Establishing the Location of Naval Base Using Fuzzy MCDM and Covering Technique Methods: A Case Study

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Naval Base located in the region of a country has a very important role as national defense aspect, and developing sea power to a military operations area (deployment forces position). This study aims to select the best site from multiple locations naval base. Model compiling an application of the theory and method of Covering Technique is integrated with Fuzzy Multi Criteria Decision Making (Fuzzy MCDM). Covering Technique method is used to select the naval base by minimizing the number of selected naval bases can cover other bases. Fuzzy MCDM method is used to select the naval base by assessing the weight value of the naval base by the political, technical and economic aspects.

Keywords: Naval Base, Covering Technique, Fuzzy MCDM

1. Introduction

Naval Base located in the region of a country has a very important role as national defense and security aspect, developing of sea power to a military operations area (Deployment Forces Position), and as "Home Base" which has the function of 5 (five) R, namely: Rest, Refresh, Refuel, Repair and Replenishment. Naval Base development requires huge resources. Therefore, we need a strategic calculations and considerations to decide the development of a naval base location. According to the author, an important factor in the development of naval base was influenced by considerations in terms of Political, Technical and Economic aspects, as in the following Figure

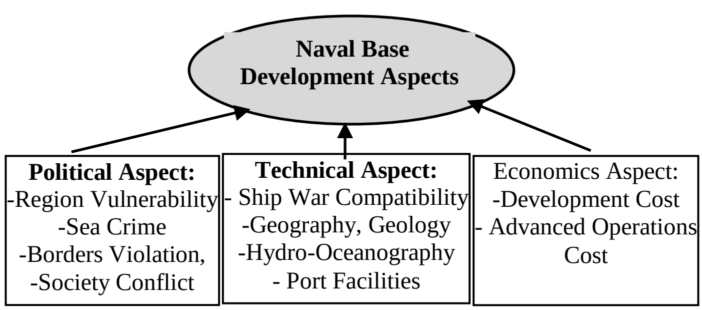

Figure 1 *The Important Aspects in the Development of Naval Base*

1.1 Indonesian Naval Base

Indonesia should be able to control and secure the owned entire sea area in accordance with the provisions in the United Nations Convention on the Law of the Sea, UNCLOS'82. Efforts to control and safeguard the territorial sea are conducted through the maritime security patrol ships held by Indonesian Navy and the Naval Bases as the supporting bases. Indonesian Navy divides the working area of its command into two main command regions that are Western Fleet Command and Eastern Fleet Command. In this research, the discussion is limited to the Naval Base in the Eastern Fleet Command. The Naval Base number in the region of Eastern Fleet Command is 26 Naval Bases, which spread from the Java Sea to the Arafura Sea appropriate in Table 1 and Figure 2.

Table 1 *The Existing Location of Naval Bases*

Naval Operation Sectors	Available Naval Base in Sector
I	Kendari, Palu, Balikpapan, Kotabaru, Banjarmasin
II	Cilacap, Tegal, Semarang, Banyuwangi, Benoa
III	Mataram, Maumere, Tual
IV	Tarakan, Nunukan, Tahuna, Toli, Gorontalo
V	Ternate, Saumlaki, Morotai
VI	Biak, Manokwari, Sorong
VII	Timika, Aru

Figure 2 *Naval Operation Sectors Map*

1.2 Important Criteria in the Naval Base Development

Each Naval Base location has different characteristics under consideration in terms of Politics, Technical and Economic aspects, which as a whole according to the author can be identified as follows:

Ships Compatibility and Dispersion of the Naval Base

Ships compatibility and dispersion are condition in area / territory covered by the naval base where operation / voyage could be implemented by Navy ships with a wide variety of vessel types and classes. They are influenced by

1. The ability of the coverage area of the vessel that includes endurance, speeds, and distance range radar vessel against hub-port network Naval Base location.
2. The ability of the technical condition of the ship which include: the size of the vessel, the type and class of vessels.

The Strategic Positions

The strategic location of Naval Base is influenced by

1. The level of the threat from outside the country, the conditions of insecurity in the border regions and encroachment.
2. The condition of vulnerability areas, illegal logging, illegal fishing and other crimes at sea such as ships piracy and hijacking.

Hydro Oceanography Nature and Beaches Conditions

Hydro oceanography nature and beaches conditions are natural condition that affects the operational activities of Naval Base, Harbor waters should be protected against attacks and a wave of rapid sedimentation. To the extent, possible ports are naturally sheltered waters. Some important geography and oceanography variables are

1. Port area geography, location altitude and climate.
2. Hydro-Oceanography, bathymetry, wind and wave velocity, water tide and sea wave height.
3. Geology port area
4. Sedimentation port area.

The Condition of Facilities at the Port of Naval Base Area

Port facilities of military naval base are the supporting facilities include the following

1. Shipping channel and berthing dock facilities
2. Maintenance and repair facilities (Naval Shipyard)
3. Logistics debriefing facilities include: fresh water, fuel, lubricating oil and personnel logistics (groceries).
4. Personnel care facilities (hospitals, mess and recreation facilities)

Naval Bases Development Cost

The cost of developing a naval base consists of two main things, as follows:

1. The cost in terms of physical development and facilities of Naval Base.
2. The operational cost arising from the continuation of a location selected as a naval base.

Based on the important factors above, each Naval Base location has the characteristics and influence in terms of political, technical and economic aspects varying in supporting the territorial integrity of Indonesia, so it is necessary to analyze the study and optimization to select a worthier naval base, to be developed in the future. Given the complexity of the problems faced in developing the election naval base, it is necessary to search the deeper and wider data to make a model of a representative. This model should certainly be able to accommodate the entire problem range in the development of Naval Station. The model is in the form of a model of site selection method of Naval Base Covering Technique and Fuzzy MCDM.

2. Literature Review

2.1 The Concept of Covering Technique Method

The concept of Covering Technique Method is intended to minimize the number of hub ports / base needed to serve / cover other bases. The selected bases will provide cover/services on ships to other bases. According Heragu (1997), covering technique appears in a system that has every customer requirement can be reached by at least one facility. Meanwhile, according to Daskin (1995), covering technique is how to determine the lowest cost of placement facilities, where each demand node can be reached by at least one facility. The second understanding of the above, generally covering technique can be defined as the selection of the alternatives location that exist for the purpose of minimizing the entire factors that influence the restriction that any demand can be reached by the selected location .

A region known to be in the range area (coverage area) if the area is located at a distance range. The determination of the distance range is very important to note the application of the method of covering technique because it is the most influential factor on resulting optimal solution.

The Problems of covering technique are placing the facilities in the minimum amount required to cover all locations clicking demand or if in this research selecting and placing naval bases in the amount planned to cover defense and security sector of the sea.

The parameters used in the model form of covering technique are the distance and location of the operating sectors naval formulated to plan the number of bases, as follows:

Objective Function: Minimize $\sum_{j \in J}^{n} Xj$

Subject to the Constrain $X\ i \sum_{j \in Ni}^{n} \geq 1 \quad \forall\ I \in I$

$Xi \in \{0,1\} \quad \forall\ j \in J$

The objective function to minimize the amount of base (Xj) are placed. Limiting function ensures that each sector (Xi) on the cover by at least one base. Variables decision is "Yes" or "No" a base selected as the cover on other bases in the sector in the form of Zero-One matrix.

Table 2 *Decision Variable of Zero-One Matrix*

NAVAL BASE	**OPERATING SECTOR**				
	j-1	.	.	.	j-n
i-1	X 1,1	X 1,2	X 1,3	X 1,4	X 1,n
.	X 2,1	X 2,2	X 2,3	X 2,4	X 2,n
.	X 3,1	X 3,2	X 3,3	X 3,4	X 3,n
.	X 4,1	X 4,2	X 4,3	X 4,4	X 4,n
i-n	X n,1	X n,2	X n,3	X n,4	X n,n

X ij = 0 (zero), that the base -i is not selected to cover sector operation -j

X ij = 1 (one), the selected base -i covers operating sector -j

2.2 The Concept of Fuzzy Theory

The concept of fuzzy theory was initiated by Lotfi A. Zadeh (1974) 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 continues membership function.

Membership Function

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

Linear Representation

In the linear representation, mapping input to the degree of membership is described as a straight line. This form is the simplest and good choice to approach a less clear and concept. There are 2 (two) fuzzy sets of the linear state, first is the increase in the set started in the domain value that has a membership degree zero [0] to move to the right toward the domain values that have a higher degree of membership.

Membership functions

$$\mu[x] = \begin{cases} 0; & x \leq a \\ \frac{x-a}{b-a}; & a \leq x \leq b \\ 1; & x \geq b \end{cases}$$

Second, is the opposite of the first one. Straight line starting from the value of the domain with the highest degree of membership on the left side, then move down to the value of a domain that has a lower membership.

Membership functions

$$\mu[x] = \begin{cases} \frac{b-x}{b-a}; & a \leq x \leq b \\ 0; & x \geq b \end{cases}$$

Representation Curve Triangle

Triangle curve is basically a combination of the two lines (linear).

Membership functions

$$\mu[x] = \begin{cases} 0; & x \leq a \; atau \; x \geq c \\ \frac{x-a}{b-a}; & a \leq x \leq b \\ \frac{c-x}{c-b}; & b \leq x \leq c \end{cases}$$

Trapezoid Curve Representation

Trapezoidal curve is essentially like a triangular shape, it's just that there is a point which has a membership value 1.

Membership functions

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

Triangular Fuzzy Number (TFN)

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

A = (a1, a2, a3)

TFN membership functions for the image above is as follows:

$$\mu[x] = \begin{cases} = 0 & \text{for } x < a_1 \\ = \dfrac{x - a_1}{a_2 - a_1} & \text{untuk } a_1 < x < a_2 \\ = \dfrac{a_3 - x}{a_3 - a_2} & \text{untuk } a_2 < x < a_3 \end{cases}$$

Defuzzification Value

Defuzzification is a process of conversion and fuzzy quantity be fixed quantity, where output and process fuzzy logic can be combined from two or more fuzzy membership functions that are defined in accordance with the universal conversation. Input and defuzzy process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a fuzzy set of numbers in the domain. There are several defuzzification methods commonly used as follows:

Centroid method (Center of Gravity / COG)

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

Bisector Method

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

Method of Maximum Mean (MOM)

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

Largest of Maximum method (LUM)

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

Smallest of Maximum method (SOM)

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

Linguistic Variables

Linguistic variable is a variable that has a description in the form of fuzzy numbers and more generally the words are represented by fuzzy sets. For example, descriptions of the linguistic variables for the temperature can be LOW, MEDIUM and HIGH wherein the description are expressed as fuzzy value. As well as algebraic variables that use numbers as its value while the linguistic variables using words or sentences as a set of values that form the so-called set of "terms". Each value of "term" is a fuzzy variable defined by base variable, while the base variable defines the universe of discourse for all fuzzy variables in the set of "terms".

2.3 Multiple Criteria Decision Making (MCDM)

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

3. The Proposed Methodology

The Proposed Methodology in this research can be shown in the following diagram

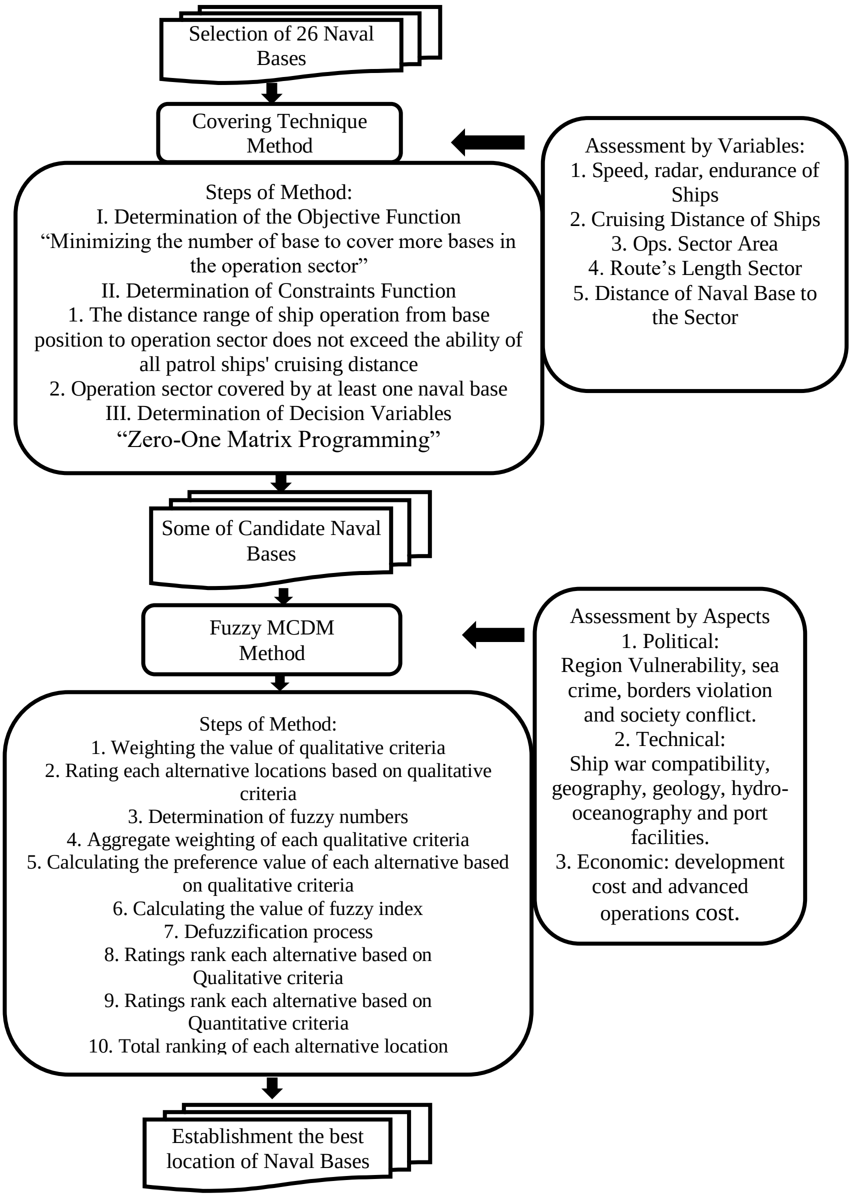

Figure 3 *The Proposed Methodology Diagram*

3.1 The First step of this research is selection of Naval Base in operations sector with the Covering Technique optimization method, the model can be formulated on the following sequences:

A. Determining the Objective Function

Minimizing the number of hub-port base to cover more bases in the operation sector by maximizing the range of the vessel in the operation sector base k to j

$$\text{Z min} = \sum_{k \in K}^{n} \sum_{j \in J}^{n} \text{X kj. (Kpb)kj}$$

$$\text{Z max} = \sum_{k \in K}^{n} \sum_{j \in J}^{n} \text{(d kj . X kj) . (Kpb)kj}$$

B. Determining the Constraints Function

1. The distance range of patrol ship operation from base position k to operation sector j and return to base k does not exceed the ability of all patrol ships' cruising distance endurance (RE patrol ship).

$$\text{d kj . Xkj} \leq \text{RE Patrol Ship,}$$

2. Patrol sector j covered by at least one naval base

$$\text{Xkj} \geq 1$$

d kj = Range of patrol ship in the base k to operation sector j then subsequently return to base k
X kj = Patrol ship operation from base k to patrol sector j
(Kpb)kj = Compatibility of base k towards operation sector j
RE = Cruising distance of patrol ship in once endurance

C. Determining the Decision Variables

Table 3 *Decision Variable of Zero-One Matrix for Naval Base Selection*

NAVAL BASE	OPERATING SECTOR				
	j-1	.	.	.	j-n
k-1	X 1,1	X 1,2	X 1,3	X 1,4	X 1,j
.	X 2,1	X 2,2	X 2,3	X 2,4	X 2,j
.	X 3,1	X 3,2	X 3,3	X 3,4	X 3,j
.	X 4,1	X 4,2	X 4,3	X 4,4	X 4,j
k-n	X k,1	X k,2	X k,3	X k,4	X k,j

X kj = 0 (zero), that the base -k is not selected to cover sector operation -j
X kj = 1 (one), the selected base –k covers operation sector -j

3.2 The Second Step in this research is applying **Fuzzy MCDM** method to get the rank for establishing Naval Base. Data processing is used by fuzzy MCDM algorithm. The algorithm of fuzzy MCDM developed by Liang and Wang

(1994), as the development of a fuzzy algorithm is introduced by Zadeh (1974) 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, sequence of data processing using 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.

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 :

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

q_{itj} = ower limit value alternative to qualitative criteria by the manufacturer to kep tj.
o_{it} = value alternative to middle-t kualitatif.ke criteria by decision makers to j.
o_{itj} = upper limit value alternative to qualitative criteria by the manufacturer to kep 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 is 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 numbers, but fuzzy numbers

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

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

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

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

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

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 as follows

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

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

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

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

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.

4. Analysis and Data Processing

4.1 Step I Methodology; Selection of Naval Base by Covering Technique Method

The results of the investigation and data process :

A. Calculation of Max Cruising Distance (RE) of patrol ship, based on the data: speed, radar range, endurance (E) and cruising distance of patrol ship (S).

Table 4 *Calculate Max Cruising Distance (RE) of Ship*

No	Ship Code	Speed (knot)	Radar (Nmil)	E (day)	S (Nmil)	RE (Nmil)
1	UP	14	48	4	336	1.344
2	LA	15	48	4	360	1.440
3	NU	14	48	4	336	1.344
4	ST	14	48	4	336	1.344
5	WI	13	48	4	312	1.248
6	MM	14	48	4	336	1.344
7	TP	15	48	4	360	1.440
8	HB	13	48	4	312	1.248
9	IM	15	48	4	360	1.440
10	PD	16	46	5	384	1.920
11	SR	16	46	5	384	1.920
12	HI	17	46	5	408	2.040
13	LY	17	46	5	408	2.040
14	KK	15	46	5	360	1.800
15	KR	15	46	5	360	1.800
16	TK	15	46	5	360	1.800
17	TD	17	46	5	408	2.040
18	LM	17	46	5	408	2.040
19	SL	24	46	5	576	2.880
20	KT	25	42	3	600	1.800
21	WR	25	42	3	600	1.800

22	PN	23	42	3	552	1.656
23	KL	25	42	3	600	1.800
24	TD	23	42	3	552	1.656
25	PT	25	42	3	600	1.800
26	TW	24	42	3	576	1.728
27	WL	25	42	3	600	1.800

B. Operation Sector of Naval Base Data, including: the number of bases in each sector of operation, route's length and sector area of operation which has to be secured, Indonesian Navy Headquarters (2009).

Table 5 *Operation Sector Area and Route's Length*

Operation sector	Number of Bases	Sector Area ($Nmil^2$)	Route's Length (Nmil)
I	6	248.720	1.650
II	5	264.975	1.370
III	3	240.900	1.610
IV	3	200.070	1.680
V	4	232.215	1.720
VI	3	245.725	1.780
VII	3	256.160	1.750

C. Data of Naval Base, including: the distance between bases and range of the bases to the operation sector as starting point for the movement of ships.

Table 6 *The Distance of Naval Base to the Operation Sector (Nmil)*

Naval Base	Sector I	Sector II	Sector III	Sector IV	Sector V	Sector VI	Sector VII
Kendari	2310	1826	1835	2130	2275	2320	2380
Palu	2235	1790	2325	2845	2310	2655	2745
Balikpapan	2357	1820	2490	2575	2375	2690	2875
Kotabaru	2300	1810	2415	2510	2305	2615	2805
Banjarmasin	2575	1815	2355	2480	2225	2580	2775
Cilacap	1662	2450	2655	2795	2873	2986	2943
Tegal	1675	2285	2433	2543	2690	2755	2735
Semarang	1590	2200	2235	2305	2415	2545	2525
Banyuwangi	1660	2250	2386	2255	2425	2505	2495
Benoa	1673	2412	2155	2102	2390	2410	2350
Mataram	1802	2765	3225	2450	2375	2510	2702
Maumere	1835	3750	3115	2640	1401	2245	3675
Tual	2850	2245	1840	2275	2750	2910	2725
Tarakan	3225	3310	1865	2560	2975	3275	2775
Nunukan	3045	3075	1812	2255	2450	2775	2455
Tahuna	2950	2875	1775	2202	2575	2810	2240
Toli	2775	3211	2655	1535	2277	2550	2470
Gorontalo	3150	3345	2455	1410	1365	2330	1925
Ternate	2975	3424	2375	1455	1390	2290	1990
Saumlaki	2865	3155	2305	2110	1312	2235	2650

Morotai	2245	3576	2648	2020	1377	2285	2780
Biak	2650	3875	2723	2093	1370	1283	2365
Manokwari	2855	3890	2833	2235	2074	1295	2476
Sorong	3035	3955	2955	2496	2255	1275	2519
Timika	2968	3825	2801	2428	2190	1225	2375
Aru	3105	3765	2791	2393	2154	2775	1390

All of data that are processed by the model of formulation in step I correspond to the formulation of the methodology. The process is done by using **excel solver optimization** program, in accordance with the methodology of this study, which includes the steps as follows

1. Set the Objective → (Determination of Objective Function)
2. Changing Variable Cell → (Determination of Decision Variable)
3. Subject to the Constrain → (Determination of Constrain)

The results obtained zero-one matrix of naval base selection in operation sectors, such as Table below

Table 7 *Zero-One Matrix of Naval Base Selection*

Naval Base	**Decision Variable Of Naval Base Selection**						
	Operation Sectors						
	I	II	III	IV	V	VI	VII
Kendari	0	0	0	0	0	0	0
Palu	**1**	**1**	0	0	0	0	0
Balikpapan	0	0	0	0	0	0	0
Kotabaru	0	0	0	0	0	0	0
Banjarmasin	0	0	0	0	0	0	0
Cilacap	0	0	0	0	0	0	0
Tegal	0	0	0	0	0	0	0
Semarang	0	0	0	0	0	0	0
Banyuwangi	0	0	0	0	0	0	0
Benoa	0	0	0	0	0	0	0
Mataram	0	0	0	0	0	0	0
Maumere	0	0	**1**	**1**	0	0	0
Tual	0	0	0	0	0	0	0
Tarakan	0	0	0	0	0	0	0
Nunukan	0	0	0	0	0	0	0
Tahuna	0	0	0	0	0	0	0
Toli	0	0	0	0	0	0	0
Gorontalo	0	0	0	0	0	0	0
Ternate	0	0	0	0	**1**	**1**	0
Saumlaki	0	0	0	0	0	0	0
Morotai	0	0	0	0	0	0	0
Biak	0	0	0	0	0	0	0
Manokwari	0	0	0	0	0	0	0
Sorong	0	0	0	0	0	0	**1**
Timika	0	0	0	0	0	0	0
Aru	0	0	0	0	0	0	0

0 (zero) = The naval base isn’t selected to cover the operation sector
1 (one) = The naval base is selected to cover the operation sector

Based on data processing and analysis methods of Covering Technique above, obtained 4 locations of 26 Naval Bases

Palu Naval Base → to cover operation sectors I & II
Maumere Naval Base → to cover operation sectors III & IV
Ternate Naval Base → to cover operation sectors V & VI
Sorong Naval Base → to covers operation sectors VII

4.2 Step II Methodology; Establishing Naval Base by Fuzzy MCDM Method

The next step in this research is to make weighted 4 naval bases results of the selection by Covering Technique method (step I methodology). The Naval Bases are: **Palu (NB1), Maumere (NB2), Ternate (NB3), and Sorong (NB4)**. The weighted Naval Bases are required as a form of giving priority to the naval base which will be developed. Previously, filling the questionnaire has been done by **6 expert assesor or decision makers (E1 - E6)** who are competent in the field of naval base. Scale questionnaire is divided into two linguistic scale and a numerical scale. The examples of linguistic scale is "very low", "low", "medium", "high" and "very high", while numerical scale interval of values take 1-10, as the Table below

Table 8 *Scale Questionnaire*

Aspect / Criteria	Very Low		Low		Medium		High		Very High	
	1	2	3	4	5	6	7	8	9	10

Having obtained the data from the questionnaire, the next step is to recapitulate the results of the questionnaire and data processing. Sequence of data processing using 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.

No	Criteria Of Naval Base	E1	E2	E3	E4	E5	E6
A	**Political Aspects**						
1	Region Vulnerability	8	9	9	8	8	9
2	Society Conflict	6	5	7	8	5	8
3	Sea Crime	7	8	7	9	7	8
4	Borders Violation	7	6	5	7	8	7
5	Foreign Countries Threats	6	7	8	6	8	8
B	**Technical Aspects**						
6	Rock Soil Conditions	5	6	8	6	5	7
7	Climate Weather Conditions	8	6	6	7	6	8
8	Environmental Conditions	6	7	8	5	5	7
9	Hinterland Conditions	9	9	9	10	9	10
10	Maintenance Facilities	9	10	9	9	10	10
11	Logistics Facilities	5	6	5	7	6	5
12	Recreational Facilities	7	8	6	7	8	5
13	Hospital Facilities	8	6	8	8	5	8
14	Broad Waters	7	8	8	7	8	8

15	Broad Land	7	7	8	7	8	7
16	Height Location	7	8	8	8	7	8
17	Bathymetry	8	7	7	8	7	7
18	Sea Wave Heights	7	8	7	7	8	7
19	Wind Velocity	6	7	7	6	6	7
20	Tide Water	8	8	8	7	7	8
21	Sedimentation Rate	6	7	7	7	8	7
C	**Economic Aspects**						
22	Development Cost	7	7	8	7	8	8
23	Advance Operations Cost	8	7	8	8	7	7

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

No	Qualitative Criteria	Naval Base	E1	E2	E3	E4	E5	E6
1	Region Vulnerability	NB1	8	7	9	8	8	7
		NB2	8	8	8	8	9	7
		NB3	7	5	7	7	7	6
		NB4	9	9	8	9	9	8
2	Society Conflict	NB1	6	5	7	8	5	8
		NB2	6	7	6	7	6	7
		NB3	8	7	9	8	8	8
		NB4	7	6	7	7	6	6
3	Sea Crime	NB1	6	5	6	6	7	6
		NB2	6	6	7	6	6	7
		NB3	9	9	10	9	9	9
		NB4	5	5	5	5	5	5
4	Borders Violation	NB1	7	6	6	7	8	7
		NB2	8	7	8	9	7	9
		NB3	7	7	7	8	7	7
		NB4	7	8	8	7	8	8
5	Foreign Countries Threats	NB1	6	7	7	6	8	7
		NB2	8	7	8	6	8	9
		NB3	9	8	7	9	8	7
		NB4	8	8	6	7	6	9
6	Rock Soil Conditions	NB1	7	6	8	6	5	7
		NB2	7	8	6	8	7	9
		NB3	8	8	8	8	8	9
		NB4	7	6	7	6	7	6
7	Climate Weather Conditions	NB1	6	6	5	7	6	8
		NB2	7	7	6	8	9	7
		NB3	8	9	8	9	8	8
		NB4	7	6	7	5	8	8
8	Environmental Conditions	NB1	6	7	8	9	5	7
		NB2	7	7	7	7	6	6
		NB3	8	7	8	7	8	8
		NB4	6	7	6	8	5	9
9	Hinterland Conditions	NB1	7	8	7	7	8	9
		NB2	5	7	5	8	6	7
		NB3	7	8	7	8	9	9

		NB4	7	7	8	7	5	8
10	Maintenance Facilities	NB1	6	8	8	7	8	8
		NB2	8	9	7	8	8	9
		NB3	9	9	10	10	9	9
		NB4	8	8	7	8	9	8
11	Logistics Facilities	NB1	8	6	5	7	6	7
		NB2	8	7	8	6	8	7
		NB3	8	7	8	8	7	6
		NB4	9	9	8	9	9	8
12	Recreational Facilities	NB1	7	8	6	7	8	5
		NB2	8	7	8	8	7	6
		NB3	7	8	6	7	8	5
		NB4	8	7	8	8	7	6
13	Healthy Facilities	NB1	7	6	8	8	5	8
		NB2	7	6	7	6	7	6
		NB3	8	8	8	8	8	9
		NB4	8	8	8	9	9	8

C. Determining the mean fuzzy numbers; (at), by adding the value that appears in each level scale linguistic and then dividing the sum by the number of criteria that value into linguistic assessment level.

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)

No	Criteria Of Naval Base	Average		
		ct	at	bt
1	Region Vulnerability	6,60	8,40	9,64
2	Society Conflict	3,26	6,39	8,41
3	Sea Crime	5,86	8,16	9,42
4	Borders Violation	4,00	6,89	8,59
5	Foreign Countries Threats	4,00	6,75	8,72
6	Rock Soil Conditions	2,49	6,09	8,10
7	Climate Weather Conditions	3,27	6,51	8,27
8	Environmental Conditions	3,28	6,38	8,40
9	Hinterland Conditions	7,34	9,30	10,00
10	Maintenance Facilities	7,34	9,30	10,00
11	Logistics Facilities	1,77	5,86	7,66
12	Recreational Facilities	4,07	6,81	8,55
13	Healthy Facilities	4,04	6,67	8,68

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. (qit, oit, pit)

NO	CRITERIA OF NAVAL BASE	NAV BASE	AVERAGE qit	oit	pit	NO	CRITERIA OF NAVAL BASE	NAV BASE	AVERAGE qit	oit	pit
1	REGION VULNERABILITY	NB1	5.993	7.812	9.21	8	ENVIRONMENTAL CONDITIONS	NB1	5.438	7.167	8.743
		NB2	6.032	7.765	9.238			NB2	5.14	6.892	8.597
		NB3	4.62	6.95	8.55			NB3	5.688	7.535	9.072
		NB4	6.93	8.55	9.695			NB4	5.168	6.848	8.482
2	SOCIETY CONFLICT	NB1	4.368	6.623	8.315	9	HINTERLAND CONDITIONS	NB1	5.988	7.78	9.238
		NB2	4.868	6.603	8.315			NB2	4.868	6.603	8.315
		NB3	5.993	7.812	9.21			NB3	6.332	8.01	9.405
		NB4	5.16	6.94	7.142			NB4	5.428	7.192	8.842
3	SEA CRIME	NB1	3.76	6.072	7.765	10	MAINTENANCE FACILITIES	NB1	5.408	7.252	8.822
		NB2	4.068	6.333	8.057			NB2	6.293	8.057	9.377
		NB3	7.535	9.072	10			NB3	7.535	9.072	10
		NB4	3.5	5.728	7.535			NB4	6.032	7.765	9.238
4	BORDERS VIOLATIONS	NB1	4.628	6.945	8.518	11	LOGISTICS FACILITIES	NB1	4.368	6.602	8.288
		NB2	6.278	8.038	9.39			NB2	5.388	7.245	8.813
		NB3	5.688	7.535	9.072			NB3	5.4	7.235	8.827
		NB4	5.688	7.535	9.072			NB4	6.93	8.55	9.695
5	FOREIGN COUNTRIES THREATS	NB1	5.108	6.962	8.563	12	RECREATIONAL FACILITIES	NB1	5.12	6.93	8.55
		NB2	5.688	7.49	8.98			NB2	5.4	7.235	8.827
		NB3	6.282	8.043	9.39			NB3	5.12	6.93	8.55
		NB4	5.448	7.132	8.732			NB4	5.4	7.235	8.827
6	ROCK SOIL CONDITIONS	NB1	4.348	6.617	8.307	13	HEALTHY FACILITIES	NB1	4.648	6.907	8.565
		NB2	5.708	7.475	8.962			NB2	4.32	6.66	8.292
		NB3	5.988	7.78	9.238			NB3	5.988	7.78	9.238
		NB4	4.32	6.66	8.292			NB4	6.322	8.023	9.39
7	CLIMATE WEATHER CONDITIONS	NB1	4.088	6.318	8.038						
		NB2	5.752	7.46	8.962						
		NB3	6.283	8.07	9.362						
		NB4	4.608	6.96	8.537						

G. Calculating the value of the fuzzy index of each alternative assessment results for the qualitative criteria.

	CRITERIA NUMBER													
Yi	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	39,546	14,2189	22,024	18,493	20,44	10,82	13,39	17,84	43,95	39,7	7,717	20,82	18,78	20,6
NB2	39,799	15,8464	23,83	25,086	22,76	14,2	18,83	16,86	35,73	46,19	9,519	21,95	17,46	22
NB3	30,484	19,5083	44,135	22,729	25,14	14,9	20,57	18,66	46,47	55,31	9,54	20,82	24,2	25,2
NB4	45,726	16,7958	20,501	22,729	21,8	10,75	15,09	16,95	39,84	44,27	12,24	21,95	25,54	22,4
Qi	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	50,353	42,3168	49,533	47,826	47	40,27	41,15	45,7	72,38	67,46	38,67	47,18	46,1	45,4
NB2	50,675	42,189	51,668	55,355	50,56	45,49	48,59	43,95	61,43	74,95	42,44	49,26	44,45	47,2
NB3	38,815	49,9091	74,008	51,889	54,3	47,35	52,56	48,05	74,52	84,4	42,38	47,18	51,93	51,2
NB4	58,222	44,34	46,732	51,889	48,14	40,53	45,33	43,67	66,91	72,24	50,08	49,26	53,55	47,9
Zi	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	88,769	69,9687	73,107	73,201	74,7	67,25	66,49	73,46	92,38	88,22	63,47	73,07	74,32	69,9
NB2	89,042	69,9687	75,854	80,691	78,33	72,56	74,13	72,22	83,15	93,77	67,49	75,44	71,94	71,8
NB3	82,408	77,5	94,15	77,956	81,91	74,8	77,44	76,21	94,05	100	67,6	73,07	80,16	75,5
NB4	93,444	60,0954	70,942	77,956	76,17	67,13	70,61	71,26	88,42	92,38	74,25	75,44	81,47	71,4
Ti1	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	3,2786	7,06728	5,3185	5,3575	5,095	8,16	7,223	5,353	3,518	3,62	9,136	4,964	5,949	5,29
NB2	3,1254	5,43757	5,2111	5,2081	4,953	6,355	5,533	5,426	3,407	3,462	7,595	5,032	6,164	4,78
NB3	4,2012	5,69874	3,5354	5,0925	4,843	6,445	5,787	5,72	3,296	3,017	7,506	4,964	4,719	4,63
NB4	2,921	5,5786	5,1268	4,866	4,628	8,418	7,617	5,204	3,462	3,404	6,627	5,032	4,482	4,81
Ti2	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	22,805	21,0306	22,191	22,636	21,46	21,29	20,54	22,51	24,91	24,15	21,82	21,4	21,37	20,6
NB2	22,313	20,905	22,627	25,181	22,85	24,93	24,22	21,67	22,29	25,3	25,32	22,27	20,83	21,5
NB3	23,704	24,7021	26,337	23,822	24,32	26	26,2	23,68	24,75	26,07	25,33	21,4	23,01	22,8
NB4	23,185	21,9656	21,105	23,822	21,71	21,36	22,63	21,52	23,6	24,57	31,21	22,27	23,53	21,6
Ui1	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	1,7296	3,42683	2,1284	2,6855	3,159	3,398	3,025	3,191	1,016	1,094	3,037	2,816	3,32	2,43
NB2	1,8224	3,46735	2,1661	2,3072	2,939	2,989	2,641	3,451	1,192	0,92	2,824	2,767	3,266	2,34
NB3	1,979	2,83262	1,1668	2,6229	2,656	2,932	2,271	3,11	0,972	0,647	2,866	2,816	2,919	2,13
NB4	1,4163	0,40852	2,2708	2,6229	3,156	3,281	2,773	3,306	1,15	1,026	2,062	2,767	2,736	2,07
Ui2	1	2	3	4	5	6	7	8	9	10	11	12	13	AVG
NB1	-24,87	-31,079	-25,703	-28,06	-30,86	-30,39	-28,36	-30,94	-21	-21,8	-27,8	-28,71	-31,5	-25,8
NB2	-25,63	-31,247	-26,352	-27,64	-30,71	-30,06	-28,18	-31,72	-22,9	-19,7	-27,9	-31,48	-30,8	-26
NB3	-26	-30,423	-21,309	-28,69	-30,27	-30,38	-27,15	-31,27	-20,5	-16,3	-28,1	0	-31,1	-23
NB4	-23,03	-16,164	-26,481	-28,69	-31,18	-29,88	-28,05	-30,89	-22,7	-21,2	-26,2	0	-30,7	-22,5
Hi1	1	Hi2	1											
NB1	1,9457	NB1	5,3078											
NB2	2,2472	NB2	5,5614											
NB3	2,463	NB3	5,3952											
NB4	2,245	NB4	5,4371											

NB	INDEX FUZZY Yi	Qi	Zi	Hi1	Ti1	Hi2	Ui1	Ti2	Ui2
NB1	20,552	45,42	69,89	1,946	5,288	5,308	2,43	20,6	-25,8
NB2	22,005	47,22	71,76	2,247	4,779	5,561	2,339	21,5	-26
NB3	25,175	51,23	75,52	2,463	4,63	5,395	2,128	22,8	-23
NB4	22,443	47,92	71,4	2,245	4,812	5,437	2,07	21,6	-22,5

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

- NB2	140,612	12,503	180,486	-50,873	11,385	61,572	45,772
-NB3	138,815	13,745	177,740	-56,166	11,026	59,632	46,464
- NB4	139,269	14,133	181,912	-56,221	11,211	60,633	46,384
XL - NB1	112,319	5,531	135,450	17,213	12,356	66,823	25,513
- NB2	115,581	6,120	150,169	18,655	12,993	70,271	25,715
-NB3	117,915	6,317	143,004	18,443	12,706	68,719	27,757
- NB4	115,557	6,079	143,958	18,603	12,750	68,955	26,340
Ut(Gt) - NB1	4,274	3,979	2,173	0,903			
- NB2	4,452	4,356	2,414	0,971			
- NB3	3,931	4,927	2,574	0,988			
- NB4	4,180	4,502	2,419	1,041	3,904		

I. Calculating the ranking value of each alternative based on qualitative criteria

NO	CRITERIA	DEFUZZYFICATION CRITERIA	DEFUZZYFICATION OF ALTERNATIVE NAVAL BASE				MULTIPLICATION VALUE OF DEFUZZY (CRITERIA*ALT)			
			NB1	NB2	NB3	NB4	NB1	NB2	NB3	NB4
1	REGION VULNERABILITY	8,213	7,672	7,678	6,707	8,392	63,005	63,060	55,080	68,918
2	SOCIETY CONFLICT	6,020	6,436	6,596	7,672	6,414	38,739	39,703	46,180	38,609
3	SEA CRIME	7,810	5,866	6,153	8,869	5,588	45,811	48,054	69,267	43,641
4	BORDERS VIOLATION	6,492	6,697	7,902	7,432	7,432	43,477	51,300	48,245	48,245
5	FOREIGN COUNTRIES THREATS	6,492	6,878	7,386	7,905	7,104	44,649	47,949	51,318	46,117
6	ROCK SOIL CONDITIONS	5,557	6,424	7,382	7,669	6,424	35,696	41,019	42,615	35,696
7	CLIMATE WEATHER CONDITIONS	6,020	6,148	7,391	7,905	6,702	37,011	44,492	47,585	40,341
8	ENVIRONMENTAL CONDITIONS	6,020	7,116	6,876	7,432	6,833	42,836	41,391	44,736	41,131
9	HINTERLAND CONDITIONS	8,881	7,669	6,596	7,916	7,154	68,108	58,575	70,298	63,534
10	MAINTENANCE FACILITIES	8,881	7,161	7,909	8,869	7,678	63,593	70,239	78,765	68,192
11	LOGISTICS FACILITIES	5,094	6,419	7,149	7,154	8,392	32,701	36,417	36,442	42,748
12	RECREATIONAL FACILITIES	6,473	6,867	7,154	6,867	7,154	44,451	46,311	44,451	46,311
13	HEALTHY FACILITIES	6,464	6,707	6,424	7,669	7,912	43,352	41,524	49,572	51,141
						AVERAGE VALUE OF DEFUZZY	**40,229**	**42,002**	**45,637**	**42,308**

NAVAL BASE	Sti
NB1	0.231
NB2	0.249
NB3	0.253
NB4	0.267

J. Calculating the ranking value of each alternative based on quantitative criteria

CRITERIA	NAVAL BASE				
	NB1	NB2	NB3	NB4	NILAI TOTAL
BROAD WATER (mil2)	25,00	33,00	27,00	32,00	117,00
BROAD LAND (Ha)	5,40	5,50	3,80	5,50	20,20
HEIGHT LOCATION (m)	35,00	20,00	15,00	25,00	95,00
BATHYMETRI (m)	12,00	15,00	20,00	24,00	71,00
SEA WAVE HEIGHT (m)	1,75	2,00	1,50	2,50	7,75
WIND VELOCITY (knot)	20,00	22,00	15,00	10,00	67,00
TIDE WATER (m)	2,00	3,00	2,50	1,50	9,00
SEDIMENTATION RATE (ppm)	4,00	5,00	7,00	6,00	22,00
DEVELOPMENT COST (Rp./m2)	7.500.000,00	5.500.000,00	9.000.000,00	6.500.000,00	28.500.000,00
OPS ADVANCE COST (Rp)	3.500.000,00	2.500.000,00	4.500.000,00	3.000.000,00	13.500.000,00
NORMALIZATION UNIT					
BROAD WATER (mil2)	0,2137	0,2821	0,2308	0,2735	1
BROAD LAND (Ha)	0,2673	0,2723	0,1881	0,2723	1
HEIGHT LOCATION (m)	0,3684	0,2105	0,1579	0,2632	1
BATHYMETRI (m)	0,1690	0,2113	0,2817	0,3380	1
SEA WAVE HEIGHT (m)	0,7742	0,7419	0,8065	0,6774	3
WIND VELOCITY (knot)	0,7015	0,6716	0,7761	0,8507	3
TIDE WATER (m)	0,7778	0,6667	0,7222	0,8333	3
SEDIMENTATION RATE (ppm)	0,8182	0,7727	0,6818	0,7273	3
DEVELOPMENT COST (Rp./m2)	0,7368	0,8070	0,6842	0,7719	3
OPS ADVANCE COST (Rp)	0,7407	0,8148	0,6667	0,7778	3
NORMALIZATION OF WEIGHT VALUE					
BROAD WATER (mil2)	0,2137	0,2821	0,2308	0,2735	1
BROAD LAND (Ha)	0,2673	0,2723	0,1881	0,2723	1
HEIGHT LOCATION (m)	0,3684	0,2105	0,1579	0,2632	1
BATHYMETRI (m)	0,1690	0,2113	0,2817	0,3380	1
SEA WAVE HEIGHT (m)	0,2581	0,2473	0,2688	0,2258	1
WIND VELOCITY (knot)	0,2338	0,2239	0,2587	0,2836	1
TIDE WATER (m)	0,2593	0,2222	0,2407	0,2778	1
SEDIMENTATION RATE (ppm)	0,2727	0,2576	0,2273	0,2424	1
DEVELOPMENT COST (Rp./m2)	0,2456	0,2690	0,2281	0,2573	1
OPS ADVANCE COST (Rp)	0,2469	0,2716	0,2222	0,2593	1
QUANTITATIVE WEIGHT	**0,2535**	**0,2468**	**0,2304**	**0,2693**	1

NAVAL BASE	Oti
NB1	0,253
NB2	0,247
NB3	0,230
NB4	0,269

K. Calculating total value rankings (end) of each alternative to qualitative criteria and quantitative criteria

TOTAL RANKING		
NAVAL BASE	Fti	RANKING
NB1	0,242	III
NB2	0,248	II
NB3	0,242	III
NB4	0,268	I

L. Choosing the best alternative based on the value of the highest rank.

Based on modeling analysis with Fuzzy MCDM algorithm model that has been done over then get to the alternate location Naval Base that could be developed for establishing Naval Base, with the following order of priority:

Rank I → NB 4: SORONG Naval Base
Rank II → NB 2: MAUMERE Naval Base
Rank III → NB 1 and NB 3: PALU and TERNATE Naval Base

5. Discussion

Site Selection Research

In general, studies on the choice of location has a lot to do. Methods for site selection have also been widely applied and developed. Some researchers who have done: Hongzong Jia et al (2006) optimizing the selection of the location of medical supplies facilities with maximal covering methods and genetic problems algorithm. Shourijeh et al (2012) in his research on the optimization of placements where telecenters by using the method of Mathematical optimization models combined with Multi objective Optimization Problem (MOP) Goal Programming. Borah et al (2013) conducted a wind turbine site selection optimization with fuzzy logic and GIS system uses three parameters that are qualitative environmental conditions, location and the physical condition of the human factor. Kengpol et al (2013) made a Decision Support System for the selection of Solar Power Plant Location by Applying Fuzzy AHP and TOPSIS. Tierno et al (2013) conducted a study on the retail site location using GIS and the Analytical Hierarchy Process (AHP). Eylem Koc (2015) did an application of Analytical Hierarchy Process (AHP) in a real world of store location selection.

The Proposed Methodology in the paper is a development of the theory of sets covering concept introduced by Duskin (1995), Heragu (1997) and the development of the concept of fuzzy MCDM theory introduced by Liang and Wang (1994). The set covering methodology followed up by Manfaat (1998) in paper about computer-based approach to the effective utilization of spatial layout design experience and the next done by Suharyo (2006) developed a set covering theory as part of the navy fleet placement. Some things become creativity and development of the methods concepts mentioned above are

A. The additional program in the form of zero-one matrix of decision variable in theoretical concept covering technique. Zero-one matrix is the decision-making variables that have price value of 0 (zero) or 1 (one). 0 (zero) means that the naval base is not elected , and 1 (one) means the naval base was selected to provide cover in the operating sectors with the aim of minimizing the hub-port base to cover more bases. Decision 0 or 1 is an integer instead of fractional decision, since the selection of the naval base is the selection of a unity variables intact as a single base unit.

B. Integration of Covering Technique concept with Fuzzy MCDM concept is one form of creativity development methods in this paper. One thing that becomes critical point in site selection issue is suitability method was applied to the condition of the real problems in the field. This is the main reason of the integration of these two concepts above. Because in choosing Naval Base locations, initial selection should be done is to minimize the number of bases in a single sector of operation, wherein the base is selected to represent the base more to cover the area of sector operations with a variable of cruising boat distance, the distance between the base and within the base to the operation sector. Basic exact method is the development of Covering Technique methods. The next step is done by analyzing qualitative variables of the political, technical and economic aspects can be solved by the algorithm of Fuzzy MCDM with the results of the weighting and ranking the Naval Base candidates.

Comparing with Fuzzy AHP Methods

Determining the location of Naval Base is a Multi Criteria Decision Making (MCDM). One method often used is Fuzzy Analytical Hierarchy Process (Fuzzy AHP) which is an integration of Fuzzy theory introduced by Zadeh (1974) and AHP initiated by Saaty (1980). This method has been widely used by previous researchers on issues of site selection.

The description of fuzzy AHP steps can be explained as follows

1. Change the linguistic variables in the form of fuzzy numbers. Questionnaire data in the form of linguistic variables are converted to the form of fuzzy numbers. Examples of fuzzy numbers for triangular fuzzy numbers (Triangular Fuzzy Number or TFN) shown in Table 9. Linguistic variable is converted into a three -level fuzzy, low (c); medium (b); and high (a).

Table 9 *Scale Variable TFN in Linguistics*

Scale Linguistics	**Value Resolute AHP**	***Fuzzy TFN Scale* (a, b, c)**	***Inverse***
Both elements are equally important	1	(1,1,1+Δ)	(1,1,1/1+Δ)
Elements of the approach a little more important than any other element	3	(3-Δ,3,3+Δ)	(1/3+Δ,1/3,1/3-Δ)
Elements of the approach are more important than others	5	(5-Δ,5,5+Δ)	(1/5+Δ,1/5,1/5-Δ)
One element of the absolute approach is more important than other elements	7	(7-Δ,7,7+Δ)	(1/7+Δ,1/7,1/7-Δ)
One element is absolutely important than other elements	9	(9-Δ,9,9)	(1/9,9,1/9-Δ)
Values between two adjacent consideration	2,4,6,8		

2. Develop a pairwise comparison matrix between all the elements / criteria in the dimension hierarchies based on assessment system linguistic variable.

$$\tilde{A} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots\cdots \tilde{a}_{1j} \\ \tilde{a}_{21} & 1 & \cdots\cdots \tilde{a}_{2j} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{i1} & \cdots & \cdots\cdots 1 \end{pmatrix} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots\cdots \tilde{a}_{1j} \\ 1/\tilde{a}_{21} & 1 & \cdots\cdots 1/\tilde{a}_{2j} \\ \vdots & \ddots & \vdots \\ 1/\tilde{a}_{i1} & \cdots & \cdots\cdots 1 \end{pmatrix}$$

$$\tilde{a}_{ij} = \begin{cases} \tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9} & \textit{Criteria i relative importance to j} \\ 1 & \textit{Criteria i equally important to j} \\ \tilde{1}^{*},\tilde{3}^{*},\tilde{5}^{*},\tilde{7}^{*},\tilde{9}^{*} & \textit{Criteria i is less important to j} \end{cases}$$

3. Calculate the Geometric Mean of the Respondents' Assessment

The next step is a recap of all respondents assessment results and calculate the geometric average of the lower limit value (c) ; a middle value (a) ; upper limit value (b) of the total respondents . Here is the formula used to calculate the geometric mean.

c = $\sqrt[n]{c1}, c2, \ldots. cn$
a = $\sqrt[n]{a1}, a2, \ldots. an$
b = $\sqrt[n]{b1}, b2, \ldots. bn$

4. Defuzzification

After calculating geometric average, these results do defuzzification to obtain crisp values of the value of the geometric mean fuzzy numbers to be processed again in the AHP. One defuzzification technique is Centre of Gravity (COG). The formula of defuzzification is as follows:

$$\text{COG} = \frac{\frac{1}{(a-c)}\left[\frac{1}{3}x^3 - \frac{c}{2}x^2\right]_c^a + \frac{1}{(a-b)}\left[\frac{1}{3}x - \frac{b}{2}x^2\right]_c^b}{\frac{1}{(a-c)}\left[\frac{1}{3}x^2 - cx^2\right]_c^a + \frac{1}{(a-b)}\left[\frac{1}{3}x^3 - bx^2\right]_c^b}$$

5. Calculate the Weight Value by AHP

Weight calculation is done if the results of the questionnaire proved to be consistent, if the value Consistency Ratio (CR) < 0.1, to get the CR calculation Consistency index (CI) in advance. Here's the formula for calculating CI:

CI = $\frac{\lambda \text{max} - \text{n}}{n-1}$

λmax = the maximum eigenvalues
n = the size of the matrix
CI = consistency Index

The CI value is compared to the value Ratio Index (RI) in accordance with the size of the matrix so that the value Consistency Ratio (CR). Matrix is otherwise consistent if the CR value is not more than 0.1

The AHP hierarchical structure diagram of Naval Base site selection can be shown as follows

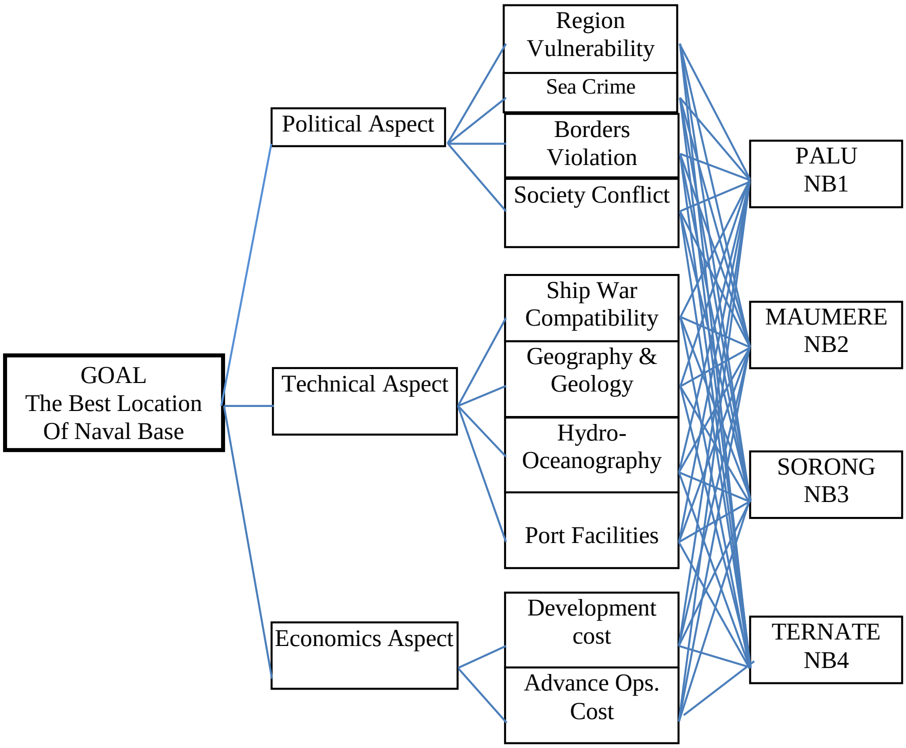

Figure 4 *Hierarchical Structure Diagram of Naval Base Site Selection*

Furthermore, by using the Fuzzy AHP steps above, the author completed the calculation of the assessment and weighting several candidate locations naval base, with the following results

Table 10 *Fuzzy AHP Result*

TOTAL RANKING		
NAVAL BASE	WEIGHT	RANKING
NB1	0,243	III
NB2	0,247	II
NB3	0,243	III
NB4	0,267	I

Figure 5 below shows a comparison diagram of the data processing result by Covering Technique- Fuzzy MCDM and Fuzzy AHP methods. Based on the Figure 5 we can analyze that the results are not much different between the two methods. This shows that the proposed methods can work well in problems of determining the location of Naval Base.

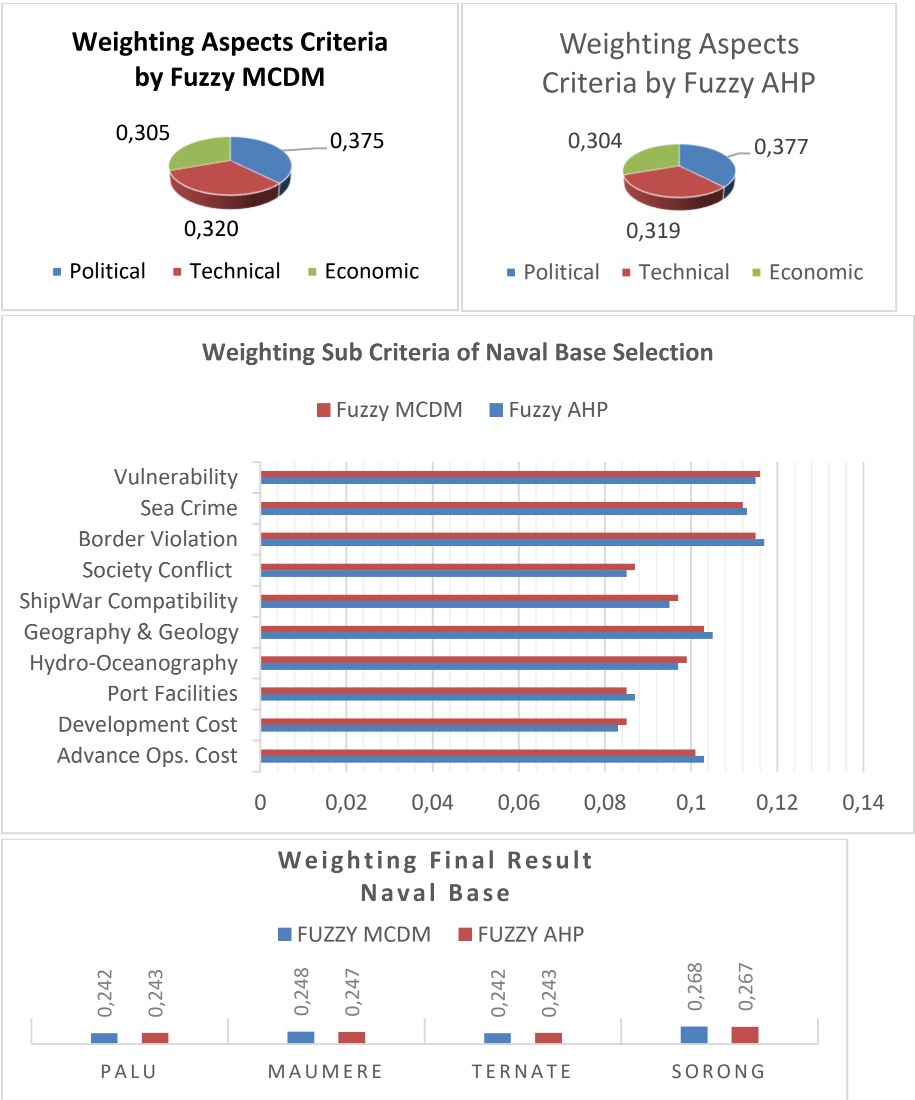

Figure 5 *Comparison of Results between Fuzzy MCDM and Fuzzy AHP Methods*

6. Conclusion and Future Work

In this paper, a case study about establishing the locations of some naval bases with the minimum number of naval bases locations was investigated. The main problem in this paper is how to determine the location of appropriate naval base to be developed into a larger naval base. The naval base selected must be able to cover the other naval bases based on the distance of cruising ship, the distance between naval bases, the distance base to operation sector, and by weighting on the political, technical and economic aspect. Variables in the Political, Technical and Economic aspects are: region vulnerability, sea crime, borders violation, society conflict, war ship compatibility, geography, geology, hydro-oceanography, port facilities, advanced development cost, operations cost assessed.

In this paper, we presented the two-step procedures or methods that in each stage regarding the situation we used different tools and models. The two-step procedure are Covering Technique including zero-one matrix programming, and Fuzzy MCDM method. The benefits of integrating two methods in this study is indeed simplification of solving problems in the field, because the development of naval base is unique and complex problem. Various variables are very influential both on quantitative and qualitative in decision-making. Integration of Covering Technique method and Fuzzy MCDM is able to solve these problems simply and systematically.

Based on the experiences gained during this case study, following researches are proposed

- Sustainability of the naval base as a system needs to be included in the future research as one aspect in determining the naval base beside political, technical and economic aspects.
- Sustainiblity aspects of the naval base is assessed on the dynamics of system that happens to any given period of time based on current developments of a political, technical and economic situation. This future research can proceed with the system dynamic methods to assess the sustainability of the naval base, see Figure 6 below. (Followed up by author on the future research)

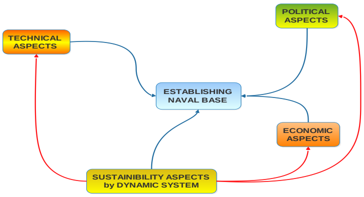

Figure 6 *Diagram of Naval Base Development in the Next Research*

Author Statement

This paper is the result of the author research for the purposes of education only and development of operations research and modeling science, not a result of the policy of the Indonesian Navy institution, because the data used is confidential, and is used for educational purposes only without reducing the substance of modeling and study interests.

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