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THE APPLICATION OF FUZZY MULTI-CRITERIA DECISION MAKING TO DETERMINE CRITERIA OF SUBMARINE TRAINING LOCATION

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ABSTRACT

Indonesian Navy as a marine security defense force has an Integrated Navy Weapon System, one of them is the power of Submarine and the amount of it will continue to evolve. The current condition demands to perform development and review of strategic and optimal submarine training areas to support the exercise and preparedness of the submarine's strength to prepare the readiness of combat conditions. The purpose of this study was to determine the best criteria for the location of the submarine training by analyzing and reviewing some of the existing locations of Navy Submarine Exercise practice and doing further development. In the selection of submarine training criteria, the method used was the Fuzzy Multiple Decision-Making Criteria (FMCDM). The result of the criteria weight assessment had been re-verified by the experts with 90% agree, 5% strongly agree and 5% disagree and 10 compatible criteria were needed to be considered in selecting the location of Navy submarine training which includes: obstacle/barrier condition, speed of the current, ship maneuver, water area, salinity, depth of water, availability of logistics, density, tidal and availability of materials.

Keywords: Fuzzy MCDM, Criteria of Location, Submarine Training

1. INTRODUCTION

To improve marine professionalism, the Indonesian Navy needs routinely and continuity to execute the training of assignment operation. Among several operational exercises conducted, one of them is Submarine Operation Training. Due to the difficulty and more complex factors in any submarine operation area, along with the growing criteria of submarine training areas, it requires better learning and analysis of various submarine training alternatives. By utilizing technology and the development of existing science, hence difficulty can be faced and solved with more effective and efficient.

In the implementation of the determination of the submarine training operation area, there is the decision-making process and operating goals setting. The right information input and accurate decision-making capabilities were needed to be able to perform this process, whether it is qualitative information or quantitative information. The location of the submarine training site as a part of the submarine training should be meticulously and precisely supporting the submarine's operational training. The deployment must be appropriate so that the impact of the submarine's training area can be felt close to the actual operating area [1].

The fuzzy theory concept was initiated by Lotfi A. Zadeh in 1965 with his seminar paper "Fuzzy Sets" [26]. The ability of fuzzy sets to express the change degree from membership and vice versa has a very wide use. It does not only represent the measurement of uncertainty but also represents the concept of fuzziness. According to [14], the fuzzy system is a structured and dynamic numerical predictor. This system can develop intelligence systems in uncertain and inapproachable environments. Fuzzy logic is part of Boolean logic that is used to handle the concept of truth degree between right and wrong. Fuzzy logic, with the original idea, is how to present the blurring, where the presentation should be sufficient to illustrate the blurring. However, on the other hand, it should be simple enough so that computing becomes easier.

The fuzzy method can be developed as a tool for assessing alternatives. The other applications as a tool in selecting alternative project partners by taking into account several criteria as requirements [2].

In this paper, the authors applied a method that could examine alternative evaluation based on qualitative and quantitative criteria by using a Multi-Criteria Decision Making Model. In this case, the method used was Fuzzy MCDM

(Fuzzy Multiple Criteria Decision Making). Fuzzy Multiple Criteria Decision Making (Fuzzy Multiple Criteria Decision Making) models is very suitable for processing quantitative and qualitative data criteria simultaneously, resulting in DSS (Decision Support System) data for decision-makers, which in this thesis research was to determine the ideal and optimal submarine training area for Indonesian Navy.

This study was based on various literature studies, such as the application of fuzzy sets in the decision-making process [25]. Decision making for leaders [27]. Concepts and Applications of Decision Support Systems [3]. Fuzzy logic and application on GIS [22]. Evaluation Development strategy using the Fuzzy MCDM approach [5]. The LCD-TV marketing strategy based on customer behavior [6]. Development of Fuzzy MCDC [7]. The search of Attribute weight on Multi-Attribute Decision Making (MADM) with the subjective approach using genetic algorithm [18]. Fuzzy Set and Its Application [27], Fuzzy Approach of MCDM for planning and selection of public facility building design auction [9]. The concept of linguistic variables and their applications [25]. Tutorials on fuzzy logic [10].

This research examined the criteria selection of submarines training areas for the Indonesian Navy. It began with data retrieval based on documents and interviews with Experts about submarines and their support with the Koarmatim Submarine Task Force as the base. These data included the factors that influence the selection of the training location and the characteristics of the training location. The data collection was based on the collection method of primary and secondary data. Primary data was obtained from the data collection through questionnaires and interviews with correspondents as the decision-makers and experts in the field of submarine training operations. The questionnaire data was the perception of correspondent against criteria and alternatives. Secondary data was obtained from the results of literature studies or reference books related to the criteria and alternatives. The data obtained was the result of the analysis and staff review in the Navy Submarine Unit and had relevance to the research.

This research consisted of several sections, section 2 was the theory of fuzzy theory, section 3 was the research result, section 4 was the explanation of weighting assessment on each quantitative criterion, the weighting of quantitative criteria, determining mean value, determining the mean value of the fuzzy number, determining upper limit value and the lower limit of the fuzzy number, calculation of the aggregate weight of each criterion, calculates the defuzzification results of the qualitative and qualitative criteria calculations, calculates the final weight value, and finally, section 5 was conclusion and recommendation.

2. MATERIALS AND METHODS

2.1. Submarine Theory

Submarines are ships that move below the surface of the water, generally used for military purposes and interests. Most of the Navy owns and operates submarines even though the number and population of each country are different (Suharjo, 2019). In addition to being used for military purposes, submarines are also used for marine and freshwater science and duty at depths that are not suitable for human divers. Military submarines are used for the benefit of war or marine investigations of a country. Based on the type, every military submarine is always equipped with weapons such as cannons, torpedoes, anti-aircraft missiles, and anti-surface vessels, as well as intercontinental ballistic missiles [21].

2.2. Submarine Training Location

In conducting combat operations and submarine training, the configuration of archipelagic geography and hydro oceanography must be taken into account (Susilo, 2020). The example of it was described as follows:

a. Geography

The geographical physical form of Indonesia consists of a group of islands that have a lot of maritime access straits and chokepoints that connect ZEE with Archipelagic Water. A large number of maritime access can cause vulnerability for Indonesian marine defense which puts archipelagic waters as resistance field and considered as a vital area for Indonesian marine defense [17].

b. Hydro-Oceanography

The geographical form of Indonesia with the number of straits and seas affects the physical properties that also directly affect the parameters of seawater characteristics (Nugroho, 2019). It was described bellow:

1) Surface currents, tidal currents, and coastal currents.

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2) Surface temperature, salinity, and density of seawater.
3) Transparency and color of seawater.
4) The depth of the sea (bathymetry).

2.3. Fuzzy Theory Concept

The concept of the fuzzy theory was initiated by Zadeh in 1965 on his paper called 'Fuzzy Set' [25]. Fuzzy theory shows that all theories can be used as the basic concept of a fuzzy set or continuous membership function. Broadly speaking, fuzzy theory can be classified into five main areas, namely:

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

2.4. Membership Function.

The membership function is a curve which presents the mapping of data input points into their membership values (also called membership degrees) that have intervals between 0 and 1. One way that can be used to obtain membership value is through approach function. Several functions can be used:

a. Linear Representation

In a linear representation, the mapping of the input to its membership degree is described as a straight line. This form is the simplest and the best choice for approaching a less obvious concept. There are two linear fuzzy set states, the first is that the set increment starts at a domain value that has a zero membership degree [0] moving right to the domain value that has a higher degree of membership (Herdiawan, 2019).

Membership Function: $[x] = \begin{cases} 0; & x \leq a \\ (x-a)/(b-a); & a \leq x \leq b \\ 1; & x \geq b \end{cases}$

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

Membership Function:

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

b. Triangular Curve Representation

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

Membership Function:

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

c. Representasi Kurva Trapesium

The trapezoid curve is a triangular shape, except that there is a point that has a membership value of 1.

Membership Function :

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

d. Triangular Fuzzy Number (TFN)

In TFN, every single value (crisp) has a membership function consisting of three values and each of it was representing the lower, middle and upper values. Graphically, the membership function with TFN can be describedin the following figure:

$$\mu[x] = \begin{cases} 0; & \text{for } x < a1 \\ \frac{x-a_1}{a_2-a_1}; & \text{for a1} < x < a2 \\ \frac{a_3-x}{a_3-a_2}; & \text{for a2} < x < a3 \end{cases}$$

d. Value of Defuzzification

Defuzzification is a process of conversion and quantity of fuzzy into a definite quantity, where the output and the fuzzy process can be a combination of logic from two or more fuzzy membership functions defined following the universe of speech. Defuzzy input and process is a fuzzy set obtained from the composition of fuzzy rules, while the

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resulting output is a number in the fuzzy set domain. Therefore, when a set fuzzy within a certain range is given, then a certain crisp value as the output should be taken. Several defuzzification methods can be used. They are described below:

1) Centroid Methods (Composite Moment). In this method, the crisp solution is obtained by taking the center point (z) of the fuzzy area.
2) Bisector method. In this method, the crisp solution is obtained by fetching a value on the fuzzy domain that has a membership value of half of the total membership value in the fuzzy area.
3) Mean of Maximum Method (MOM). This method of crisp solution is obtained by taking the average value of domains that have a maximum membership value.
4) Largest of Maximum Method (LUM). This method of crisp solution is obtained by taking a magnified value from a domain that has a maximum membership value.
5) The Smallest of Maximum Method (SOM). In this method, the crisp solution is obtained by taking the smallest value of the domain that has the maximum membership value.

2.5 Linguistic Variable

Variable linguistics is a variable that has a description of fuzzy numbers and more generally a word represented by a fuzzy set. For example, the descriptions of linguistic variables for the criteria of threat area of the country in the form of LOW, MEDIUM, and HIGH where the description is expressed as fuzzy value (fuzzy value) [23]. Like algebraic variables that use numbers as values, linguistic variables use words or sentences as values. It forms a set called the "term" set and each value of "term" is a fuzzy variable defined by the base variable. While the base variable defines the universe of speech for all fuzzy variables in the "term" set (Jantzen, 1998).

2.6. Multi-Criteria Decision Making

Multi-Criteria Decision Making (MCDM) is an approach for a decision-making process that has a decision problem situation with criteria, objective, or multiple attributes [15].

2.7. Data Processing

After the data obtained from the questionnaire, the next step was to recapitulate the results of questionnaires and to process the data. The data processing used the fuzzy MCDM algorithm. In data processing used the MCDM fuzzy algorithm, the sequence of the process would be described as follows (Liang, 1994):

a. Tabulate the criteria weighting result of the qualitative criteria to get the aggregate weight value.

b. Tabulate the results of ratings or preferences for each alternative based on existing qualitative criteria.

c. Determine the middle value of the fuzzy number, by summing the values that appear at each level of the linguistic scale and then dividing the sum with the number of criteria whose value falls into the level of the linguistic assessment. The mathematical notation was described as follows:

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

a_t = Mean of the level fuzzy

T = Level of assessment, namely very low, low, medium, high, and very high.

n = The number of scale factors of the linguistic scale T for the 1st alternative of the i-th factor.

T_{ij} = The numerical value of the linguistic scale T for the 1st alternative of the j-th factor

d. Determining the lower bound value and the upper limit value of the fuzzy number, where the lower bound value (ct = b (i - 1)) was equal to the lower mean value, while for the upper bound value (bt = b (i - 1)) was equal to the mean value of the level above it.

e. Determining the aggregate weighting of each qualitative criterion. This study used a linguistic appraisal form that already has the definition of a fuzzy triangular number. Thus, the aggregate weighting was needed to be determined. The aggregation process was performed by finding the aggregate value of each lower limit value (c), the mean value (a) and the upper limit value (b), which can be modeled as follows:

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

c_{tj} = the value of the lower limit of the qualitative criterion t by the j-th decision maker

a_{tj} = the mean value of the t-th qualitative criterion by the j-th decision maker

b_{tj} = the upper limit value to the t-th qualitative criteria by j-th decision-makers

n = the number of assessors (decision-makers) The Aggregate value was

N = (c_j,a_j,b_j) Where:

Nt = the aggregate weighting value for the t-th qualitative criterion

f. The next step was to find the value of criteriadefuzzification. The defuzzification method used wass the method of centroid. The formula of the defuzzification criteria was described as follows:

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

Where: t = criteria of 1, 2, 3......n

g. The Defuzzification value processing into the Final Weight Value of each criterion, by dividing the Weight Value of each defuzzification criterion by the total number of weight values across the defuzzification criteria.

NB t = Nt /ΣNt(1-n)

Where :

NB t = The final weighting value of each criterion

Nt = The value of the defuzzification criteria weight

ΣNt (1-n) =The total weighted value of the entire defuzzification criteria

3. RESULT AND DISCUSSION

The analysis and discussion of choosing submarine location criteria consist of several steps which were:

Step 1. Collection and data processing for data analysis and interpretation and the preparation of the Fuzzy MCDM Model.

Based on collecting and processing the data, the desired result Data and questionnaires were known to be used to determine the weight of qualitative and quantitative criteria based on each criterion by using the fuzzy MCDM algorithm. So, the value rank of importance wight on each could be obtained. Data input was performed using manual calculations from questionnaires. Questionnaires were distributed to DM (Decision Maker) Submarine Unit Commander (DM 1), Submarine Academy Commander (DM2), Commander of Navy Ships A (DM3), and Commander of Navy Ships B (DM4). The data obtained were used to determine the weight of each criterion. The Fuzzy method was used for data processing and to quantify the data.

Table 1. Describes the recapitulation of the weight in each criterion by the questionnaire generated by Fuzzy MCDM. It calculated by two scoring scales of Linguistic scale (L) and Numerical scale (N). The linguistic scale was divided into 5 levels of assessment, namely "very low", "low", "medium", "high" and "very high", while the assessment for a numerical scale was between 1-10.

Table 1: Recapitulation of questionnaire data for criteria assessment.

No.	Criteria		DM 1		DM2		DM3		DM4	
			L	N	L	N	L	N	L	N
1	Qualitative	Conditions of water barrier	ST	9	ST	9	ST	9	ST	10
2		Ship Maneuver	T	8	T	7	T	7	T	8
3		Personnel Logistic Availability	T	7	T	8	T	7	ST	6
4		Materials Availability	S	6	S	6	S	5	T	7
5	Quantitative	Waters Area	T	8	T	7	T	8	T	8
6		Depth	S	6	T	7	T	7	T	8
7		Speed of Current	T	8	T	8	ST	9	ST	9
8		Water Density	T	7	S	6	S	5	T	7
9		Water Salinity	T	7	T	8	T	7	T	8
10		Water Tidal	T	7	T	6	S	5	T	7

Based on the results data presented above, a graph of membership function for each respondent based on the level of importance of qualitative and quantitative criteria could be arranged on the scale of the lower, middle, and upper-value limits. The results were described as follows:

Table 2: TFN Respondent of qualitative and quantitative assessment

No.	LINGUISTIC LEVEL	DM 1			DM 2			DM 3			DM 4		
		ct	at	bt	ct	at	bt	ct	at	bt	ct	at	bt
1	Very Low	-	-	-	-	-	-	-	-	-	-	-	-
2	Low	-	-	-	-	-	-	-	-	-	-	-	-
3	Moderate	1	6	7,43	1	6	7,5	1	5	7,2	1	6	7,6
4	High	6	7,43	9	6	7,5	9	5	7,2	9	6	7,6	9,5
5	Very High	7,43	9	10	7,5	9	10	7,2	9	10	7,6	9,5	10

The chart below shows the TFN membership function for each respondent in the criteria importance level. Each criterion of respondents was shown in the value of lower, middle and upper limit with the membership degree of 0-1.

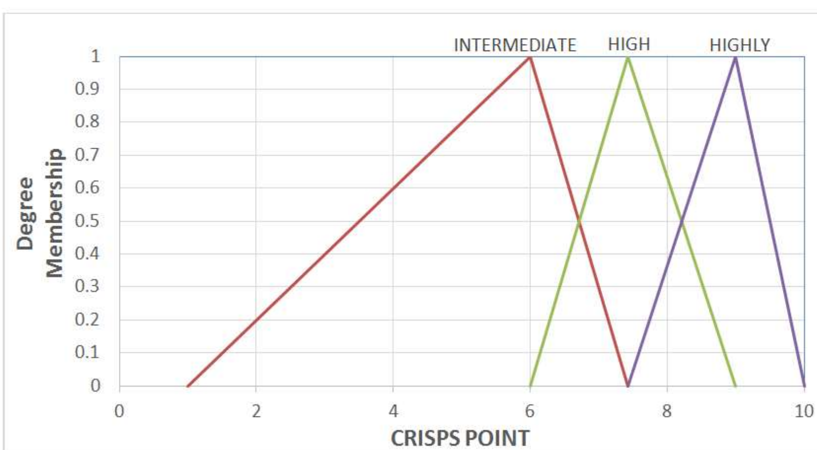

Figure 1: Membership Function of Triangular Fuzzy Number from DM 1

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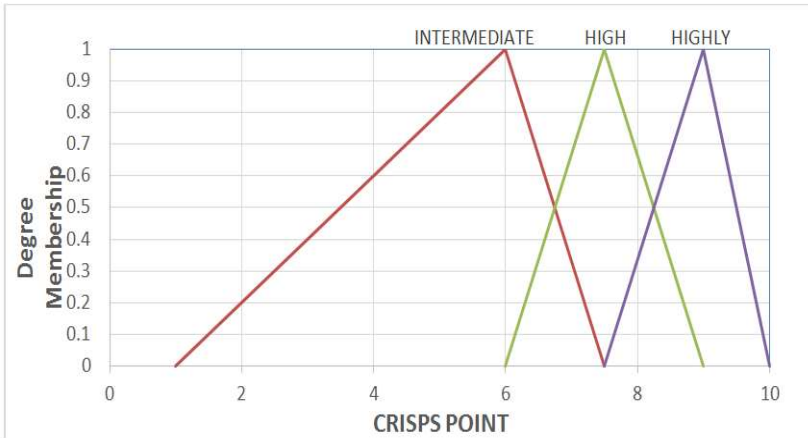

Figure 2: Membership Function of Triangular Fuzzy Number from DM 2

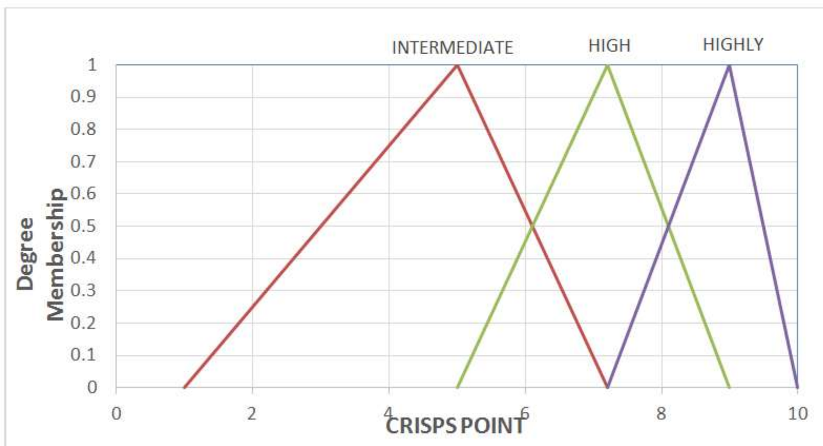

Figure 3: Membership Function of Triangular Fuzzy Number from DM 3

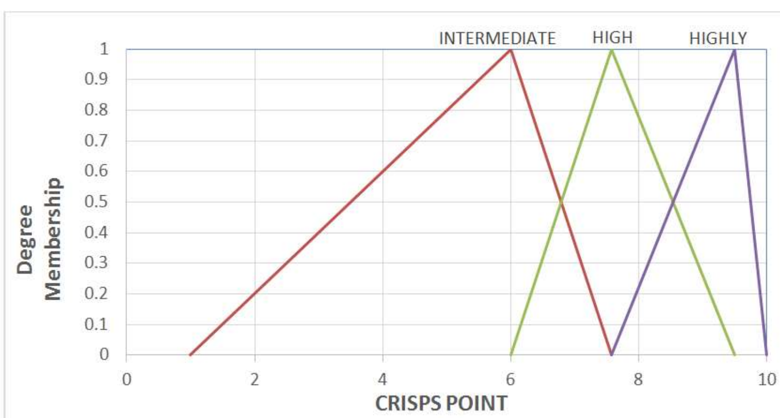

Figure 4: Membership Function of Triangular Fuzzy Number from DM 4

Respondents evaluated each selection of criteria by using linguistic scales to obtain weight levels for the criteria importance. The weights on the Linguistic and Numeric scale were shown in Table 1.

Step 2. Calculate the aggregate weight for each criterion that will be used in defuzzification. The results of the average Aggregate Weight for the criteria importance were presented in Table 3.

Table 3: Aggregate Weight of Qualitative and Quantitative Criteria

No.	Criteria		Weight Average		
			ct	at	bt
1	Qualitative	Conditions of water barrier	7,43	9,13	10
2		Ship Maneuver	5,75	7,43	9,13
3		Personnel Logistic Availability	4,5	7,03	8,64
4		Materials Availability	2,25	6,14	7,91
5	Quantitative	Waters Area	5,75	7,43	9,13
6		Depth	4,5	7,07	8,73
7		Speed of Current	6,69	8,36	9,5
8		Water Density	3,5	6,5	8,3
9		Water Salinity	5,75	7,43	9,13
10		Water Tidal	3,5	6,5	8,3

Step 3. Calculate the defuzzification using the centroid method by taking the *Crisp* value (singular value) coming from the middle of the existing fuzzy area so that it would match the design of the membership function and the fuzzy rule base used. Defuzzification results were presented in Table 4.

Table 4: Criteria of Defuzzification Weight

No	Criteria		Defuzzification Weight
1	Qualitative	Conditions of water barrier	8,850
2		Ship Maneuver	7,433
3		Personnel Logistic Availability	6,725
4		Materials Availability	5,433
5	Quantitative	Waters Area	7,433
6		Depth	6,767
7		Speed of Current	8,183
8		Water Density	6,100
9		Water Salinity	7,433
10		Water Tidal	6,100

Step 4. Calculate the final weight value of each qualitative and quantitative criteria. The results were presented as follows:

Table 5: Rank in Each criterion

No.	Criteria		Final Weight	Ranking
1	Qualitative	Conditions of water barrier	0,126	1
2		Ship Maneuver	0,105	3
3		Personnel Logistic Availability	0,095	7
4		Materials Availability	0,077	10
5	Quantitative	Waters Area	0,105	4
6		Depth	0,096	6
7		Speed of Current	0,116	2
8		Water Density	0,087	8
9		Water Salinity	0,105	5
10		Water Tidal	0,087	9

Based on the ranking result on the qualitative and quantitative criteria described above, it could be seen that the first criterion was the condition of water obstacle/barrier was the first rank with the weight of 0.126 followed by the criteria of Current Speed with the weight of 0.116, and the third rank was the criteria of Ship Maneuvers and the last weight was the availability of material with a weight of 0.077.

Step 5. Verification. Verification was performed to check and collect Expert/DM/Respondents' opinions about the final weighting criteria of submarine training location. Verification was performed by sending the Questionnaire back to the Decision-maker about the final weighted criteria of the submarine training location with the results described in Table 6.

Table 6: The Results of Verification Total in DM 1 to 4

No.	LOCATION CRITERIA	Final Weight	Ranking	Strongly Disagree	Disagree	Agree	Strongly Agree
1	Barrier Condition	0,126	1	0	0	2	2
2	Speed of Current	0,116	2	0	0	2	2
3	Ship Maneuver	0,105	3	0	0	2	2
4	Waters Area	0,105	3	0	0	3	1
5	Water Salinity	0,105	3	0	0	4	0
6	Depth	0,096	4	0	1	3	0
7	Personnel Availability	0,095	4	0	0	3	1
8	Water Density	0,087	5	0	0	4	0
9	Water Tida	0,087	5	0	1	2	1
10	Material Availability	0,077	6	0	0	3	1
Percentage Amount				**0 %**	**5 %**	**70 %**	**25 %**

The other results of weight in DM 1, DM2, DM3, and DM 4 all stated **Agree** and **Strongly Agree** on the weighting of 10 Criteria of Submarine training location. So that the final weighting/value of each Determination Criteria on Location of Submarine Training with Fuzzy MCDM method could be described.

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4. CONCLUSION.

After performing research methods and data processing on the selection of naval submarine training location by using MCDM fuzzy method, it can be concluded that:

a. Based on the result of literature study and brainstorming with the experts in conducting the election of Navy submarine training location, 10 compatible criteria were needed to be considered in selecting the location of Navy submarine training which includes: obstacle/barrier condition, speed of the current, ship maneuver, water area, salinity, depth of water, availability of logistics, density, tidal and availability of materials.

b. The decision-making process within the Navy's submarine training location was not done by a single decision-maker, but it involves many decision-makers so that each decision-maker would provide a different assessment of subjectivity to those criteria.

c. The fuzzy algorithm could be applied in the selection of this submarine location because it can eliminate the fuzziness of data and criteria that were qualitative with high subjectivity value. The FMCDM method was able to accommodate and analyze all the criteria and processes so that it could become more easily translated in supporting the decision-making system.

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