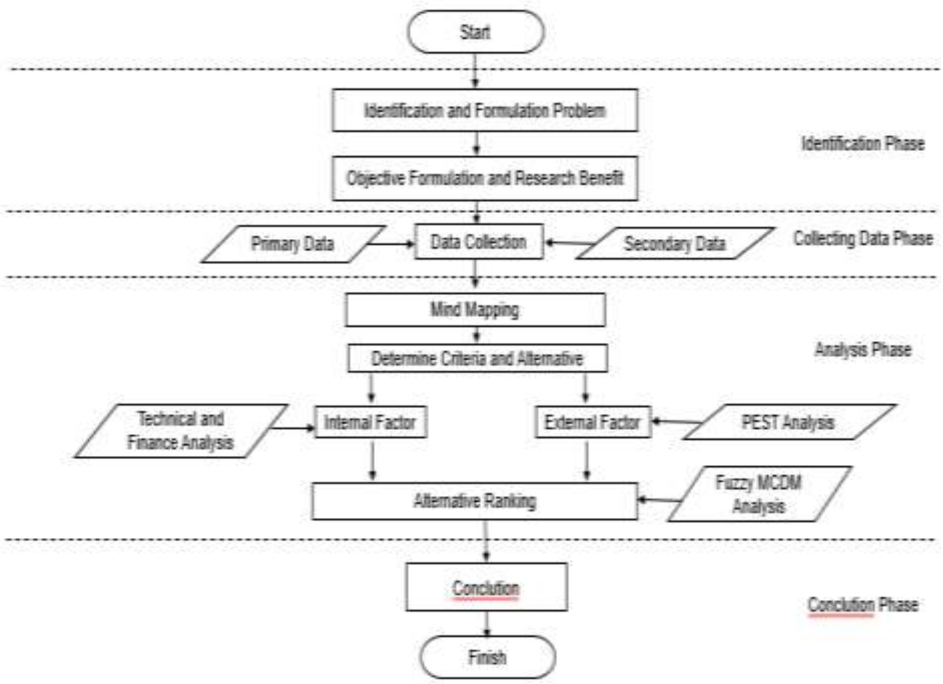

Figure 3. Flow Chart Diagram

In this study, it is divided into 4 (four) main phases, namely the identification phase, the data collection phase, the analysis phase and the conclusion drawing phase. In the first phase of identification, identification of problems and research objectives is carried out. In the second phase of data collection, the primary data were collected from interviews and questionnaires, secondary data were obtained from literature studies in the form of books and journals. In the third phase, namely analysis. The first analysis is to make a mind mapping that is writing everything that is in the mind in the form of problems, objectives, aspects, step and methods in research (Figure 4).

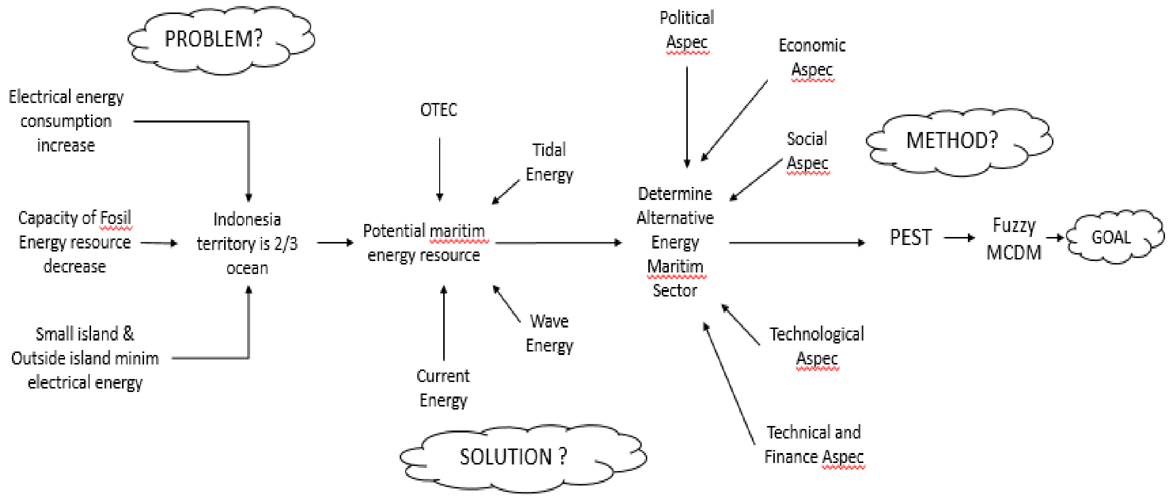

Figure 4. Mind Map

The method used for this research is Fuzzy MCDM to get the alternative value offered. In the Fuzzy MCDM method to determine alternative values, previously it must go through stages beginning with determining the criteria and alternative research. The criteria in this study can be divided into two, namely the criteria of internal factors and criteria of external factors. The internal factors criteria in the form of quantitative data used technical analysis and financial analysis.

For the external factors criteria in the form of qualitative data, PEST analysis is used by mapping the political, economic, social and technological sectors in each alternative energy. Furthermore, from the existing criteria and alternatives, Fuzzy MCDM analysis is done by weighting and ranking to get the ranking value of each alternative. The ranking value obtained is used to determine the potential of alternative energy resources which can be considered by the government to be developed.

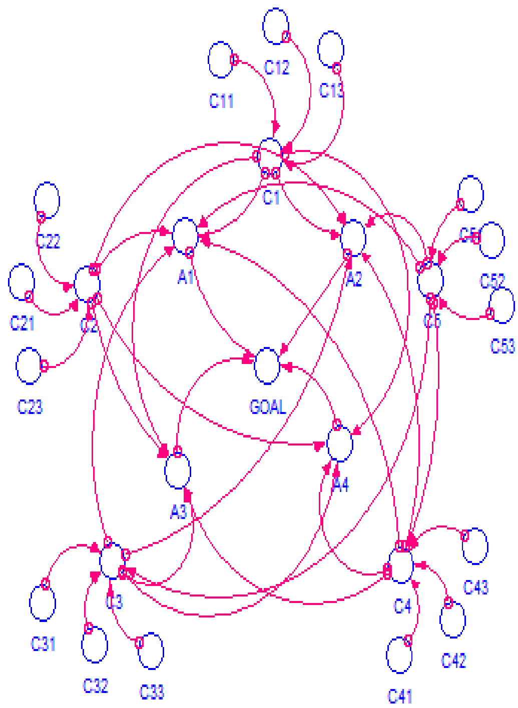

Figure 5. Framework relationships between variables using influence diagrams

In figure 5 to achieve the goal, namely the selection of alternative energy resources, maritime potential A_1, A_2, A_3, and A_4 it is understood that each alternative is influenced by the criteria of C_1, C_2, C_3, C_4, and C_5. Each criterion is influenced by sub-criteria $C_{1.1}$, $C_{1.2}$, $C_{1.3}$, $C_{2.1}$, $C_{2.2}$, $C_{2.3}$, $C_{3.1}$, $C_{3.2}$, $C_{3.3}$, $C_{4.1}$, $C_{4.2}$, $C_{4.2}$, $C_{5.1}$, $C_{5.2}$, and $C_{5.3}$.

Criteria can be determined by technical analysis and financial analysis for internal factors (C_1), and PEST analysis (Politics, Economy, Social, and Technology) for external factors (C_2, C_3, C_4, and C_5). Criteria for internal factors, technical and financial aspects can be break down as follows:
Efficiency of electricity tariffs ($C_{1.1}$), Efficiency of project development costs ($C_{1.2}$), and Age of power plants ($C_{1.3}$). Criteria for external factors of political, economic, social and technological aspects can be broken down as follows: Government Policy ($C_{2.1}$), Legislation ($C_{2.2}$), Political Stability ($C_{2.3}$), Inflation Rate ($C_{3.1}$), Interest Rates ($C_{3.2}$), Economic Stability ($C_{3.3}$), Culture Of Surrounding Peoples ($C_{4.1}$), Attitudes Of Surrounding Peoples ($C_{4.2}$), Community Mindset ($C_{4.3}$), Global Trends Technology ($C_{5.1}$), Technology Mastery ($C_{5.2}$), Availability Of Supporting Technology In The Region ($C_{5.3}$), Furthermore, after the criterion variables have been obtained, data grouping is then carried out an analysis of determining the alternative energy resources of the maritime sector with fuzzy MCDM analysis with the following steps:

a. Determine the weighting of qualitative criteria assessments
b. Determine the rating of each alternative energy
c. Determine Fuzzy Numbers
d. Determine the aggregate weights for each qualitative criteria
e. Calculate the preference value of each alternative-qualitative
f. Calculate fuzzy index values for each alternative-qualitative
g. Defuzzification
h. Calculate the ranking value of each alternative-qualitative
i. Calculate the ranking value of each alternative-quantitative
j. Get the total ranking value of each alternative energy
k. Choose the best alternative based on the ranking value

3. RESULT AND DISCUSSION

3.1 Processing Data and Analysis

Criteria data as in the methodology, especially qualitative data is processed by the Fuzzy MCDM method. To obtain qualitative data in the study carried out interviews and questionnaires to several expert stakeholders. For quantitative data obtained from secondary data retrieval through journal reviews based on technical and financial analysis that has been done previously. Several steps of Fuzzy MCDM analysis are carried out to get the final weighting/ranking results for each alternative (tables 3.1 to table 3.9).

Table 1. Weight of **Aggregate** Qualitative Criteria

NO	CRITERIA	AVERAGE WEIGHT		
		ct	at	bt
1	GOVERNMENT POLICY	7,462	9,396	10
2	LEGISLATION	6,125	7,869	9,615
3	POLITICAL STABILITY	7,462	9,396	10
4	CULTURE OF SURROUNDING PEOPLES	3,500	6,542	8,358
5	ATTITUDES OF SURROUNDING PEOPLES	3,500	6,542	8,358
6	COMMUNITY MINDSET	6,569	8,549	9,615
7	GLOBAL TRENDS TECHNOLOGY	5,750	7,462	9,396
8	TECHNOLOGY MASTERY	3,250	6,671	8,500
9	AVAILABILITY OF SUPPORTING TECHNOLOGY IN THE REGION	7,462	9,396	10
10	ECONOMIC STABILITY	6,643	8,309	9,781

Table 2. Weight of **Aggregate** Qualitative Alternative

NO	CRITERIA	ALT	AVERAGE			NO	CRITERIA	ALT	AVERAGE		
			qit	oit	pit				qit	oit	pit
1	GOVERNMENT POLICY	1	3,464	6,687	8,265	6	COMMUNITY MINDSET	1	3,464	6,737	8,299
		2	3,859	7,091	8,549			2	3,464	6,737	8,299
		3	6,341	7,944	9,313			3	5,897	7,519	9,146
		4	1,964	4,827	6,002			4	3,464	6,737	8,299
2	LEGISLATION	1	2,250	6,292	7,874	7	GLOBAL TRENDS TECHNOLOGY	1	3,464	6,687	8,265
		2	4,679	7,131	8,690			2	3,464	6,687	8,265
		3	2,219	6,286	7,974			3	5,897	7,519	9,146
		4	3,464	6,737	8,299			4	5,897	7,519	9,146
3	POLITICAL STABILITY	1	6,687	8,265	9,646	8	TECHNOLOGY MASTERY	1	3,429	6,735	8,336
		2	2,658	6,766	8,111			2	4,679	7,131	8,690
		3	5,127	7,550	8,921			3	3,464	6,737	8,299
		4	3,873	7,160	8,502			4	4,679	7,131	8,690
4	CULTURE OF SURROUNDING PEOPLES	1	5,074	7,485	8,940	9	AVAILABILITY OF SUPPORTING TECHNOLOGY IN THE REGION	1	3,429	6,735	8,336
		2	3,859	7,041	8,515			2	5,073	7,522	8,940
		3	5,468	7,877	9,190			3	4,683	7,125	8,754
		4	3,429	6,735	8,336			4	3,464	6,737	8,299
5	ATTITUDES OF SURROUNDING PEOPLES	1	3,859	7,041	8,515	10	ECONOMIC STABILITY	1	4,647	7,124	8,791
		2	3,464	6,687	8,265			2	1	4,433	5,611
		3	5,074	7,485	8,940			3	6,291	7,911	9,396
		4	3,464	6,687	8,265			4	5,041	7,515	9,041

Table 3. Defuzzification

ALT	INDEX								
	Yi	Qi	Zi	Hi1	Ti1	Hi2	Ui1	Ti2	Ui2
1	23,11	55,99	79,84	2,89	4,53	6,19	2,09	26,17	-25,94
2	20,53	53,87	76,60	2,40	5,52	6,15	2,01	26,46	-24,75
3	29,67	59,35	83,44	2,90	4,18	6,36	2,05	24,27	-26,14
4	22,01	54,04	77,46	2,93	4,35	6,11	2,09	25,48	-25,50

Table 4. Evaluation index value

NO	CRITERIA	DEFUZZIFICATION WEIGHT	DEFUZZIFICATION ALTERNATIVE			
			ALT 1	ALT 2	ALT 3	ALT 4
1	GOVERNMENT POLICY	8,953	6,139	6,500	7,866	4,265
2	LEGISLATION	7,869	5,472	6,833	5,493	6,167
3	POLITICAL STABILITY	8,953	8,199	5,845	7,199	6,512
4	CULTURE OF SURROUNDING PEOPLES	6,133	7,167	6,472	7,512	6,167
5	ATTITUDES OF SURROUNDING PEOPLES	6,133	6,472	6,139	7,167	6,139
6	COMMUNITY MINDSET	8,244	6,167	6,167	7,521	6,167
7	GLOBAL TRENDS TECHNOLOGY	7,536	6,139	6,139	7,521	7,521
8	TECHNOLOGY MASTERY	6,140	6,167	6,833	6,167	6,833
9	AVAILABILITY OF SUPPORTING TECHNOLOGY IN THE REGION	8,953	6,167	7,178	6,854	6,167
10	ECONOMIC STABILITY	8,244	6,854	3,681	7,866	7,199

Table 5. Alternative Performance Value (Gi)

ALT	Gi
ALT 1	50,176
ALT 2	47,531
ALT 3	55,088
ALT 4	48,451

Table 6. Index Utility Value (fGi)

ALT	fGi
ALT 1	2,556
ALT 2	2,662
ALT 3	2,757
ALT 4	2,512

Table 7. Weight of Qualitative Alternative (Sti)

ALT	Sti
ALT 1	0,244
ALT 2	0,254
ALT 3	0,263
ALT 4	0,240

Table 8. Weight of Quantative Alternative (Oti)

ALT	Oti
ALT 1	0,230
ALT 2	0,294
ALT 3	0,274
ALT 4	0,202

Table 3.9 Final Process of Alternative Rank

ALTERNATIVE ENERGY	Fti	RANK
OCEAN WAVE	0,237	III
OCEAN CURRENT	0,274	I
TIDAL	0,268	II
OTEC	0,221	IV

Based on calculations and data processing using the MCDM fuzzy analysis method, it is found that Alternative Energy Resources for Marine Currents have a higher priority or ranking to develop. The ranking priority of data processing results using the Fuzzy MCDM method is as follows:

a. Ocean Current Energy weights: 0.274
b. Tidal Energy with a weight: 0.268
c. Ocean Wave Energy with a weight: 0.237
d. OTEC (Ocean Thermal Energy Conversion) with a weight: 0.221.

4. CONCLUTION

Based on research, the fuzzy MCDM (Multi Criteria Decision Making) method combined using the PEST analysis enables it to be used to determine the potential alternative energy resources of the maritime sector that needs to be developed. The results of the study indicate that ocean current energy resources have the highest potential to be developed. Furthermore, the results of this study can be used for consideration by the government in determining policies of energy stability sector where the current state of the energy crisis is starting to occur because fossil energy capacity continues to run low.

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