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PATROL SHIPS ASSIGNMENT MODEL IN EASTERN AREA OF INDONESIA WATER USING SET COVERING

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ABSTRACT

Maintaining stability of the National jurisdiction security, particularly in the Indonesian eastern waters is one of the roles of Indonesian Navy which is implemented in the Maritime Security Opeation (MSO) by assigning Navy Patrol Ships (PC). In terms of capabilities and the number of Indonesian PC compared to the extensive area of the MSO sector, it still considered to be not optimal, so the Navy need to think and perform right calculations in the assignment of PC and choose Navy Bases as the initial position of MSO by PC. This study aims to create a set covering model in calculating the assignment of patrol ships to create a set covering model to calculate the assignment of patrol ships optimally by minimizing assigned patrol ships number however can still cover all patrol sectors. This model also used the Analytic Network Process (ANP) approach to select the Naval base as the initial base for patrol ships in implementing MSO. Optimization results were to assign 12 patrol ships which could cover 18 patrol ships and 3 Naval bases from 9 bases that can be used as an initial base for PC in the implementation MSO.

Keywords: Naval Maritime Security Operations (MSO), Set Covering, Analytic Network Process (ANP).

1. INTRODUCTION.

Indonesia is the largest archipelagic state in the world which has ± 17,400 islands, with a sea area of 5.8 million km2 and a coastline of ± 81,000 km. The territory of the Republic of Indonesia lies in the crossing of the world between two continents and two oceans, such as geographical position that causes the sea between the islands become a sea channel which is very important for international shipping traffic. In this vast sea, there is a potential for abundant marine resources and strategic value for the sustainability of national development, but still not optimally managed. However, such location and massive areas of waters fall within Indonesia's jurisdiction have exposed the nation to various maritime threats, such as illegal logging and fishing, smuggling, human trafficking, drug trafficking, and territorial breaches that affect its security policies (Puspitawati, 2017). Maintaining stability of the National jurisdiction security, particularly in the Indonesian eastern waters is one of the roles of Indonesian Navy which is implemented in MSO with daily presence operation at sea carried out by the PC. However, in terms of the capacity and number of Indonesian PC compared to the extensive area of the maritime security operations sector still considered not optimal, so the Navy need to think and perform right calculations in the assignment of PC and choose Naval Base as the initial position of Marine Security Operations by patrol ships so that they can cover all sectors of MSO.

To overcome the problems above, the author attempted to optimize the assignment of PC in carrying out MSO in eastern territorial waters by using the set covering model and using the ANP model in the Naval Base selection process.

This study describes the right Naval Base selection model from 9 existing bases for Patrol

Ships placement and optimal assignment of 18 PC to the MSO sectors, so that the result of the optimization was expected to determine the composition of Indonesian PC at the Naval Base to reach optimal coverage area in MSO. The benefit of this research was to create an optimization formulation that can be applied in the Indonesian Navy.

This paper have any literature to support the research about it, for example paper with title Urgent Need For National Maritime Security Arrangement In Indonesia: Towards Global Maritime Fulcrum (Puspitawati, 2017), Principles of Maritme Security (Mabesal, 2011), United Nations Convetion On The Law Of The Sea (NATIONS, 1982), Principles of TNI AL Policy (Kasal, 2011), Maritime Air Surveys Guide Book (Mabesal, 2005), Maritime Security White Book (Mabesal, 2002), The Analytic Hierarchy Process (Saaty, 1980), Decision Making with Feedback: The Analytical Network Process (Saaty, 1996), Facility Location Selection For Seasonal Product: A Case Study For New Business And A Comparative Study Of AHP And ANP (Mahmud, et al., 2016), The Location Of Emergency Service Facilities (Toregas, et al., 1971), What You Should Know About Location Modeling (Daskin, 2008),

This Paper is organized as follows. Section 1 Introduction, Section 2 review about Material and Methodology. Section 3 gives result and discussion of research. Finally, in section 4 present conclusion this paper.

2. MATERIALS AND METHODOLOGY

Analytic Network Process (ANP)

ANP is an extension of Analytic hierarchy process (AHP), and AHP models a decision-making framework that assumes an undirectional hierarchical relationship among decision levels. Although AHP can help resolve complex multi-criteria decision problems, it is less successful when applied to problems involving multi-criteria or hierarchy dependence relationships (Saaty, 1980). The AHP is used to solve problems that have independencies on alternatives or criteria and ANP is used to solve the problem having dependence or relationship among alternatives or criteria (Saaty, 1996). The ANP method can be applied by following these steps for facility location selection (Mahmud, et al., 2016).

Step 1: Model construction and problem formulation.

Step 2: Establishment of the pair-wise comparison matrixes and criteria interdependency matrixes.

Step 3: Calculation of the priority vectors or priority weights.

Step 4: Consistency test by using the Eigen value and Random consistency index.

Step 5: Construction of supermatrix by using the priority that are calculated in the comparison matrixes.

Step 6: Computations of limit supermatrix by multiplying the supermatrix itself numerical times.

Step 7: Selection of best alternatives from the Limit matrix.

Set Covering

Set covering problem was the first location covering problem (Toregas, et al., 1971). (Daskin, 2008) illustrated the formulation of discrete location models, the model begin with the set covering model. Let I be a set of demand nodes and J be a set of candidate locations. The distance between demand node $i \in I$ and candidate site $j \in J$ is d_{ij} . Demand node i is covered by candidate site j if $d_{ij} \leq D_c$ where D_c is the coverage distance. Define $N_i = \{j \in J : d_{ij} \leq D_c\}$. In other words, N_i is the set of all candidate sites which can cover demand node i. Finally, define a binary decision variable Xj to be 1 if we locate at candidate site j and 0 otherwise. The location set covering model can now be formulated as follows :

$$Minimize \sum_{j \in J} x_j \qquad (1)$$

$$Subject\ To: \sum_{j \in Ni} x_j \geq 1 \ \forall_i \in I \qquad (2)$$

$$x_j \in \{0,1\} \ \forall_j \in J \qquad (3)$$

The objective function (1) minimizes the number of facilities needed to cover all demands. Constraint (2) stipulates that each demand node must be covered. Constraints (3) are integrality constraints.

Methodology

The design of this research is divided into three stages : preparation stage, implementation stage and termination stage. The preparation stage includes identification of problems and research objectives, literature study, preliminary study and method identification. Implementation stages include data collection, methods application and modelling, analysis and discussion. While at termination stage will be determined conclusions and suggestions from the results of research. The research flowchart shown in Figure1

Data Collection

The data collection process is conducted using interviews and questionnaires with the following objectives :

a. Naval Base data in Eastern Indonesia in the form of operational support and environmental conditions that will later be used as base selection criteria for patrol ships.

b. The ability of patrol ships.

c. Patrol Sector data.

Modelling

1. ANP Model Network

The first step of this method is to determine criteria. Based on the results of interviews with several experts in the field of marine security operations, several criteria in the ANP network structure that have been put into the super decision software is shown in Figure 2.

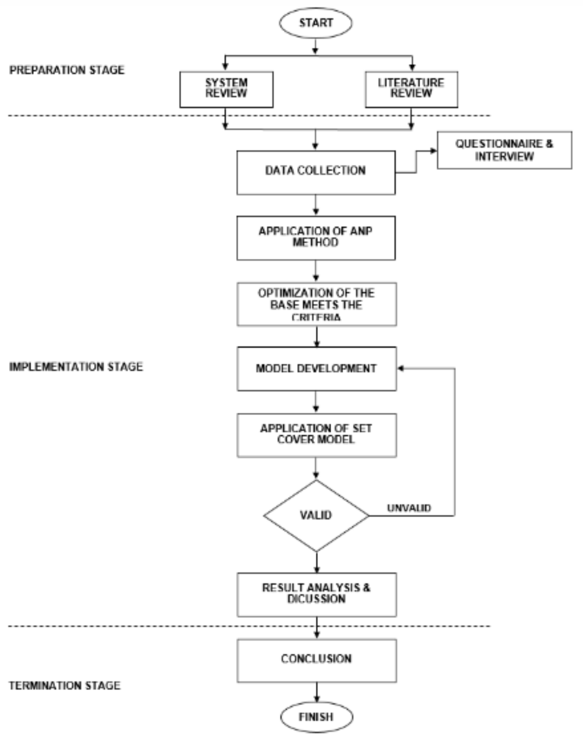

Fig. 1 Flowchart Diagram

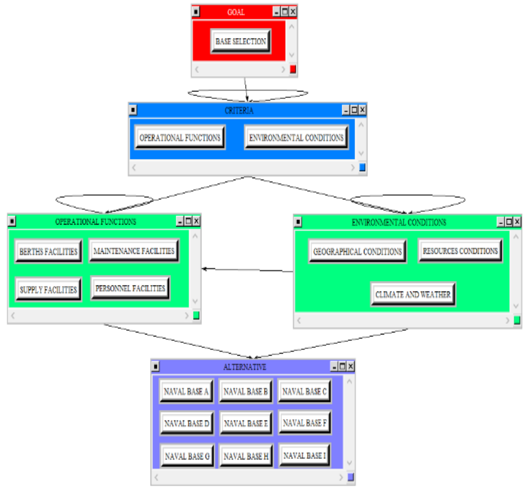

Fig. 2 Model Network of ANP

2. Pairwise Comparison Matrix

At this stage, a pairwise comparison matrix inter-criteria and inter-alternatives was made for each sub-criteria. The pairwise comparison value was obtained from the decision maker using a questionnaire. One pairwise comparison matrix can be seen in table 1.

After obtaining one pairwise comparison value for each relationship, calculate the local priority weights. This calculation aimed to determine the weight of each element that was interconnected. Every time local priorities weighting was done, the necessary thing to note was the value of the consistency, the inconsistency value should not exceed 0,1. An example can be seen in Table 2. which shows the inconsistency value of pairwise comparisons between sub-criteria in operational functions criteria.

Table 1. Pairwise comparison matrix between sub-criteria in operational functions criteria

	MAINTENANCE FACILITIES	PERSONNEL FACILITIES	SUPPLY FACILITIES
BERTHS FACILITIES	3,00	5,00	3,00
MAINTENANCE FACILITIES		3,00	3,00
PERSONNEL FACILITIES			0,333

Table 2. Inconsistency Index of Inter-Criteria Pairwise Comparison in Operational Function Criteria.

Inconsistency Report

Rank	Row	Col	Current Val	Best Val	Old Inconsist	New Inconsist	% Improvement
1.	MAINTENANCE F	SUPPLY FACILITI	3.000000	1.000001	0.074183	0.016290	78.04 %
2.	PERSONNEL FA(	SUPPLY FACILITI	3.000003	1.361631	0.074183	0.040299	45.68 %
3.	BERTHS FACILIT	MAINTENANCE F	3.000000	1.224022	0.074183	0.040299	45.68 %
4.	BERTHS FACILIT	PERSONNEL FA(	5.000000	9.000003	0.074183	0.057866	22.00 %
5.	MAINTENANCE F	PERSONNEL FA(	3.000000	4.051429	0.074183	0.070978	4.32 %
6.	BERTHS FACILIT	SUPPLY FACILITI	3.000000	3.702397	0.074183	0.070979	4.32 %

Table 2 shows that the Inconsistency Index is 0.074183. This value is still below 10% or 0.1 which means that the answers given in the questionnaire are consistent.

3. Data Processing

After inputting all the answers into the questionnaire format in the Super Decisions software, the software did all the stages of the ANP method by running Synthesize, which included the alternative weight values as seen in the Column values of Normals in Table 3.

4. Sensitivity Analysis

In this test, it will be known that whether changing the weight value of the tested alternatives will affect the original ranking result or not. When there is a point where a ranking/priority changed, the point called the critical point of an alternative. Figure 3 shows the sensitivity test on the alternative Naval Base A which produces a critical weight value of 0.05096. The results of sensitivity analysis can be carried out for each alternative.

Table 3. Value of Alternative Weight

New synthesis for: Super Decisions Main Window: ...

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: ANP PANGKALAN.sdmod

Name	Graphic	Ideals	Normals	Raw
NAVAL BASE A		1.000000	0.233417	0.059459
NAVAL BASE B		0.410541	0.095827	0.024410
NAVAL BASE C		0.342203	0.079876	0.020347
NAVAL BASE D		0.353875	0.082601	0.021041
NAVAL BASE E		0.489038	0.114150	0.029078
NAVAL BASE F		0.439389	0.102561	0.026125
NAVAL BASE G		0.236403	0.055181	0.014056
NAVAL BASE H		0.563902	0.131624	0.033529
NAVAL BASE I		0.448824	0.104763	0.026686

Okay Copy Values

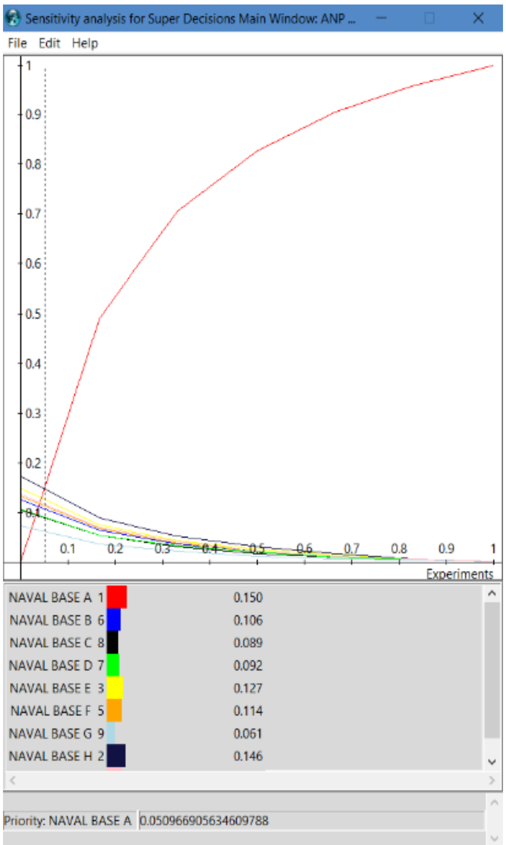

Fig. 3 Alternative Sensitivity Analysis of Naval Base A

5. Set Covering Application

The data required for the application of set covering is the MSO operating sector and the capability of the patrol ships of area coverage. Data is presented in tables 4 and 5 and figure 4.

In Figure 4, the red dot is the selected base based on the weight that has been obtained from the ANP calculation

Table 4. Patrolling sector area

No	SECTOR	AREA NM²
1	SECTOR I	234,987
2	SECTOR II	261,217
3	SECTOR III	235,249
4	SECTOR IV	175,246
5	SECTOR V	235,215
	Total =	1,141,914

Table 5. PC coverage area on each patrolling sector

No.	SHIP	COVERAGE AREA				
		SECTOR I	SECTOR II	SECTOR III	SECTOR IV	SECTOR V
1	PC 1	79,274	65,821	77,352	80,715	82,637
2	PC 2	78,741	65,379	76,832	80,172	82,081
3	PC 3	79,274	65,821	77,352	80,715	82,637
4	PC 4	79,274	65,821	77,352	80,715	82,637
5	PC 5	78,741	65,379	76,832	80,172	82,081
6	PC 6	79,274	65,821	77,352	80,715	82,637
7	PC 7	78,741	65,379	76,832	80,172	82,081
8	PC 8	79,274	65,821	77,352	80,715	82,637
9	PC 9	78,741	65,379	76,832	80,172	82,081
10	PC 10	77,863	64,650	75,975	-	81,166
11	PC 11	78,274	64,991	76,377	-	81,595
12	PC 12	77,863	64,650	75,975	-	81,166
13	PC 13	77,863	64,650	75,975	-	81,166
14	PC 14	78,741	65,379	76,832	-	82,081
15	PC 15	78,274	64,991	76,377	-	81,595
16	PC 16	78,741	65,379	76,832	-	82,081
17	PC 17	77,863	64,650	75,975	-	81,166
18	PC 18	77,863	64,650	75,975	-	81,166

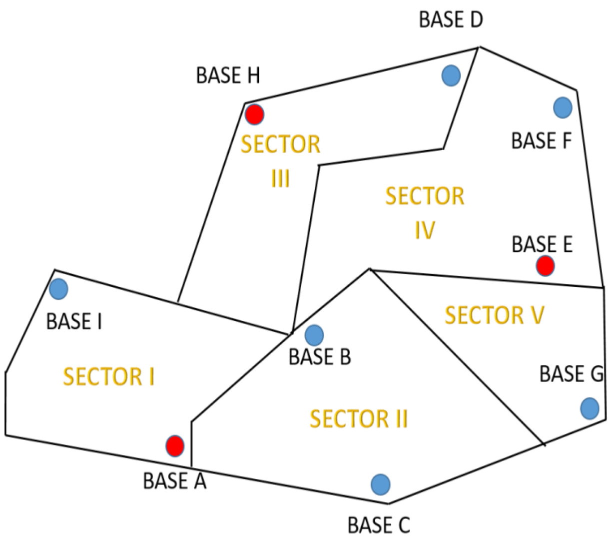

Fig. 4 Naval Base Deployment

The next step in set covering modeling is to make the following formulations:

a. Determine the decision variable.

The decision on this issue was whether a PC was assigned to the operating sectors. The form of the decision variable is integer and 0-1 (zero - one). Decision variables consist of 18 patrol vessels allocated to 7 operating sectors.

SHIP	PATROLLING SECTORS				
	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

Xij = PC i (1-18) to be assigned to patrol sector j (1-5)

Xij = 0, PC to i was not assigned to the patrol sector j

Xij = 1, PC assigned to the patrol sector j

b. Determining the objective function

In this problem the objective function is to achieve the maximum area (coverage area) of the operating sector that must be secured by the patrol ships.

Z max Cij Xij = Area of Operating Sector

Max Z= Coverage area of patrol vessels

Cij = Coverage Value of each PC (1-18) in the Patrol Sector (1-5)

Xij = PC (1-18) assigned to the patrol sector (1-5)

c. Determining the Function of Constraints

X ij ≥ N min

N min = Minimum Number of PC that must be in Patrolling sector

3. RESULT AND DISCUSSION

Result

The results of ANP calculations using Super Decision Software in the form of weights on base selection can be seen in table 6.

Table 6. Naval Base Weight Value

NO	BASE	WEIGHT VALUE
1.	Naval Base A	0,2334
2.	Naval Base H	0,1316
3.	Naval Base E	0,1141
4.	Naval Base I	0,1048
5.	Naval Base F	0,1026
6.	Naval Base B	0,0958
7.	Naval Base D	0,0826
8.	Naval Base C	0,0799
9.	Naval Base G	0,0552

By using Excel Solver results of the Set Covering method decision variable in the form of assignment for patrol ships to the patrol sector in the form of integers 0 - 1 (Zero - One) can be seen in table 7.

Table 7. The Results of Decision Variable

No	SHIP	DECISION VARIABLE(ZERO-ONE, 0-1)				
		SECTOR I	SECTOR II	SECTOR III	SECTOR IV	SECTOR V
1	PC 1	0	0	0	0	0
2	PC 2	0	0	0	1	0
3	PC 3	0	0	0	0	0
4	PC 4	0	0	0	0	0
5	PC 5	0	0	0	0	1
6	PC 6	0	0	0	0	0
7	PC 7	0	0	0	0	1
8	PC 8	0	0	0	0	0
9	PC 9	0	0	0	1	0
10	PC 10	1	0	0	0	0
11	PC 11	0	1	0	0	0
12	PC 12	1	0	0	0	0
13	PC 13	0	0	1	0	0
14	PC 14	0	0	1	0	0
15	PC 15	0	0	0	0	1
16	PC 16	0	0	0	0	0
17	PC 17	1	0	0	0	0
18	PC 18	0	0	1	0	0

Discussion

Based on the results of the ANP calculation and brainstorming did by MSO experts, the selected Naval Base as the initial base of the PC in carrying out MSO are Naval Base A, H and E. Naval Base A was intended for patrol ships that will carry out operations in sectors I and II, Base H intended for patrol ships which will carry out operations in sectors III and IV while base E is for patrol ships that will carry out operations in sector V. Placement of Patrol Ships at each Bases can be seen in table 8.

Table 8 Placement of PC in Naval Base

NO	BASE	SHIP
1.	Naval Base A	PC 10, PC 11, PC 12, PC 17
2.	Naval Base H	PC 2, PC 9, PC 13, PC 14, PC 18
3.	Naval Base E	PC 5, PC 7, PC 15

Patrol ships that are not assigned were guard ships which can be used at any time if urgent.

4. CONCLUSION.

From the implementation of the study, it can be concluded as follows:

a. The Naval Base chosen as the initial base for patrol ships to carry out MSO was base A, H and E. While other bases can be used to carry out other Navy operations.

b. The Patrol Ships assigned to the implementation of MSO in the eastern waters was 12 ships, 6 patrol ships not assigned were to be a standby force function which could at any time be used in urgent circumstances.

5. ACKNOWLEDGEMENTS.

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