Strategic Management For Determination Of Ship Facilities Location Based On Operational And Environmental Factors

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STRATEGIC MANAGEMENT FOR DETERMINATION OF SHIP FACILITIES LOCATION BASED ON OPERATIONAL AND ENVIRONMENTAL FACTORS

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ABSTRACT

To support the presence of elements of naval vessels in the North Natuna Sea, it is necessary to have supporting facilities for Ship Maintenance and Repair Facilities that function as logistical support, especially ship repair and maintenance. Mileage The nearest ship maintenance and repair facility from the North Natuna Sea is the Mentigi City area which is approximately 510 Nautical miles. This becomes an obstacle if the presence of the shipping element in the North Natuna sea operation area requires logistical support. Because the distance is too far to carry out ship maintenance and repairs, it is deemed necessary to have another location for ship maintenance and repair facilities to support ship operations in the North Natuna waters. In selecting the location for ship maintenance and repair facilities, several factors must be considered, especially the Environmental Requirements & Operational requirements. The method that can be used to solve these problems is the Fuzzy Multi-Criteria Decision Making (Fuzzy MCDM) method. The Environmental Requirement factors consist of the Earthquake Threat, the distance of the operating field, the distance to the city center, and the hydrographic and oceanographic factors (sea depth, tides, and ocean current speed). While the Operational Requirement factors are influences on other countries, threats from other countries and community conflicts, transportation access to public ports and airports, supporting facilities (water facilities, communication facilities, electricity facilities, transportation facilities, and sea lanes), and operational costs. For alternative locations, ship maintenance and repair facilities consist of the Pontianak area (DP), the Ranai area (DR), and the Tarempa area (DT). From the three alternative locations, the best alternative for the location of ship maintenance and repair facilities is Ranai Region (DR) with the highest-ranking value of 0.403, then Pontianak Region (DP) with a value of 0.302, and Tarempa Region (DT) with a value of 0.295.

Keywords: *Location Determination, Fuzzy MCDM, Environmental Requirements, Operational Requirements*

1. INTRODUCTION

Ship maintenance and repair facilities are part of the Navy which has the duty and responsibility to provide material maintenance services, ship repairs, and the manufacture of PC class ships (Patrol Craft) whose ship buildings are made of fiber or plate iron. The existence of ship maintenance and repair facilities is very much needed to support the maintenance and repair of these ships. A main base of the Indonesian Navy must have Class A ship maintenance and repair facilities whose capabilities are capable of carrying out maintenance and repairs up to the depot level for all types of ships, both shipbuilding, ship machinery, rental boat electricity, and ship weaponry [17].

Therefore, to support the readiness of ships in the North Natuna Sea, Indonesia is required for ship maintenance and repair facilities that function as logistical support, especially ship repair and maintenance [16]. According to data from the Ship Maintenance and Repair Service, ships that are damaged and cannot be repaired organically must return to the nearest ship maintenance and repair facility for inspection and repair, for example, the case of a fuel carrier ship carrying liquid logistics to support a ship carrying out Operations in the North Natuna Sea had to return to Jakarta due to engine failure, this, of course, had an impact on the technical readiness of other ship operations in carrying out operations because the distribution of liquid logistics ships could not be accommodated by the fuel carrier ship.

Based on Figure 1, the naval operation area consists of 3 Fleet Zones spread from west to east of the Indonesian archipelago. Based on

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current facts and conditions, the closest ship maintenance and repair facility from the North Natuna Sea in Indonesia is located in the Indonesian Mentigi city area which is approximately 510 Nautical miles [15]. This becomes an obstacle if the presence of ships in the North Natuna sea operation area requires repair support in the Fleet Zone 1 operation area. Due to the distance of the ship maintenance and repair facilities from the far North Natuna waters to carry out maintenance and repairs, it is deemed necessary to have another facility location. maintenance and repair of ships to support the operations of ship elements in the North Natuna waters so that the operations of ship elements can be carried out properly. These facts are the basis for the need to support the importance of selecting ship maintenance and repair facilities in the operational area around the Natuna Sea north of Indonesia.

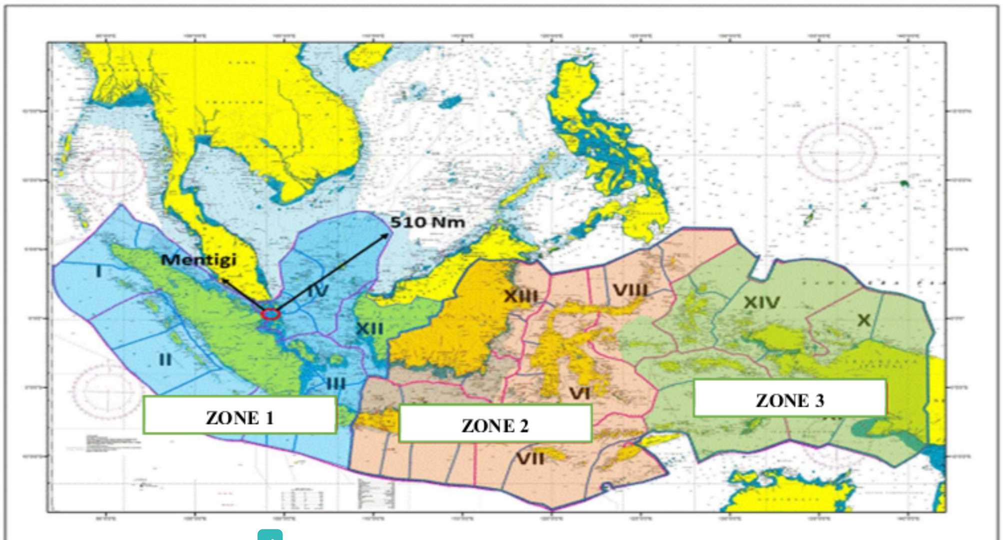

Figure 1. Distance of ship maintenance and repair facilities in Mentigi to the Fleet Zone 1 operation area (510 Nautical miles)

This study aims to choose the best alternative location in determining the location of ship maintenance and repair facilities which will later be used to support the operation of ships and other main defense system tools in the North Natuna sea waters. Furthermore, in the selection of an alternative location, the best/Mutually Exclusive location alternative will be selected, so that the chosen alternative can provide maximum benefits for achieving the vision and mission of the operation, namely securing the Indonesian maritime territory.

The alternative locations for ship maintenance and repair facilities located in the North Natuna waters include the Pontianak area (DP) on the island of Borneo, the Ranai area (DR) in the Natuna Islands, and the Tarempa area (DT) in the Anambas Islands, which are based on the distance from the base. on the ability of the coverage area of ships operating in the North Natuna Sea, the ability of the base, and access to transportation and environmental factors. The process of determining this location considers qualitative criteria, namely environmental factors, security, transportation access, and supporting factors for ship maintenance and repair facilities, and quantitative criteria consider the distance to the operating area, distance to the city center, hydrographic conditions, and factors of earthquake natural disasters. In this study, to determine the class or type of ship maintenance and repair facilities used is based on data on the highest wave heights in 2018, 2019, 2020 in the North Natuna Sea and the criteria for what types of ships can carry out operations in North Natuna seas so that the selected ship maintenance and repair facilities can carry out the main task.

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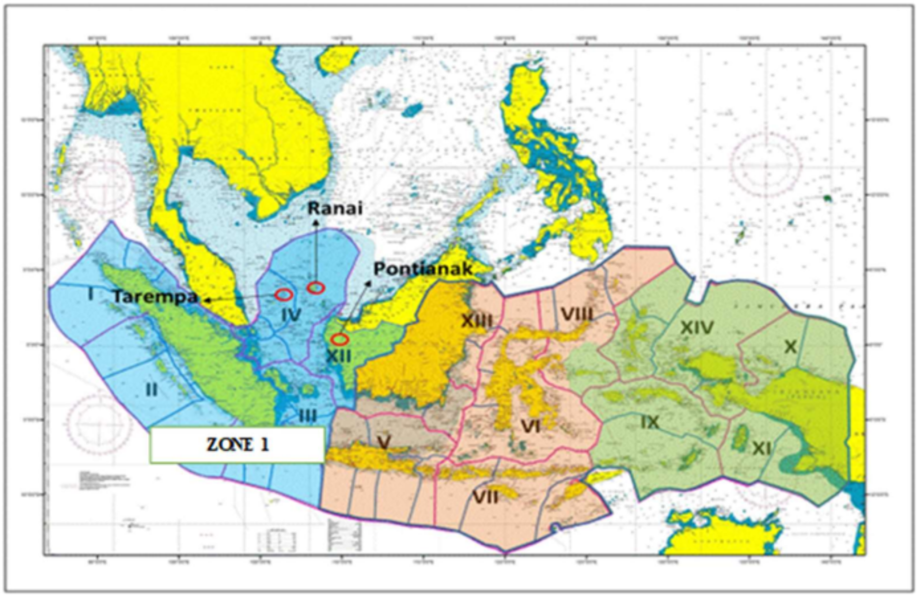

Figure 2. Alternative locations for ship maintenance and repair facilities (Pontianak, Ranai, Tarempa)

Based on Figure 2, the alternative locations for ship maintenance and repair facilities located in the North Natuna waters according to Figure 2 are (1) Pontianak (DP) Kalimantan Island, (2) Ranai (DR) Natuna Islands, and (3) The Tarempa (DT) area of the Anambas Islands.

This study aims to solve the problem by using the Fuzzy MCDM method as a model that is applied to obtain a priority value in determining the location of ship maintenance and repair facilities, which will later be used to support ship operations in the waters of the North Natuna Sea by taking into account several criteria, including Environmental, Operational and Environmental Requirements criteria. In addition, the Fuzzy MCDM method will overcome multi-criteria problems in the process of determining the location of ship maintenance and repair facilities, as well as overcoming the possibility of qualitative data or containing elements of uncertainty [3].

Based on the background that has been presented, the problem statement or problem that can be raised in this study is how to determine the location of maintenance and repair facilities to support the Navy's operations in the North Natuna Sea, Indonesia. Based on the problem statement, several Research Questions in this study are (1) How to identify the criteria for ship maintenance and repair facilities in North Natuna seas based on Environmental Requirements and Operational Requirements factors, (2) How to determine alternative locations for maintenance and repair facilities the best ship repairs to support ship operations in the North Natuna waters.

The detailed objectives of this research are (1) to formulate criteria and modeling with the Fuzzy Multi-Criteria Decision Making (Fuzzy MCDM) approach to obtain the location of ship maintenance and repair facilities based on predetermined criteria, and (2) determine alternative locations for maintenance and repair facilities. the best ship from the available alternatives around the North Natuna marine area based on criteria using the Fuzzy MCDM method.

2. MATERIALS AND METHODS

2.1. Selection of Locations for ship maintenance and repair facilities

Research on site selection has been carried out by previous researchers including the selection of the location of the Mentawai naval base with the Borda and promethee method approach by [1] with the results of the first order location being in Semebai Bay. Furthermore, [14] in his research entitled The naval harbors priority development using zero-one matrix decision variable (ZOMDV) and fuzzy MCDM methods, and [15] in his research entitled Establishing the location of the naval base using fuzzy MCDM and covering technique methods. This shows that the Fuzzy MCDM method has been widely used for the selection of strategic locations. Likewise, this research will solve the problem of choosing the location of ship maintenance and repair facilities optimally in the form of a model that will be used for a decision support system.

Decision support systems that are often used today usually use quantitative data so that they can handle structured problems with definite data. However, in reality on the ground, it is not uncommon to find data that is qualitative in nature and contains an element of uncertainty. Uncertainty data like this is not appropriate to be used as a reference in decision-making. So to overcome this problem can be used the concept of fuzzy logic. This is because the concept of fuzzy logic has tolerance for inaccurate or uncertain data. In addition, in fuzzy logic the data obtained in the field can be classified into qualitative data [8].

The fuzzy concept itself has been widely used as a model to build a decision support system, one of which is Fuzzy Multi-Criteria Decision Making (FMCDM). In several studies it is stated that MCDM is a method that refers to the process of screening, prioritizing, ranking, or choosing a set of alternatives. MCDM is very appropriate to be implemented in multi-criteria cases with all alternatives having criterion weights in nominal form [4]. However, for the problem of determining the location of ship maintenance and repair facilities, not all alternatives have nominal weight criteria, for example, security factors, transportation access, supporting facilities, etc. So to overcome this, the Fuzzy concept is used for Multi-Criteria Decision Making and is called Fuzzy MCDM which is considered very appropriate for the problem of criteria weights that are uncertain in research [9].

2.2. Fuzzy MCDM Methods

Fuzzy Logic Concept

The concept of fuzzy theory was initiated by [20] [21] with his paper "Fuzzy sets and their applications to cognitive and decision processes". With fuzzy theory, it can be shown that all theories can be used as the basic concept of fuzzy or continuous membership function. Fuzzy logic is an appropriate way to map an input space into an output space. The starting point of the modern concept of uncertainty is a paper made by [20] [21], in which Zadeh introduced a theory that has objects from fuzzy sets that have imprecise boundaries and membership in fuzzy sets, and not in true logic form. true) or false (false), but expressed in degrees (degrees). This concept is called fuzziness. The fuzzy approach has advantages in results related to human cognitive properties, especially in situations involving concept formation, pattern recognition, and decision making in an uncertain or unclear environment. uncertain [10].

Multiple Criteria Decision Making (MCDM)

MCDM is a sub-discipline of operations research that involves the analysis of a limited number of alternatives, which is described in terms of evaluating criteria based on the values and preferences of decision-makers [7]. The MCDM method is a useful tool in many problems both economics, manufacturing, material selection, military, construction, etc. It specifically plays an important role in the fields of investment decisions, project evaluation, evaluation of economic benefits, staff appraisal, and so on [6].

In MCDM the use of conventional optimization methods is generally limited to only one selection criteria, where the selection taken is the choice that best meets the objective function. However, the problems faced, especially those of a more practical nature, are not that simple. Other advantages of MCDM can include: making decisions more transparent to others, providing a means of structuring problems and working through information, providing a focus for discussion, and helping people better understand problems from their own and others' perspectives. MCDM has been used at all levels of decision-making related to agriculture and the environment, from farm-level decisions to agricultural policy decisions. Environmental, economic, social, and cultural considerations can be traded without changing all measures to the same unit [5].

MCDM provides an alternative to utilize objective and subjective considerations as a basis for decision-making [12]. There are two groups in MCDM, namely the decision-making group based on the selected attributes or often known as Multiple Attribute Decision Making (MADM), and the group in which the selection is based on the synthesis of selected attributes or often referred to as Multi-Objective Decision Making (MODM). Multiple Objective Decision Making (MODM) uses an optimization approach, so to solve it, it is necessary to first find a mathematical

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model of the problem to be solved. Then it is maximized or minimized according to the mathematical model that has been obtained [19]. Meanwhile, Multiple Attribute Decision Making (MADM) uses a selection approach by first determining the quantitative and qualitative attributes of the components to be selected.

2.3. Research Methods

Based on the focus and objectives of the research, the research approach used in this decision-making research is to use a quantitative approach, because this research is presented with numbers [13]. This is following the opinion of [2] who stated that quantitative research is a research approach that is required to reveal numbers, starting from data collection, interpretation of the data, and the appearance of the results. This study describes the stages of data collection, including tests, questionnaires, interviews, observations, diaries, journals, and so on. In the quantitative method, closed tests and questionnaires are used to collect, analyze and interpret data [11].

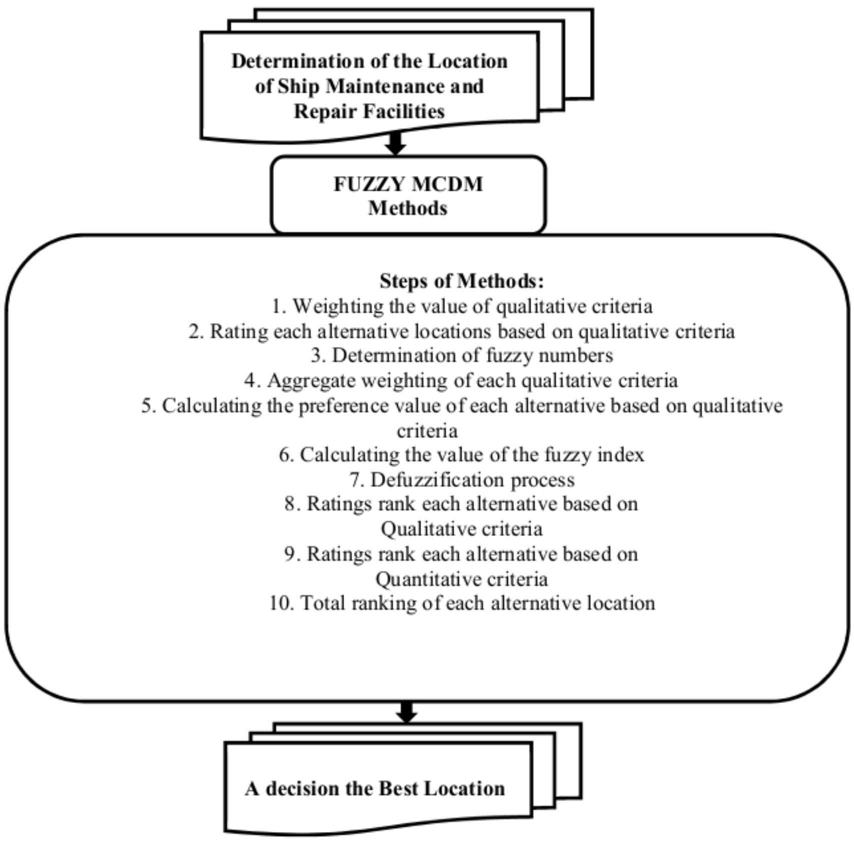

Figure 3. Research Flowchart

The algorithm of Fuzzy MCDM developed by [18], as the development of a fuzzy algorithm, is introduced by [19] [20] by combining the method of Multiple Criteria Decision Making (MCDM), as a method of decision making based on analytical methods that involve uncertainty, subjectivity from the aspect of multi-criteria and decisions. For more details, the sequence of data processing using the fuzzy MCDM algorithm above is as follows:

a. Weighting the results to diagram level assessment qualitative criteria to get the value of the weight aggregates.

b. Diagraming the results of the assessment or preference rating for each alternative based on qualitative criteria that exist.

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c. Determining the mean fuzzy numbers, by adding the value that appears in each level scale linguistic and then dividing the sum by the number of criteria that value into the inside of the linguistic assessment level. The mathematical notation is as follows:

$$a_t = \frac{\sum_{i=1}^{k} \sum_j T_{ij}}{\sum_{i=1}^{k} n_{ij}}$$

a_t = median fuzzy numbers to levels
T= the level of assessment is very low, low, medium, high, and very high.
n= number of scale linguistic scale factor for an alternative to T-1 of the i-th factor
T_{ij} = numerical value of the scale for an alternative to linguistic T-1 of the j-th factor.

d. Determining the value of the lower limit and upper limit value fuzzy numbers, where the lower limit value (ct = b (i - 1)) is equal to the mean level down, while the upper limit value (bt = b (i - 1)) is the same as the mean level on it.

e. Determining the aggregate weight of each qualitative criteria, as used in this study linguistic assessment form that has had the definition of triangular fuzzy numbers, then the aggregation process is done by searching for the aggregate value of the respective lower limit value (ct), the mean (at) and the upper limit value (bt), which can be modeled as follows:

$$c_t = \frac{\sum_{j=1}^{n} c_{tj}}{n} \qquad a_t = \frac{\sum_{j=1}^{n} a_{tj}}{n} \qquad b_t = \frac{\sum_{j=1}^{n} b_{tj}}{n}$$

c_{tj} = lower limit value of qualitative criteria to-t by decision-makers to-j
a_{tj} = median qualitative criteria to-t by decision-makers to-j
b_{tj} = the value of the upper limit to the qualitative criteria-t by decision-makers to-j
n = number of assessors (decision maker)
Aggregate value is $N = (c_j, a_j, b_j)$
where:
Nt = Value aggregation weights for qualitative criteria to-t

f. Calculating the value of the preference of each alternative based on qualitative criteria. In calculating the aggregate weight each alternative for each criterion may look fuzzy aggregate value with the following models :

$$q_t = \frac{\sum_{j=1}^{n} q_{tj}}{n} \qquad o_t = \frac{\sum_{j=1}^{n} o_{tj}}{n} \qquad p_t = \frac{\sum_{j=1}^{n} p_{tj}}{n}$$

q_{itj} = ower limit value alternative to qualitative criteria by the manufacturer to keep tj.
o_{it} = value alternative to middle-t qualitative.ke criteria by decision-makers to j.
o_{itj} = upper limit value alternative to qualitative criteria by the manufacturer to keep tj.
N = number of assessors (decision maker).
Aggregate value is $M_{itj} = (q_{it}, o_{it}, p_{it})$, where:
M_{itj}= weighted aggregation value for the i-th alternative to qualitative criteria to-t.

g. Calculating the value of the fuzzy index of each alternative assessment results for the qualitative criteria which are denoted by Gi. First obtained value Mit and Nt, to get a fuzzy match index value for each Gi subjective criteria. Here Gi is not a triangular fuzzy number, but fuzzy numbers

$$G_i = (Y_i, Q_i, Z_i, H_{i1}, T_{i1}, H_{i2}, U_{i1}),\quad i = 1, 2, \ldots\ldots\ldots\ldots m$$

The fuzzy index values are obtained by operating each element of triangular fuzzy numbers from the numbers 2 and 4 with the following notations:

$$T_{i1} = \frac{\sum_{t=1}^{k} (o_{it} - q_{it})(a_t - c_t)}{k}$$

$$T_{i2} = \frac{\sum_{t=1}^{k} [q_{it}(a_t - c_t) + c_t(o_{it} - q_{it})}{k}$$

$$U_{i1} = \frac{\sum_{t=1}^{k} (p_{it} - o_{it})(b_t - a_t)}{k}$$

$$U_{i2} = \frac{\sum_{t=1}^{k} [b_t(o_{it} - p_{it}) + p_t(a_t - b_t)}{k}$$

$$H_{i1} = \frac{T_{i2}}{2T_{i1}}$$

$$H_{i2} = -\frac{U_{i2}}{2U_{i1}}$$

$$Y_i = \frac{\sum_{t=1}^{k} q_{it} c_t}{k}$$

$$Q_i = \frac{\sum_{t=1}^{k} o_{it} a_t}{k}$$

$$Z_i = \frac{\sum_{t=1}^{k} p_{it} b_t}{k}$$

h. Calculating the value of the utility of each alternative to qualitative criteria.

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$$U_t(G_t) = \frac{1}{2}\left[H_{i2} - \left({H_{i2}}^2 + \frac{X_R - Z_i}{U_{i1}}\right)^{\frac{1}{2}} + 1 + H_{i1} - \left({H_{i1}}^2 + \frac{X_L - Y_i}{T_{i1}}\right)^{\frac{1}{2}}\right]$$

$$X_R = \frac{1}{2}\left\{2x_1 + 2H_{i2}(x_2 - x_1) + \frac{(x_2 - x_1)^2}{U_{i1}} - (x_2 - x_1)\left[\langle 2H_{i2} + \frac{(x_2 - x_1)^2}{U_{i1}} + 4\frac{x_1 - z_1}{U_{i1}}\rangle\right]^{\frac{1}{2}}\right\}$$

$$X_L = \frac{1}{2}\left\{2x_2 + 2H_{i1}(x_2 - x_1) + \frac{(x_2 - x_1)^2}{T_{i1}} - (x_2 - x_1)\left[\langle 2H_{i2} + \frac{(x_2 - x_1)^2}{T_{i1}} + 4\frac{x_1 - z_1}{T_{i1}}\rangle\right]^{\frac{1}{2}}\right\}$$

The first step to do is by looking for the criteria and preferences of defuzzification value alternative to the criteria, which the defuzzification method used is the centroid method. The formula of defuzzification criteria is as follows:

Defuzzification N_{it}

$$= \frac{\left[\left[\int_{c_t}^{a_t} \frac{(x - c_t)}{(a_t - c_t)} x dx + \int_{a_t}^{b_t} \frac{(x - b_t)}{(a_t - b_t)} x dx\right]\right]}{\left[\left[\int_{c_t}^{a_t} \frac{(x - c_t)}{(a_t - c_t)} dx + \int_{a_t}^{b_t} \frac{(x - b_t)}{(a_t - b_t)} dx\right]\right]}$$

t = criteria 1,2,3..................n

While the formula for determining the value defuzzification alternative preference for qualitative criteria is as follows:

Defuzzification M_{it}

$$= \frac{\left[\left[\int_{q_{it}}^{o_{it}} \frac{(x - q_{it})}{(o_{it} - q_{it})} x dx + \int_{o_{it}}^{p_{it}} \frac{(x - p_{it})}{(a_t - p_{it})} x dx\right]\right]}{\left[\left[\int_{q_{it}}^{o_{it}} \frac{(x - q_{it})}{(o_{it} - q_{it})} dx + \int_{o_{it}}^{p_{it}} \frac{(x - p_{it})}{(a_t - p_{it})} dx\right]\right]}$$

i = alternative 1,2,3,..............m;
t = criteria 1,2,3..................n

i. Calculating the value of the ranking of each alternative based on qualitative criteria by using the following formula:

$$ST_i = \frac{U_T(G_i)}{\sum_{i=1}^{m} U_T(G_i)}$$

ST_i= the value of the i-th rank alternatives based on qualitative criteria.

j. Calculating the value of the ranking of each alternative based on quantitative criteria by using the following formula:

$$OT_i = \frac{\sum_{j=1}^{p}\left[T_{ij} l\left(\sum_{i=1}^{m} T_{ij}\right)\right]}{p}$$

T_{ij} = value (score) of the i-th alternative to quantitative criteria to-j
M = number of alternative
P = number of quantitative criteria
OT_i= the value of the i-th rank alternatives based on quantitative criteria

k. Calculating total value ranking of each alternative to qualitative criteria and quantitative criteria by using the following formula:

$$FT_i = \frac{ST_i + OT_i}{\sum Vk}, 0 \leq x \leq 1$$

ST_i = the value of the i-th rank alternatives based on qualitative criteria.
OT_i = the value of the i-th rank alternatives based on quantitative criteria
Σ Vk = number of variables
FT_i = rank total value for the alt to-i

l. Selecting the best alternative based on the value of the highest rank.

3. RESULT AND DISCUSSION

3.1. Criteria level weight assessment.

The results of the weighting there are two scales in the assessment, namely the linguistic scale and the numerical scale. The linguistic scale is divided into 5 levels of assessment, namely "very low", "low", "medium", "high" and "very high" (Zadeh, 2004). While the rating for the Numerical scale (N) is between 1-10. 1 shows the results of the data recapitulation of the Expert 1-4 respondent questionnaires for the importance of the operational requirements and environmental requirements criteria.

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Table 1. Recapitulation of Expert Data Assessment for Criteria Level

No	Criteria	Sub Criteria	Expert 1	Expert 2	Expert 3	Expert 4
			N	N	N	N
A.	**Operational Requirement**					
1	Influence of other countries		7	7	7	6
2	Security	Safe form Pollution	8	8	7	8
		Safe of Social Conflict	7	7	7	8
3	Access of transportation	Public Port	7	8	8	10
		Airport	7	7	8	8
4	Supporting facilities	Communication Facility	8	8	10	9
		Electrical Facility	9	8	8	10
		Water Facility	8	8	8	10
		Transport Facility	7	8	8	10
5	Operational Cost		7	7	7	8
No	**Criteria**	**Sub Criteria**	***Expert 1***	***Expert 2***	***Expert 3***	***Expert 4***
			N	**N**	**N**	**N**
B.	**Environmental Requirement**					
1	Area Environment	ALKI 1	7	7	8	8
		LCS	9	8	8	8
2	City Environment	City Center	6	6	6	5
		Settlement	5	6	6	5
3	Hydrography Environment	Sea Depth	9	8	8	8
		Sea Tide	9	8	8	8
		Sea Current Speed	9	8	9	8
4	Earthquake		8	8	8	8

3.2. The results of alternative location.
Results of the alternative assessment ratings can be seen in Table 2 with the same scale as the assessment criteria, namely the linguistic scale and the numerical scale.

Table 2. Recapitulation of Expert Assessment for Alternative Locations.

No	Criteria	Sub Criteria	Alternative Location	E1	E2	E3	E4
				N	N	N	N
1	Influence of other countries		DP (Pontianak)	6	6	6	3
			DR (Ranai)	8	8	8	6
			DT (Tarempa)	7	7	7	6
2	Security	Safe form pollution	DP (Pontianak)	8	8	8	7
			DR (Ranai)	7	9	8	5
			DT (Tarempa)	6	7	7	3
		Safe of Social Conflict	DP (Pontianak)	8	7	7	3
			DR (Ranai)	8	8	8	7
			DT (Tarempa)	7	8	8	7
3		Public Port	DP (Pontianak)	7	7	7	7

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	Acces of Transportation		DR (Ranai)	6	6	6	6
			DT (Tarempa)	5	4	5	3
		Airport	DP (Pontianak)	7	7	7	8
			DR (Ranai)	6	7	7	8
			DT (Tarempa)	5	5	4	3
4	Supporting facilities	Communication Facility	DP (Pontianak)	8	8	8	8
			DR (Ranai)	6	6	6	5
			DT (Tarempa)	5	5	5	3
		Electrical Facility	DP (Pontianak)	7	8	8	8
			DR (Ranai)	6	7	7	5
			DT (Tarempa)	5	6	6	3
		Water Facility	DP (Pontianak)	8	8	8	8
			DR (Ranai)	7	7	7	5
			DT (Tarempa)	6	4	4	3
		Transport Facility	DP (Pontianak)	8	8	8	8
			DR (Ranai)	6	6	6	5
			DT (Tarempa)	6	4	4	3
		Sea Channel	DP (Pontianak)	6	6	5	5
			DR (Ranai)	8	8	8	8
			DT (Tarempa)	7	7	7	7
5	Operational Cost		DP (Pontianak)	5	6	7	6
			DR (Ranai)	7	8	8	8
			DT (Tarempa)	7	7	6	7

3.3. Determine the middle value of the fuzzy number.

The fuzzy middle number is the number obtained from the sum of the values that appear at each level of the linguistic scale divided by the number of those scales. The calculation results are then used to create a Triangular Fuzzy Number.

Determine the Triangular Fuzzy Number (Lower, middle and upper limit values)

a. Medium linguistic level: for the lower value of ct = 1 (as the lower limit), the middle limit: a_(t=) (6+5)/2 = 5.5 (ct level above), bt = at level above.

b. High linguistic level: ct = 6 (at low level), a_(t =) (7+7+7+7+7+7+7+8+8+8+8)/11= 7.36 (bt medium level and very high level ct) and bt = at very high level.

c. Very high level: ct = at high level, a_t=(9(5)+10(1))/6 = 9.16 and bt = 10. Calculation of expert 1, 2, 3 and 4 using Microsoft mathematic program.

Determine the aggregate weight of each operational requirement criteria.

Respondents evaluate each selection criteria by using a linguistic scale to obtain the level of weight for the criteria. The weight of the expert scores for the criteria in the linguistic scale shown in Table 3, then evaluated against the TFN expert for criteria assessment. So with this calculation, an aggregate weight will be obtained for each operational requirement criterion, which will later be used in defuzzification. The results of the average Aggregate Weight for the purposes of the operational requirement criteria are shown in the following Table:

Table 3. Aggregate TFN weight of operational requirement criteria

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No	Criteria	Average of TFN Weight		
		Ct	At	Bt
1	Influence of others country	4.625	6.900	8.790
2	Safe from Pollution	5.700	7.575	9.240
3	Safe of Social Conflict	5.700	7.575	9.240
4	Public Port	6.375	8.025	9.290
5	Airport	5.700	7.575	9.240
6	Communication Facility	6.675	8.475	9.540
7	Electrical Facility	6.850	8.500	9.500
8	Water Facility	6.375	8.025	9.290
9	Transport Facility	6.375	8.025	9.290
10	Sea Channel	7.000	8.800	9.950
11	Operational Cost	5.700	7.575	9.240

3.4. Calculating the preference value of each alternative based on the operational requirement criteria.

To calculate the preference value of each alternative based on the operational requirements criteria, the aggregate weight of each alternative is calculated for each operational requirement criteria so that the alternative preference values are obtained in the Table as follows:

Table 4. Alternative Location Preference Values Based on Criteria

No	Criteria	Alt.	TFN Value			No	Criteria	Alt.	TFN Value		
			Qit	Oit	Pit				Qit	Oit	Pit
1	Influence of other countries	DP	2.500	4.975	6.950	6	Communicate Facility	DP	5.575	7.425	9.750
		DR	4.975	6.950	9.125			DR	3.000	5.575	7.475
		DT	4.975	6.950	9.125			DT	2.500	4.975	6.950
2	Safe from pollution	DP	5.575	7.475	9.750	7	Electrical Facility	DP	5.575	7.425	9.750
		DR	5.425	7.325	9.375			DR	3.825	6.500	8.475
		DT	3.325	5.900	7.950			DT	2.500	4.975	6.950
3	Safe of Social Conflict	DP	4.475	6.350	8.600	8	Water Facility	DP	5.575	7.425	9.750
		DR	5.575	7.325	9.750			DR	4.975	6.950	9.125
		DT	5.575	7.325	9.750			DT	1.000	4.150	6.025
4	Public Port	DP	5.575	7.425	9.750	9	Transport Facility	DP	5.575	7.425	9.750
		DR	3.000	5.575	7.475			DR	3.000	5.575	7.475
		DT	1.750	4.550	6.500			DT	1.000	4.150	6.025
5	Airport	DP	5.575	7.425	9.750	10	Sea Channel	DP	3.000	5.575	7.475
		DR	4.425	7.025	9.100			DR	5.575	7.475	9.750
		DT	1.750	4.575	6.475			DT	5.575	7.475	9.750
11	Operational Cost	DP	3.400	6.050	8.100						
		DR	5.575	7.475	9.750						
		DT	5.175	7.000	9.125						

Table 5. Value Formation of Fuzzy Index Evaluation

Alt.	Index of Fuzzy								
	Yi	Qi	Zi	Ti1	Ti2	Ui1	Ui2	Hi1	Hi2
DR	29,34	54,29	80,35	3,82	21.13	3,09	-33.10	2.76	5.35
DT	27,03	53,02	78,64	4,04	21.95	2,98	-32.10	2.72	5.39
DP	19,04	44.56	68,46	4,43	21.10	2.91	-30.12	2.38	5.18

3.5. Calculates the utility value of each alternative for the Operational Requirement criteria.

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Before calculating the utility value, the defuzzification process is carried out using the centroid method, as shown in Table 6 below:

Table 6. Defuzzification Of Operational Requirements Criteria

No	Criteria	Defuzzification of Weight	Defuzzification of Alternative		
			DP	DR	DT
1	Influence of others country	6.771	4.808	7.016	7.016
2	Safe from Pollution	7.505	7.600	7.375	5.725
3	Safe of Social Conflict	7.505	6.475	7.600	7.600
4	Public Port	7.897	7.600	5.350	4.322
5	Airport	7.505	7.600	6.850	4.266
6	Communication Facility	8.230	7.600	5.412	4.808
7	Electrical Facility	8.275	7.600	6.266	4.808
8	Water Facility	7.897	6.600	6.798	3.725
9	Transport Facility	7.897	7.600	5.350	3.725
10	Sea Channel	8.550	5.350	7.600	7.600
11	Operational Cost	7.505	5.878	7.600	7.100

Table 7. Performance Value Of Alternative Locations

No	Alternative Location	Gi
1	DP (Pontianak)	53,688
2	DR (Ranai)	51,627
3	DT (Tarempa)	42,737

Table 8. Utility-Forming Index

No	Alternative Location	Gi
1	DP (Pontianak)	1.040
2	DR (Ranai)	0.974
3	DT (Tarempa)	0.870

3.6. Calculate the ranking value of each alternative based on the Operational Requirement criteria.

After all, calculations have been made, the rankings for alternatives based on the operational requirements criteria are as follows:

Table 9. Ranking Of Alternatives On Operational Requirement Criteria

No	Alternative Location	Sti
1	DP (Pontianak)	0,360
2	DR (Ranai)	0,338
3	DT (Tarempa)	0,302

From the ranking results based on the Operation Requirement criteria above, it can be seen that of the three alternative locations for the construction of ship maintenance and repair facilities to support operations in the North Natuna Sea, the first alternative is the Pontianak area (DP) as the best choice with a value of 0.360.

3.7. Calculating alternative ranking values based on Environmental Requirement criteria.

The calculation on this criterion is the same as the calculation on the operational requirement criteria and the aggregate weight is obtained.

Table 10. Aggregate Weight Of Environmental Requirements

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No	Criteria	Average of TFN Weight		
		Ct	At	Bt
1	Environmental -ALKI 1	5.7	7.6	9.24
2	Environmental -LCS	6.2	8	9.45
3	City Center	1	5.7	7.58
4	Settlement	1	5.7	7.58
5	Sea Depth	6.1	8	9.45
6	Sea Tide	6.5	8.6	9.7
7	Sea Current Speed	6.1	8.	9.45
8	Earthquake threat	5.7	7.6	9.24

From Table 10, the data on the aggregate weight of the Environmental Requirements criteria above is then carried out by the defuzzification method using the centroid method, so that the defuzzification results for the Environmental Requirements criteria are obtained in the following table, then the unit normalization is performed.

Table 11. Defuzzification Of Weight Criteria Environmental Requirement

No	Criteria	Weight of Criteria	
1	Operation Fields-ALKI 1	7.505	0.133
2	Operation Fields -LCS	7.883	0.139
3	City Center	4.758	0.084
4	Settlement	4.758	0.084
5	Sea Depth	7.811	0.138
6	Sea Tide	8.490	0.150
7	Sea Current Speed	7.811	0.138
8	Earthquake threat	7.505	0.133

The weight of the Environmental Requirements criteria above is then multiplied against the Environmental Requirement data for alternative locations for ship maintenance and repair facilities as shown in the table below.

Table 12. Recapitulation Of A Weighting Of Environmental Requirement Criteria

Criteria	Weight of Criteria	Alternative Location			Total of Value
		DP (Pontianak)	DR (Ranai)	DT (Tarempa)	
Environmental Fields-ALKI 1	0.132	135.000	32.000	110.000	277
Environmental Fields -LCS	0.141	350	220	320	890
City Center	0.084	5	65	2	72
Settlement	0.084	55.000	500	50	605
Sea Depth	0.145	4	12	11	27
Criteria	Weight of Criteria	Alternative Location			Total of Value
		DP (Pontianak)	DR (Ranai)	DT (Tarempa)	
Sea Tide	0.141	50	119	72	241
Sea Current Speed	0.141	0.400	0.400	0.200	1
Earthquake threat	0.132	25	5.	5	35
		Unit Normalization			
Environmental -ALKI 1	0.132	0.513	0.884	0.603	2.000
Environmental -LCS	0.141	0.607	0.753	0.640	2.000
City Center	0.084	0.067	0.905	0.028	1.000
Settlement	0.084	0.091	0.826	0.083	1.000
Sea Depth	0.145	0.148	0.444	0.407	1.000
Sea Tide	0.141	0.793	0.506	0.701	2.000
Sea Current Speed	0.141	0.400	0.400	0.200	1.000
Earthquake threat	0.132	0.286	0.857	0.857	2.000
		Unit Normalization			
Environmental -ALKI 1	0.132	0.256	0.442	0.301	1.000

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Environmental -LCS	0.141	0.303	0.376	0.320	1.000
City Center	0.084	0.067	0.905	0.028	1.000
Settlement	0.084	0.091	0.826	0.083	1.000
Sea Depth	0.145	0.148	0.444	0.407	1.000
Sea Tide	0.141	0.396	0.253	0.351	1.000
Sea Current Speed	0.141	0.400	0.400	0.200	1.000
Earthquake threat	0.132	0.143	0.429	0.429	1.000

The data above uses a variety of units so it is necessary for unit normalization. Furthermore, by using the Fuzzy MCDM equation, the ranking value for the Environmental Requirements criteria can be calculated.

Table 13. Ranking Of Alternatives On The Criteria Of Environmental Requirement

No	Alternative Location	Otj
1	DP (Pontianak)	0.244
2	DR (Ranai)	0.468
3	DT (Tarempa)	0.288

Based on the Environmental Requirements criteria in the table above, it can be seen that of the three alternatives, the second alternative, namely DR (Ranai) has the highest-ranking value with a ranking value of 0.468.

3.8. Calculating the total (final) ranking value of each alternative

Based on the Operational Requirements and Environmental Requirements criteria, the total ranking value for each alternative location can be calculated using the formula:

$$FT_i = \frac{ST_i + OT_i}{\sum Vk} \quad ; \sum Vk = 2$$

(quantitative and qualitative criteria)

$$= \frac{0,360 + 0,244}{2}$$

$$= 0,302$$

(for alternative 1)

With the same formulation, the results of calculating other alternative locations can be seen as shown in the following Table:

Table 14. Total Ranking Of Alternative Locations For Determining Ship Maintenance And Repair Facilities.

No	Alternative Location	Fti	Rank
1	DP (Pontianak)	0.302	2
2	**DR (Ranai)**	**0.403**	**1**
3	DT (Tarempa)	0.295	3

3.9. Choose the best alternative based on the highest-ranking value.

From the table above, it can be seen that then choose the best alternative with the highest total ranking value. The alternative location for the best ship maintenance facility is the second alternative location, namely Ranai Region (DR) with a total value of 0.403.

4. CONCLUSION

After carrying out the entire research process, conclusions can be formulated based on the application of the Fuzzy MCDM method in the selection of ship maintenance and repair locations in the marine area of North Natuna Indonesia, as follows:

a. The decision-making process for determining the location of ship maintenance and repair facilities can be modeled by applying the Fuzzy Multi-Criteria Decision Making model as a reliable and optimal method of making decisions with multi-criteria nature.

b. Based on the literature review and investigations with experts, 19 selection criteria were obtained consisting of 11 operational requirements criteria and 8 environmental requirements as a consideration in determining the location of ship maintenance and repair facilities to support operations in the North Natuna Sea.

c. The decision-making process in determining the location of ship maintenance and repair facilities is carried out by several experts as decision-makers so that each decision-maker will provide a different subjective assessment of the available alternative locations. The Fuzzy MCDM algorithm can be applied to determine the location of ship maintenance and repair facilities that can

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eliminate the fuzziness of data on operational criteria and environmental requirements that have a high subjective value.

d. Based on data processing using the Fuzzy MCDM method, the best location for the placement of ship maintenance and repair facilities is Ranai Region (DR) with the highest total ranking value of 0.403 then Pontianak (DP) area with a ranking value of 0.302 and Tarempa Region with a ranking value 0.295.

5. FUTURE WORK

Some of the further work that can be done to improve this research are as follows:

a. At the stage of determining the criteria for alternative locations for ship maintenance and repair facilities, a forward picture of the social and cultural criteria of the surrounding community as well as the development of economic development in each alternative location can be added. This can be continued in the next research.

b. All the shortcomings in the research are due to time and place limitations and difficulties in obtaining information or data from criteria that have not been included, but this is a challenge and experience and information for further researchers in the next stage of development.

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