MODELING MARINE OPERATIONS BASED ON INTELLIGENCE THREAT PREDICTION IN INDONESIAN NAVAL 2ND FLEET COMMAND USING MCDM

By Okol Suharyo

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Okol Sri Suharyo , Budi Santoso W , Faiq Mumtaz M

[1,3]Indonesian Naval Technology Collage
Bumimoro-Morokrembangan, Surabaya 60178, Indonesia
[2]November 10th Institute ofTechnology
Keputih-Sukolilo, Surabaya 60111, Indonesia
e-mail: okolsrisuharyo@sttal.ac.id

ABSTRACT

Indonesia, which is an archipelago country, needs strong maritime sector security. Indonesian Navy in Law No. 34 of 2004 has been given the mandate to safeguard the sovereignty of the Republic of Indonesia. Indonesian Naval 2^{nd} Fleet Command as the executing command and operational supervisor every year carries out the OMSP, which is carried out under the command of naval battle group (Guspurla) and marine security group (Guskamla). The importance of intelligent information regarding the estimated threat / contingency that will occur is very influential on decision makers in an operational planning and in the context of taking action against the contingency/threat. With the contingencies that have been given by the intelligence sector staff, it is necessary to have an appropriate marine operation modeling. In multi-operation operations, it is necessary to have a supporting attribute, namely a headquarters warship (C2). The purpose of this study is to formulate an operation modeling using the selection of a headquarter warship which is preceded by the prior determination of contingency priorities. This study uses MCDM which consists of MCDA and MCDO which uses the integration of the Delphi method, AHP, Fuzzy Weighting, Goal programming and integer linear programming. Based on the processing of Delphi and AHP in determining contingencies, there are 6 (six) contingency priorities in the order: National jurisdiction marine security got a value of 0,23792; the spread of the pandemic was 0,22492; VVIP security was 0,20416; security of vital objects was 0,15410 and violence at sea was 0,12923 while marine pollution was 0,04967. While in the selection of a headquarters warship that functions to coordinate warships in carrying out sector patrols using FWH and IGP, 1^{st} warship was selected to be the headquarters warship (C2) with a value of 6,006; with the second priority 4^{th}warship, which was 6,652; 5^{th} warship was 7,198; 2^{nd} warship was 7,890 and 3^{rt} warship of 8,763. While in the modeling, it is found that in a year there are 4 operations under 2^{nd} Guskamla where the level of area is security obtained from the KRI (warship) assignment for ALFA operations is 152 with 4.963.600 Kl of fuel, KILO is to consume 8.104.200 Kl of fuel, MIKE is 59,13 with 765.079 of fuel and by consuming 425.906 Kl of fuel on INDIA operations get a level of safety area of 44,91.

Keywords: *MCDM, Contigency,headquarters warship.*

1. INTRODUCTION

The Navy is an integral part of the TNI having a role as a major component of state defense and security in the maritime dimension, carrying out its duties based on state policy and political decisions in order to uphold state sovereignty, maintain the territorial integrity of the Unitary State of the Republic of Indonesia (NKRI) based on Pancasila and the 1945 Constitution (Marsetio , 2013).In accordance with Article 9 of Law Number 34 Year 2004 concerning the TNI, the duties of the Indonesian Navy are as follows: 1) Carry out the duties of the Navy Marine Corps in the defense sector; 2) Upholding the law and maintaining security in the marine area of national jurisdiction in accordance with the provisions of national law, international law that has been ratified; 3) Carrying out the diplomatic duties of the Navy in order to support the foreign policy stipulated by the government; 4) Carry out TNI duties in the development and development of the strength of the marine dimension; 5) Implementing the empowerment of marine defense areas.

A marine operation planning needs intelligence support as an early warning system that produces intelligence information obtained through a processing process from information obtained in order to anticipate possible threats that will arise in order to determine steps with calculated risks.Intelligence as information that has been processed is a product which is subsequently conveyed to the users to be used as material for the preparation of plans and policies to be pursued and which allow for decision making materials.In other words, intelligence is needed to make correct decisions in three aspects, namely planning, wisdom and how to act.

Currently the Indonesian Navy in carrying out maritime territorial cover in all parts of Indonesia is divided into 3 commands, namely the Indonesian Naval Fleet Command (Koarmada) where the demands of Koarmada's duties are to carry out daily operations and marine combat operations for sea control and power projection to land via the sea in order to enforce the sovereignty and law at sea. The wide working area of 2nd Naval Fleet is faced with a variety of threats that arise as well as the limited number and capability of patrol boats and limits on operational support, on the other hand the rapid changes in the strategic environment will add to the increasingly complex problems of enforcement and security at sea.

Based on the above problems, this study offers a modeling of a marine operation in maintaining national maritime security based on threat prediction based on intelligent forecasting in Naval Fleet.

Like most real-world decision making problems, the selection of a predection of threats and C2 and modelling maritime operation systems requires a multiple criteria decision analysis (MCDA). Ho (2007) classified MCDAs into two technical categories, multiple objective decision making (MODM) and multiple attribute decision making (MADM). MODM is mathematical programming that has multiple objective functions and constraints. When an MCDA involves a number of independent or competing objectives, a multi-criteria mathematical programming approach is useful because it forces the simultaneous resolution of various objectives. Linier programming (LP) is an example of MODM.

MADM selects the best alternative among the various attributes that are to be considered. One of the most popular MADM techniques includes AHP. AHP structurally combines tangible and intangible criteria with alternatives in decision making. AHP logically integrates the judgment, experience, and intuition ofdecision makers. Because of its usability and flexibility, AHP has been widely applied to complex and unstructured decision making problems such as resource allocation, alternative selection, manufacturing, and military decision making. Recently, the analytic network process has been developed to handle decision problems that are not hierarchically structured (Saaty, 2008). Further, the fuzzy AHP is introduced to facilitate decisions under fuzzy situations (Kong & Liu, 2005).

A number of studies have integrated MADM and MODM. These studies have included a combined AHP-mathematical programming approach. On selection of a headquarters warship, some researchers applied combined approaches such as a hybrid AHP-integer programming approach to screen weapon systems projects (Greiner, Fowler, Shunk, Carlyle, & McNutt, 2003), an AHP approach based on linguistic variable weights (Cheng & Lin, 2002) an approach that integrated AHP with a technique for ordering performance by comparing alternatives to an ideal solution under a fuzzy environment (Dagdeviren, Yavuz, & Kılın, 2009), and an A hybrid approach of goal programming for weapon systems selection (Jaewook Le, Suk-Ho Kang, & Jay Rosenberger, 2009).

This research aims to make planning of a marine operation for Indonesian Naval 2nd Fleet Command in facing security threats in national waters, which includes obtaining priority for predicting threats that will arise in the future, Obtain the best alternative in order to select a base warship in a multi-operation operation and get the Guskamla operation model in 2nd Naval Fleet in order to maximize the coverage area with existing resources.

2. ANALYTICAL METHODS

2.1. Analytic hierarchy process

AHP, introduced by Saaty (1980), designs general decision problems based on a multilevel hierarchy of goals, criteria, subcriteria, and alternatives. AHP is characterized by three basic principles: hierarchical structure, the relative priority of decision criteria; and consistent judgment. It uses a pairwise comparison technique to derive the relative importance (or weight) of each criterion that reflects reasonable human judgment on elements in the same category. A pairwise comparison allows conversion of linguistic judgmentsinto numerical scales. When the importance of one element to another can be expressed as a scale of 1–9, scale 1 means the two elements are of equal importance, and scale 9 means one is extremely more important than the other. Pairwise comparison helps decision makers simplify a complex problem by focusing their interest on the comparison of just two criteria and improves their consistency across the decision process (Badri, 2001). Judgment by pairwise comparison produces a reciprocal matrix A, represented as follows:

$$A = \begin{pmatrix} a_{11} & a_{12} \cdots & a_{1n} \\ a_{21} & \ddots & \vdots \\ \vdots & & \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}$$

Each entry of A represents the relative importance of decision elements.For example aij is the relative importance in decision elementi against decision element j, and vice versa. It satisfies $a_{ij} = 1/a_{ji}$. The actual relative weights of decision elements can be obtained by computing the normalized eigen vector of A that satisfies the following equation:

$$A \cdot w = \lambda \cdot w_1$$

where k is the eigen value associated with eigen vector. Saaty (1980) recommended using the eigen vector, $w_{max} = [w_1, w_2, \ldots, w_n]$ T correspondin to the maximum eigen value, k_{max}, to represent the relative weights of each of the n criteria. This process should be performed at all levels of the criteria to obtain all the relative weights of the decision elements. During the process of deducing the weights, a consistency test can be performed to verify the reasonability of the decision makers' pairwise comparison. The measure of consistency is obtained by a consistency index (CI) and a consistency ratio (CR), which are definedas follows:

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

$$CR = \frac{CI}{RI(n)}$$

where n is the number of decision elements, and the random consistency index (RI) is an experimental value provided by Saaty (1990) as shown in Table 1.

Table 1. RandomConsistency Index

Tabel Index Random Konsistensi															
RCI values corresponding to the order of the matrix															
No. of criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

It can be seen that the RI increases in proportion to the order of matrix A. k_{max} equals to n if the judgments by comparison are perfectly consistent. If the CR is less than 0.1, the judgment is consistent; if the CR is greater than 0.2, the judgment is not consistent. If the value of the CR is between 0.1 and 0.2, the judgment is acceptable (Saaty, 1990).

2.2 Fuzzy Weighting

Fuzzy set theory was first developed by Zadeh, while the concept of fuzzy numbers was introduced by Dubois and Prade which aims to present and make the fuzzy theory concept more applicable (Liang & Wang, 1994).The main objective of the FWT method is to eliminate subjective judgments from the preferences of the experts by quantifying qualitative data or data that is uncertain into data that is quantitative and definite.The data processing step using the Fuzzy Weighting algorithm is to compile a qualitative/preference assessment table of the experts on the main aspects of the research object, compile a qualitative assessment table for the experts on the criteria and sub-criteria of the main aspects of the research object. Determine the mean value of the fuzzy number (at), by adding the values that appear at each level of the linguistic scale and then dividing the sum by the number of aspects or criteria whose valuesfall into the level of the linguistic assessment. The mathematical notation is as the following formula:

$$at = \frac{\sum_{i=1}^{k} \sum_{j} T_{ij}}{\sum_{i=1}^{k} n_{ij}}$$

After that determine the lower limit value (ct) and the upper limit value (bt) of fuzzy numbers, where the lower limit value (ct = b (i - 1)) is equal to the middle value of the level below, while for the upper limit value (bt = b (i - 1)) is equal to the middle value of the above level. Then determine the aggregate weight of each qualitative criterion, because in this study a form of linguistic assessment that already has a triangular fuzzy number definition is used, the aggregation process is to look for the aggregate value of each lower limit value (c), the middle value. (a) and the ceiling value (b), which can be modeled as follows:

$$ct=\frac{\sum_{j=1}^{n} c_{tj}}{n}$$

$$at=\frac{\sum_{j=1}^{n} a_{tj}}{n}$$

$$bt=\frac{\sum_{j=1}^{n} b_{tj}}{n}$$

The next step is to look for the defuzzification criteria, where the defuzzification method used is the centroid method. The formula for the defuzzification criteria using the centroid method is as follows:

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

Defuzzyfication can also be determined using the Aritmetic mean and the geometric mean. The results of previous studies indicate that the defuzzyfication using Geomean is close to the centroid results. Meanwhile, the aritmetic mean still has a low level of confidence.

The last stage is processing the defuzzification value into the final weight value of each criterion, by dividing the weight value of each defuzzification criterion by the total number of weight values of all defuzzification criteria.

$$NB\,t = \frac{Nt}{\sum Nt\,(1-n)}$$

2.3. Integer Linear Programming

Linear Programing is a planning technique that uses a mathematical model with the aim of finding the best product combinations in constructing a limited allocation of resources in order to achieve optimally used goals.

In building the formulation model of an optimization problem, the characteristics of Integer Linear Programing (ILP) are used (Suharyo, 2014), namely:

a. Decision variables are variables that describe the complete decisions to be made, which are denoted by X1, X2, X3, ..., Xn.

b. The objective function is a function of the decision variable that will be maximized or minimized. Expressed using the decision variables X1 and X2, to express the value of this objective function denoted Z.

c. Constraints are constraints faced, or limits that affect the decision variables. The coefficient of the decision variable on the constraint is called the technological coefficient, while the number on the right side of each delimiter is called the right side of the delimiter.

The sign delimiter is a delimiter which explains that the decision variable is assumed to have only non-negative value or that the decision variable can be positive or negative (not limited in sign).

In general, (Ryan, 2014) the Integer Linear Programming problem model can be formulated in the following example:

Maks : $Z = C_j X_j$.

Constraints: $C_{ij} X_j \leq / = / \geq B_i$, $j = 1,2,3, \ldots n$

$X_j \geq 0$, $j = 1,2,3, \ldots n$

X_j dengan $j = 1,2,3, \ldots, p$ ($p \leq n$)

2.4 Coverage Area

TNI AL warship that moves from one point to another during its endurance has a variable radar capability and speed. For the calculation of the patrol boat coverage and cruising range is described and formulated in the following figure

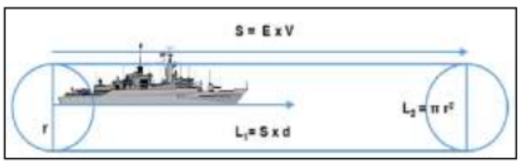


Figure 1. Illustration of a warship carrying out a patrol

$S = V \times E$ .... (4.5)

$L1 = S \times d$ .... (4.6)

$L2 = \pi r2$

Where :

S = Cruising distance per day (mil)

V = Speed (mil/hours)

E = Endurance (hours)

L1 = Rectangular area (mil^2)

L2 = Circle area (mil^2)

d = Radar range (mil)

r = The radius of the radar range circle (mil)

The patrol boat's coverage area is the area of a rectangle (L1) plus the area of the circle (L2).

Coverage Area = (L1+L2) x Prob radar detection

= (L1+L2) x (0,9)

2.5 Flow Chart

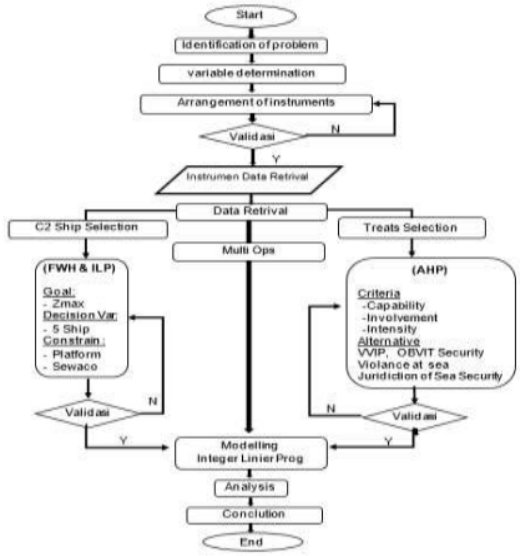


Figure 2. Flow Chart

3. RESULT AND DISCCUSION

3.1 Selection Of Threat Priority.

3.1.1. The Criteria And Alternatives Are Determined Using The Delphi Method.

At this stage, the identification of assessment criteria is carried out for weighting the level of importance of intelligent forecasting in supporting the implementation of operations. Based on Indonesian Law No. 34 of 2004 about the Indonesian National Army and interviews with several Intelligence experts in 2^{nd} Fleet.

Table2. Withdrawal of the Delphi Opinion Round 1

No	Aspect	Interviewees					Average	Std. Dev	Modus	Q1	Q2	Q3	R	Evaluation	
		X1	X2	X3	X4	X5								Std. Dev	R
Criteria															
1	Capability	8	8	7	8	9	8	0,707106781	8	8	8	8	0	Kon	Kon
2	Impact of Ipoleksosbudhankam	9	8	8	7	7	7,8	0,836660027	8	7	8	8	1	Kon	Kon
3	Budget Availability	2	4	5	5	0	3,2	2,167948339	5	2	4	5	3	Div	Div
4	Readiness	7	8	8	0	2	5	3,741657387	8	2	7	8	6	Div	Div
5	Involvement	8	7	6	8	7	7,2	0,836660027	8	7	7	8	1	Kon	Kon
6	The intensity of the incident	8	8	8	7	7	7,6	0,547722558	8	7	8	8	1	Kon	Kon
7	Accesibility	7	4	5	0	5	4,2	2,588435821	5	4	5	5	1	Div	Kon
Sub Kriteria															
1	Marine Pollution	6	6	5	5	6	5,6	0,547722558	6	5	6	6	1	Kon	Kon
2	Pandemic Spread	8	7	7	8	6	7,2	0,836660027	8	7	7	8	1	Kon	Kon
3	VVIP security	8	6	6	7	8	7	1	8	6	7	8	2	Kon	Kon
4	SAR aviation and shipping	6	7	7	4	0	4,8	2,949576241	7	4	6	7	3	Div	Div
5	Natural Disaster,	4	3	0	7	7	4,2	2,949576241	7	3	4	7	4	Div	Div
6	Security of Border Areas	0	7	5	7	8	5,4	3,209361387	7	5	7	7	2	Div	Kon
7	Obvitnas Security	7	8	7	8	7	7,4	0,547722558	7	7	7	8	1	Kon	Kon
8	Violence at Sea	6	7	8	7	7	7	0,707106781	7	7	7	7	0	Kon	Kon
9	National Marine Security Jurisdiction	9	8	7	7	8	7,8	0,836660027	8	7	8	8	1	Kon	Kon

Most of the informants have filled in the value of the questionnaire data but there are still sources who still have not provided real value so it is necessary to hold a second round as well as to validate the speakers on the results of the first round questionnaire scores.

Table 3. Withdrawal of the Delphi Opinion Round 2

No	Aspect	Interviewees					Average	Std. Dev	Modus	Q1	Q2	Q3	IR	Evaluation	
		X1	X2	X3	X4	X5								Std Dev	IR
Criteria															
1	Capability	8	7	7	8	8	7,6	0,547722558	8	7	8	8	1	Kon	Kon
2	Impact of Ipoleksosbudhankam	8	8	9	7	7	7,8	0,836660027	8	7	8	8	1	Kon	Kon
3	Budget Availability	3	5	7	5	2	4,4	1,949358869	5	3	5	5	2	Div	Kon
4	Readiness	7	6	7	4	4	5,6	1,516575089	7	4	6	7	3	Div	Div
5	Involvement	7	8	7	8	7	7,4	0,547722558	7	7	7	8	1	Kon	Kon
6	The intensity of the incident	8	8	7	9	8	8	0,707106781	8	8	8	8	0	Kon	Kon
7	Accesibility	8	6	5	3	6	5,6	1,816590212	6	5	6	6	1	Div	Kon
Sub Kriteria															
1	Marine Pollution	6	7	6	5	7	6,2	0,836660027	6	6	6	7	1	Kon	Kon
2	Pandemic Spread	8	8	7	8	7	7,6	0,547722558	8	7	8	8	1	Kon	Kon
3	VVIP security	7	6	6	7	7	6,6	0,547722558	7	6	7	7	1	Kon	Kon
4	SAR aviation and shipping	8	7	7	4	5	6,2	1,643167673	7	5	7	7	2	Div	Kon
5	Natural Disaster, Tsunami	4	7	5	7	3	5,2	1,788854382	7	4	5	7	3	Div	Div
6	Security of Border Areas	5	7	4	5	8	5,8	1,643167673	5	5	5	7	2	Div	Kon
7	Obvitnas Security	8	7	7	7	8	7,4	0,547722558	7	7	7	8	1	Kon	Kon
8	Violence at Sea	7	7	8	8	6	7,2	0,836660027	7	7	7	8	1	Kon	Kon
9	National Marine Security Jurisdiction	8	8	9	7	7	7,8	0,836660027	8	7	8	8	1	Kon	Kon

Based on the results of processing, it has obtained a selection of criteria, contingent alternatives that are important and potential to be developed. Based on the average, the criteria are 1) Number/intensity of events; 2) Impact of Ipoleksosbudhankam; 3) Capability; and 4) Engagement. As for the contingency itself, they are 1) National jurisdiction marine security; 2 The spread of the pandemic; 3 Obvitnas safeguard; 4) Violence at sea; 5) VVIP security and 6) Marine pollution.

3.1.2 AHP Data Processing

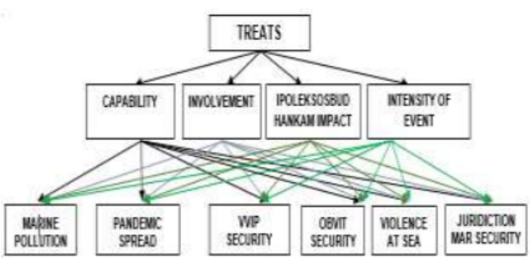


Figure 3.The hierarchy of treat decision making

The data that has been obtained from distributing questionnaires in the form of pairwise comparison between the criteria for each alternative. The assessments of the informants will be combined using the formula for the geometric mean. The calculated geometry is then entered into the pairwise comparison matrix in software super decisions.

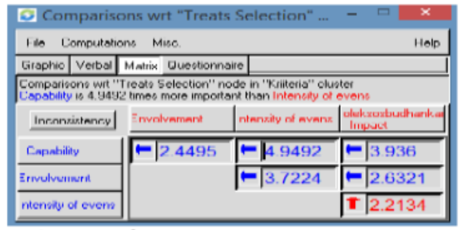


Figure 4. Geomean in comparison matrix

The processing results produce an Inconsistency Index (CI) of 0,0268. This value is still below 0.1 which means that the answers given by the speakers in the questionnaire are consistent.

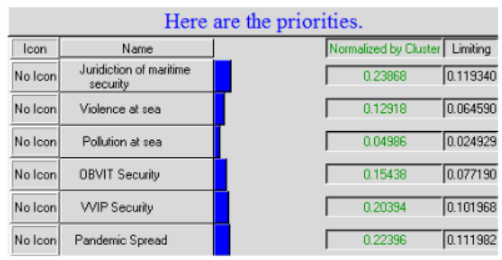


Figure 5. Threat priority

After normalization is carried out at the final weighting magnitude, the national jurisdiction kamla contingency weight gets a value of 0,23792; violence at sea is 0,12923; marine pollution is 0,04967; vital object security is 0,15410 and VVIP security is 0,20416 while pandemic spread of 0,22492. So that in the operation modeling that will be made based on the threat of national security and jurisdiction.

3.2 Determination of Headquarters Warship (C2)

The problem is designed as a hierarchical structure of four levels: First the goal of the decision problem, followed by the criteria, subcriteria, and alternative levels. As shown in Fig. 6, to select an optimal alternative, we considered five candidate C2 warship as decision variables (x1, x2, . . ., x5) and evaluated them based on four criteria and 16 subcriteria.

Each subcriterion, identified and structured in the previous stage, has its own characteristic data about the candidate C2 warship (table 5). The criteria and characteristic data were identified by the research team on the basis of confidential materials on C2 warship. Because of the confidentiality issue, part of the data was arbitrary but meaningfully generated.

We also have target values, or goals, for each subcriterion that should be achieved in the decision making process. Expert and determine the target values in the form of requirements for operational capability that describe the capabilities demanded for successful operational performance.

3.2.1 Hybrid ILP Model

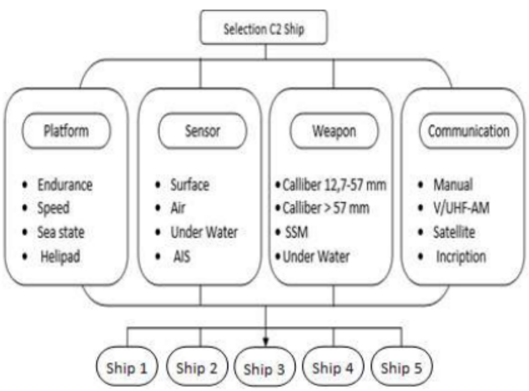


Figure 6. Hierarchical structure for C2 warship selection.

Table 4. Fuzzy Weight-deriving process for criteria.

Criteria	Sub Criteria	Agregat Value			Defuzzy	Weight	Round
		ct	at	bt			
Platform	Endurance	5,975	7,875	9,43155	7,62765	0,07038	0,070
	Speed	4	6,55833	8,32738	6,02265	0,05557	0,056
	Sea state	5,6	7,41667	9,26488	7,27354	0,06712	0,067
	helipad	6,93333	8,78571	9,8125	8,42364	0,07773	0,078
Sensor	Surface	6,55833	8,32738	9,64583	8,07633	0,07452	0,075
	Air	6,475	8,32738	9,64583	8,04197	0,07421	0,074
	Under Warter	1,75	5,18333	6,95833	3,98154	0,03674	0,037
	AIS	7,41667	9,26488	10	8,82435	0,08143	0,081
Weapon	12,7-57 mm	3,75	5,975	7,86905	5,60743	0,05174	0,052
	> 57 mm	4,1	6,91667	8,35417	6,18768	0,0571	0,057
	SSM	2,5	5,6	7,41667	4,70016	0,04337	0,043
	Under Water	1,75	5,18333	6,95833	3,98154	0,03674	0,037
Com	Manual	1	4,83333	6,475	3,15134	0,02908	0,029
	V/UHF-AM	7,41667	9,26488	10	8,82435	0,08143	0,081
	Sattelite	7,41667	9,26488	10	8,82435	0,08143	0,081
	Inkripsi	7,41667	9,26488	10	8,82435	0,08143	0,081
Total					108,373	1	1

Table 5. Characteristic data on alternative C2 warship systems

Sub Criteria	Value	Ship 1	Ship 2	Ship 3	Ship 4	Ship 5
Endurance	5	9	7	10	6	7
Speed	12	14	12	14	14	15
Sea state	3	4	4	5	3	3
Helipad	1	1	0	1	0	0
Surface	48	98	98	48	48	48
Air	60	105	100	60	60	60
Under Water	1	1	1	0	0	0
AIS	1	1	1	1	1	1
Caliber 12,7-57mm	2	2	2	4	2	2
Caliber > 57mm	1	1	1	1	1	1
SSM	1	1	1	1	1	1
Under Water	1	2	3	1	2	2
Manual	4	5	5	8	6	5
V/UHF – AM	3	8	6	6	4	4
Satellite	1	1	1	1	1	1
Enkripsi	2	2	2	2	2	2

A weighted integer GP model can be formulated with a decision variable of xj (0 or 1) to indicate whether warship j is selected. Because we have 16 goals to satisfy, 16 goal constraints are also present.

The constraints on the platform are expressed as follows:

$$9X_1+7X_2+10X_3+6X_4+7X_5-d_1^++d_1^- = 5 \quad ...(1)$$

$$14X_1+12X_2+14X_3+14X_4+15X_5-d_2^++d_2^- = 12 \quad ...(2)$$

$$4X_1+4X_2+5X_3+3X_4+3X_5-d_3^++d_3^- = 3 \quad ....(3)$$

$$X_1+X_3-d_4^++d_4^- = 1 \quad ...(4)$$

The constraints on sensor capabilities are:

$$96X_1+96X_2+48X_3+48X_4+48X_5-d_5^++d_5^- = 48 \quad ...(5)$$

$$105X_1+100X_2+60X_3+60X_4+60X_5-d_6^++d_6^- = 60 \quad ...(6)$$

$$X_1+X_2-d_7^++d_7^- = 1 \quad ...(7)$$

$$X_1+X_2+X_3+X_4+X_5-d_8^++d_8^- = 1 \quad ...(8)$$

A set of the constraints on weapon are:

$$2X_1+2X_2+4X_3+2X_4+2X_5-d_9^++d_9^- = 2 \quad ...(9)$$

$$X_1+X_2+X_3+X_4+X_5-d_{10}^++d_{10}^- = 1 \quad ...(10)$$

$$X_1+X_2+X_3+X_4+X_5-d_{11}^++d_{11}^- = 1 \quad ...(11)$$

$$2X_1+3X_2+1X_3+2X_4+2X_5-d_{12}^++d_{12}^- = 1 \quad ...(12)$$

The constraints on communication capabilities are:

$$5X_1+5X_2+8X_3+6X_4+5X_5+d_{13}^+ - d_{13}^- = 4 \quad .....(13)$$

$$8X_1+6X_2+6X_3+4X_4+4X_5+d_{14}^+-d_{14}^- = 4 \quad ....(14)$$

$$X_1+X_2+X_3+X_4+X_5-d_{15}^++d_{15}^- = 1 \quad .....(15)$$

$$2X_1+2X_2+2X_3+2X_4+2X_5-d_{16}^++d_{16}^- = 2 \quad .....(16)$$

where decision variables are C2 warchip alternatives.

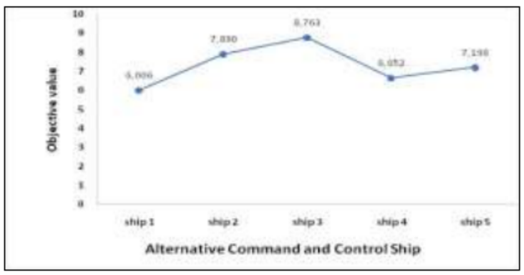
$$X_j = \begin{cases} 1 \text{ if the jth alternative is selected;} \\ \quad ; j = 1; 2; \ldots ; 5: \\ 0 \text{ otherwise;} \end{cases}$$

The model also includes the following hard constraint:

$$\sum_{j=1}^{5} Xj = 1$$

The objective function is to minimize the total weighted deviations from the goals that satisfy the above constraints. It can be expressed as follows:

$$Z_{min}=0{,}070d_1^- +0{,}056d_2^- +0{,}056d_3^- +0{,}078d_4^- +0{,}075d_5^- + 0{,}074d_6^- +0{,}037d_7^- +0{,}081d_8^- +0{,}052d_9^- +0{,}057d_{10}^- +0{,}043d_{11}^- +0{,}037d_{12}^- +0{,}029d_{13}^+ +0{,}081d_{14}^+ + 0{,}081d_{15}^- +0{,}081d_{16}^-$$



Graph 1. The results of the selection of headquarters warships

The objective function of the LP problem is a combination of the heterogeneous units of measure. Thus, the constraints should be normalized before solving the problem so that the deviation variables in the objective function are adjusted to the same unit of measure. We used excel solver to solve the LP model. Because the purpose of the problem is to select the C2 warship, the optimal alternative in our case study was warship 1.

3.3 Marine Operations Modeling With ILP

3.3.1 Decision Variables

The decision on this matter was that several warships were assigned to sectors of the operation. The form of the decision variable is integer and 0-1 (zero-one). In this modeling, the assignment of 27 warships will be the decision variable where 4 of them become C2 warships in turn. The warship will be assigned to areas 1 to 8.

$$X_{ij} \begin{cases} \text{Matrix valuable = 0, meaning Warship i NO SELECTED assignments in sector j} \\ \text{Matrix valuable = 1, meaning Warship i SELECTED assignments in sector j} \end{cases}$$

Table 6. Warship capability data

Warship	Speed (Knot)	Endurc (day)	Sensor (Nm)	Distance (Nm/day)	Coverage (Nm2/day)	Pola operasi		Fuel/Etmal		Person
						Ops	Harbour	speed eco	Harbour	
1	12	7	96	288	31.394	6	3	12.620	2.300	106
2	12	7	96	288	31.394	6	3	12.620	2.300	106
3	12	7	96	288	31.394	6	3	12.620	2.300	106
4 (C2)	14	9	96	336	35.542	6	3	16.800	3.000	93
5	12	6	48	288	14.069	6	3	5.880	800	68
6	12	6	48	288	14.069	6	3	5.880	800	68
7	12	6	48	288	14.069	6	3	5.880	800	68
8	12	6	48	288	14.069	6	3	8.900	1.200	68
9	13	5	48	312	15.106	6	3	3.888	960	59
10	13	5	48	312	15.106	6	3	3.888	960	59
11	13	5	48	312	15.106	6	3	3.888	960	59
12	14	5	48	336	16.143	5	3	7.008	960	57
13	14	5	48	336	16.143	5	3	7.008	960	57
14	14	5	48	336	16.143	5	3	12.200	720	59
15	14	5	48	336	16.143	5	3	12.200	720	59
16	14	4	48	336	16.143	4	3	16.968	768	36
17	13	5	48	312	15.106	5	3	10.920	720	51
18	13	5	48	312	15.106	5	3	10.515	210	50
19	13	5	48	312	15.106	5	3	9.560	700	50
20	14	5	24	336	7.665	5	3	8.244	756	32
21	14	5	24	336	7.665	5	3	7.669	756	33
22	14	5	24	336	7.665	5	3	7.669	756	33
23	10	3	24	240	5.591	3	3	6.720	720	33
24	10	3	24	240	5.591	3	3	6.720	720	33

Table 7. sektor, wide area and person support datas

Ops	ALFA	KILO					MIKE	INDIA
SECTOR	A1	A2	A3	A4	A5	A6	A7	A8
SQUARE	32750	136.000	145.250	152.310	125.610	125.150	23.624	20.866
PERSON	170	180					80	80
TIME	60	60					30	30

3.3.2 Objective Function

The goal of this modeling is to minimize the use of fuel by the operating elements.

3.3.3 Determination of Constraints

In this mathematical model of solving there are several constraints, namely as follows:

a. The first constraints: the amount of operational support is still based on the quota from Indonesian Nation Armed Forces headquarters in the form of the number of personnel in each operation.

- Operation ALFA which consists of 3 sectors is given a quota of 170 personnel.

- KILO operations in securing 5 sectors of the Main naval base sea area are given a quota of 180 personnel.
- Operation MIKE in carrying out joint patrols with Malaysia and Philippines is given a quota of 60 personnel.
- INDIA operations in carrying out joint patrols with the Philippines are given a quota of 60 personnel.

b. Second constraints: the assignment of warship corresponds to each warship Home Base.

- The 20th and 21st warships were only involved in ALFA operations and patrols in sector A6
- Warships 24th Only involved in ALFA operations and patrol sector A3
- Warships 22nd and 23rd Only involved in ALFA operations and patrol sector A2
- Warships 19th Only involved in ALFA operations and patrol sector A4
- Warships 17th and 18th Only involved in ALFA operations and patrol sector A5 and A7.
- Warship C2 is only assigned to ops Alfa or A3 and must be in an operation.
- Warships 14th and 15th can operate in all operating sectors.
- The remaining warships only get ALFA and KILO operations

c. Third constraints: warship used in surgery is not used in the following three months to carry out maintenance and repairs.

d. The fourth constraints: The coverage area of warship/operations must be larger than the area of the sector in the operational period.

3.3.4 Optimization Result Data Analysis

Solving this model produces a zero-one (0-1) assignment table. $X_{ij} = 1$ means that the i-th warship is assigned to sector j and $X_{ij} = 0$ means that the i-th warship is not assigned to sector j.

Table 8. The Processing Results Of The Model

Ops	Sektor	SHIP PATROL			
		TW 1	TW2	TW2	TW4
ALFA	**A1**	**SHIP C2, 6**	**SHIP C2, 7**	**SHIP 2, 13**	**SHIP 1, 12**
Person		161	161	163	63
Coverage (Nm2)		1.984.435	2.976.653	2.791.701	1.861.134
Fuel (KL)		983.200	1.474.800	1.252.800	1.252.800
KILO	A2	SHIP 9	-	-	SHIP 5
	A3	SHIP 11	-	SHIP C2	SHIP C2
	A4	-	SHIP 3	SHIP 8	-
	A5	-	SHIP 5	-	SHIP 17
	A6	SHIP 10	-	-	-
Person		177	174	161	177
Coverage (Nm2)		1.963.104	3.430.979	2.700.449	1.949.529
Fuel (KL)		524.160	1.203.000	1.668.000	2.071.350
MIKE	A7	SHIP 21	SHIP 20	SHIP 17	SHIP 15
Person		33	32	51	59
Coverage (Nm2)		229.846	229.853	453.061	484.170
Fuel (KL)		152.299	163.080	212.850	236.850
INDIA	A8	SHIP 18	NO OPS	NO OPS	SHIP 14
Person		55	NO OPS	NO OPS	59
Coverage (Nm2)		453.066	NO OPS	NO OPS	484.170
Fuel (KL)		197.156	NO OPS	NO OPS	228.750

The maximum total coverage area that can be secured by patrol boats in all areas of Indonesian Naval 2nd Fleet Command for 1 year in maritime security operations under 2nd Guskamla with existing resources is 21.992.150 NM² where with minimum fuel use is 15.077.335 Kl but still covering the entire work area in Indonesian Naval 2nd Fleet Command. (687.320 NM²)

Security Level = (Area of Coverage Area that is secured divided by Total Area of Indonesian Naval 2nd Fleet Command)

(**Area Security Level = 31.997)**

The higher the Area Security Level obtained from the warship assignment, the higher the coverage area that is secured in presence operations at sea by Patrol Boats with the composition of the warship assignment above.

4. CONCLUSIONS

a. The results of intelligence analysis of various possible contingencies have been analyzed from several criteria and sub-criteria carried out with separate FGD and processed using the Delphi method then prioritized using AHP where the results of determining threat priority using AHP are as follows: National jurisdiction marine security got a value of 0,23792; the spread of the pandemic was 0,22492; VVIP security was 0,20416; security of vital objects was 0,15410 and violence at sea was 0,12923 while marine pollution was 0,04967. The selection of the national jurisdiction maritime security contingency in the future forecast will maximize the operation of 2nd Guskamla.

b. From the results of the processing of fuzzy weighting and linear goal programming, it was found that 1st warshipwas selected to be the headquarters warship (C2) with a value of 6,006; with the second priority 4th warship, which was 6,652; 5thwarshipwas 7,198; 2ndwarshipwas 7,890 and 3rt warship of 8,763. This Hq warship must be in operation under 2nd Guskamla. In determining the operating sector for headquarters warships in a separate discussion, a questionnaire determines that the headquarters warships (C2) are operating in sector A1 or A3.

c. Operations modeling under 2nd Guskamla used 27 patrolling forces and combat patrols where 4 warships of type S were used as Hq warships. With the presence of 7 patrol boats that have been dispersed to each Main naval base which automatically makes the home base warship to carry out operations according to the closest sector, the warship headquartered in Surabaya can carry out operations in all sectors with the following results:

1) Modeling in 1st quarter resulted in the ALFA operation carried out by 2 warships, namely warship C2 and 6thwarship with a coverage area of 1.984.435 Nm2 and use of 983.200 Kl of fuel while in KILO operation carried out 3 warships, namely 9th, 10th and 11stwarshipswith coverage of 1.963.104 Nm^2 and fuel consumption of 524.160 Kl and MIKE operation using 1 warship, namely 21st warshipwith a coverage of 229.846 Nm^2 and fuel consumption of 152.299 Kl. As well as INDIA operations using 18thwarshipwith a coverage of 453.066 Nm^2 and fuel consumption of 197.156 Kl.

2) Modeling in 2nd quarter resulted in the ALFA operation carried out by 2 warships, namely the C2 warship and 7th warshipswith a coverage area of 2.976.653 Nm^2 and the use of fuel 1.474.800 Kl while the KILO operation carried out 2 warships, namely 3rd and 5th warships with a coverage of 3.430.979 Nm^2 and fuel consumption of 1.203.000 Kl and MIKE operation using 1 warship, namely 20th warship with a coverage of 229.853 Nm^2 and fuel consumption of 163.080 Kl. and the INDIA operation was not scheduled.

3) Modeling in 3th quarter resulted in the ALFA operation carried out by 2 warships, namely 2nd and 13rd warship with a coverage area of 2.791.701 Nm^2 and the use of fuel 1.252.800 Kl while in the KILO operation 2 warships were carried out, namely C2 and 8th warships with a coverage of 2.700.449 Nm^2 and fuel consumption of 1.668.000Kl and MIKE operation using 1 warship, namely 17th warship with coverage of 453.061 Nm^2 and fuel consumption of 212.850 Kl. and the INDIA operation was not scheduled.

4) Modeling in 4th quarter resulted in the ALFA operation carried out by 2 warships, namely 1st and 12nd warship with a coverage area of 1.861.134 Nm2 and fuel consumption of 1.252.800 Kl while in KILO operation 3 warships were carried out, namely C2, 5th and 17th warships with coverage of 1.948.529 Nm2 and fuel consumption of 1.252.800 Kl and MIKE operation using 1 warship, namely 15th warship with a coverage of 484.170 Nm^2 and fuel consumption of 236.850 Kl. As well as the INDIA operation using 14th warships with a coverage of 484.170 Nm^2 and fuel consumption of 228.750 Kl.

5) The level of area security obtained from the warship assignment to ALFA operations is 152; KILO is 14,68; MIKE is 59,13 and INDIA operations are 44,91

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