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OPTIMIZATION ASSIGNMENT OF WESTERN PATROL UNIT (KRI) ELEMENT IN SEA SECURITY OPERATIONS IN RIAU ISLANDS WATER AREAS USING SET COVERING MODEL

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ABSTRACT

The territorial waters of Riau Islands are one of the locations with a high level of vulnerability to violations in the sea in Indonesia, because this region is directly adjacent to neighboring countries and is an international trade and shipping route. One of the roles of the Indonesian Navy is to maintain the security of national jurisdictions, including in the territorial waters of Riau Islands, which are then realized in Operation Sea Security, where the implementation still has several constraints, namely budget constraints, technical capabilities, number of ships, limited information, and limitations supporting facilities, so that the implementation of Marine Security Operations is not optimal. The main reason is the placement of patrol boats during operations is not well organized. With these problems, a study was conducted using the set covering method to get the most optimal location for patrol boat placement with as few ships as possible but still be able to reach the entire waters of the Riau Islands and minimize operational costs. In this study a discrete approach was taken, namely the determination of the critical points, which numbered 37 vulnerable points. All these points must be affordable by the ship on duty.

Keywords: *Set Covering, Location Selection, Marine Security Operations, Riau Islands Waters Region*

1. INTRODUCTION

The Indonesian Navy as the enforcer of state sovereignty at sea has a very important role in relation to the security of the territorial sea area of the Unitary State of the Republic of Indonesia. The security activities of this region are realized through the implementation of Marine Security Operations which are part of the Sea Combat Operation which aims to prevent and take action on any form of security disturbance in the Sea as a form of law enforcement and sovereignty in the Sea . The territorial waters of Riau Islands are one of the locations with a high level of vulnerability to violations in the sea in Indonesia, because this region is directly adjacent to neighboring countries and is an international trade and shipping route. One of the roles of the Indonesian Navy is to maintain the security of national jurisdictions, including in the territorial waters of Riau Islands, which are then realized in Operation Sea Security, where the implementation still has several constraints, namely budget constraints, technical capabilities, number of ships, limited information, and limitations supporting facilities, so that the implementation of Marine Security Operations is not optimal. The main reason is the placement of patrol boats during operations is not well organized.

With these problems, a study was conducted using the set covering method to get the most optimal location for patrol boat placement with as few ships as possible but still be able to reach the entire waters of the Riau Islands and minimize operational costs. In this study a discrete approach was taken, namely the determination of the critical points, which numbered 37 vulnerable points. All these points must be affordable by the ship on duty Based on the background of the research presented above, the problem raised in this thesis research is "How to optimize the placement of KRI element assignments in the Armabar Patrol Ship Unit in the implementation of Marine Security Operations in the territorial waters of Riau Islands using a set covering model?".

The objectives to be achieved in this thesis research are as follows: Optimizing the use / operation of the number of Patrol Vessels to cover the entire operating sector and knowing the estimated operational costs and determine the location / sector of the patrol for Patrol Ships in optimal Marine Security Operations. The benefits that can be obtained from this Final Project research are: Providing input to decision makers, TNI leaders, especially the Western Military Co-operative Staff and Marine Security Task Force (Guskamlabar) as well as KRI (Patrol Ship) elemental commanders in determining the strategy for carrying out maritime security operations, increase success in sea security operations carried out by elements of KRI (Patrol Ships) located in the waters of the Riau Islands, save existing resources and Produce an optimization formulation that can be applied in the Coalition and Guskamlab Operations Staff in order to assign Navy patrol ships to the operating sector.

The limits used in this Final Project research are: The sea security operation was only carried out by the KRI from the Armabar patrol unit, The area that became the object of research was the waters of the Riau Islands alone,assignments carried out based on existing limitations or constraints and do not make changes to these constraints and not discussing the weaponry of the Navy Navy Patrol Ship. The assumptions used in this Final Project research are ; the boundaries of the Operational Security Sea area have not changed from before,base and Intelligence titles are ready to support operations, All elements of the Armabar Patrol ship are assumed to be ready for operation, Sea Security Operations are carried out with the condition of the State in a state of peace and Weather conditions in the Sea are calm, sea state 1-2

2. MATERIAL AND METHODS

2.1 Material

2.1.1 Operation Sea Security is the operation of daily presence in the sea carried out by ships and aircraft of the Indonesian Navy's maritime patrol which have strategic value for the existence of national sovereignty and stability of security at sea in Indonesia's national jurisdiction.

2.1.2 The Patrol Ship Unit is the implementing unit tasked with developing Personnel and Material under the Fleet Command. In addition, Satrol is a unit that supports the main task of the Fleet Command, namely, among others, its involvement in the title of security operations in the territorial waters of National Jurisdiction.

2.1.3 KRI is a ship owned by the Indonesian Navy that has special signs, under the command of a Navy Officer who is manned by ABK who are subject to army discipline laws that have integrated technical requirements and requirements.

2.1.4 The covering set is part of an integer linear programming that aims to minimize the number of location points of service facilities but can serve all points of demand (Toregas, 1971). To be able to describe the set covering model can be formulated or formulated as follows:

X = Facilities (ships) used by ships used will be symbolized by alphabet A, B, and so on until all types of vessels are represented. So x = { A, B, ... }

I = Critical points or alternative points of placement of ships

j = Prone point

n = *The number of alternative points or vulnerable points that exist*

C_x = Ship operating costs x.

$K_{ix} = \{j \mid d_{ij} \leq D_x\}$ *that is, all points that can be reached by ship x which are placed at point i. Where the distance between the vulnerable points occupied by the ship and the vulnerable* *points to be reached (smaller) is smaller than the distance of the ship's reach x.*

m_x = The number of vessels available for this type of ship x

Decision variable:

$$x_i \begin{cases} 1 \\ 0 \end{cases}$$

A_i worth 1 if at location i is placed by ship A. Bi is worth 1 if at location i is placed ship B, and so on. Value 0 if not occupied by the ship. From the above notation, the set covering model can be formulated as follows:

Minimize

$$\sum_{i=1}^{n} A_i + \sum_{i=1}^{n} B_i + \cdots \qquad (2.7)$$

$$\sum_{j \in Kix} A_j + B_j + \cdots \geq 1 \ \forall\, i \in n \qquad (2.8)$$

$$Ai, Bi, \ldots \in \{0.1\} \ \ \forall i \in I \qquad (2.9)$$

$$\sum_{i=1}^{n} x_i \leq m_x \qquad (2.10)$$

$$\sum_{i=1}^{n} A_i + B_i + \cdots \leq 1 \qquad (2.11)$$

From the above formulation it can be seen that the aim (2.7) is to minimize the use of the number of vessels / facility placement. Limiter (2.8) shows that each vulnerable point can be reached by at least 1 ship. The delimiter (2.9) indicates that the decision variable is a member of a binary number. Limiting (2.10) indicates that each type of vessel must not exceed the number of vessels available. Limiter (2.11) shows that each critical point is not occupied by more than one swamp point.

2.1.5 Distance Between Two Points

The formula for calculating the distance between two points $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ based on Pythagoras's Theorema is

$$\overline{P_1P_2} = \sqrt{(x_2 - x_1)^2 + (y_1 - y_1)^2} \qquad (2.12)$$

The distance between two points is to draw the shortest line between the two points

2.1.6 Determination of Selective Prone Areas

Selective vulnerable areas are areas that are considered prone to the emergence of various forms of violations of sovereignty and security disturbances at sea that can harm national interests in and or by sea. The presence of Navy patrol aircraft and aircraft that are faced with limited operational facilities and infrastructure, requires an operational pattern and a strategic plan and title in the priority of marine security operations in certain waters which are considered prone to various forms of violations of sovereignty and security disturbances in the sea.

2.1.7 Logistics Planning and Costs

Hadi Firmanto (2006), Logistics planning is a process of strategy in regulating a procurement, transfer and storage, final inventory through company organizations and channels / civil and military agencies, so that current and future benefits can be maximized through cost effectiveness.

The logistical costs of ships and the Indonesian Navy's maritime patrol aircraft are broadly divided into two, namely liquid logistics costs and personnel logistics. Included in the liquid logistics costs are the costs of fuel, engine oil, lubricating oil, hydraulic oil and fresh water, while those that include personnel logistics costs are the cost of food during operations, screen allowances, non-screen allowances, leadership benefits, flight allowances, pocket money as well as operating vessel maintenance costs

2.2 Methods

The research method is the steps taken in solving a problem faced. The type of data collected is in the form of qualitative data and quantitative data consisting of primary data and secondary data. The research method used in this thesis research is as follows:

a. This type of research used in the research on the optimization of placement of patrol boat assignments is a type of quantitative research that is research that aims to explain the differences, comparisons, relationships, or influence between two or more variables.

b. The data used in this study are secondary data in the form of data from inspection results by Patrol Ships and data from Armabar operations staff about the division of the operating sector. The data needed is the coverage coverage of the Indonesian Navy ships, vulnerable points at sea, and KRI logistics costs. So to get this data it is necessary to collect documents that record the data.

c. Data collection in this study using the documentary method is to collect data by collecting and analyzing

2.3 Data Analysis and Interpretation Methodse Analisis dan Interpretasi Data

After the required data is available, then the data analysis and interpretation are then carried out. In this stage the existing data will be processed in several stages as follows:

a. Calculation of Coverage of KRI Coverage, Circle KRI coverage coverage obtained through calculation. The circle radius of the KRI coverage range is assumed to be the fulfillment distance *Coverage* KRI (D_c).

b. Determination of Prone Location Points The point of prone location can be seen from historical data of violations. The vulnerable location points will also be an alternative location for the Marine Security Operation patrol.

c. Calculation of Distance Between Prone Locations Using the Pythagorean theorem, the distance between two points, namely between the vulnerable locations can be known. In the set covering model, this distance becomes the distance between the vulnerable points of k and alternative patrol locations *j* (d_{kj}).

Set Covering Model Compilation

1. Objective function *Minimize* :

$$Z = C_A\sum_{i=1}^{n} A_i + C_B\sum_{i=1}^{n} B_i + C_C\sum_{i=1}^{n} C_i + C_D\sum_{i=1}^{n} D_i + C_E\sum_{i=1}^{n} E_i + C_F\sum_{i=1}^{n} F_i + C_G\sum_{i=1}^{n} G_i \quad ..(3.1)$$

2. Decicions variable

$$Ai, Bi, Ci, Di, Ei, Fi, Gi \begin{cases} 1 \\ 0 \end{cases}$$

3. Constrain function

a. $\sum_{j \in Kix} A_j + B_j + \cdots \geq 1 \;\; \forall\, i \;\in n$ (3.2)

b. $Ai, Bi, Ci, Di, Ei, Fi, Gi\ \{0,1\} \;\; \forall\, i$ (3.3)

c. $\sum_{i=1}^{n} x_i \;\; m_x$ (3.4)

d. $\sum_{i=1}^{n} A_i + B_i + \cdots \leq 1$ (3.5)

3. RESULT

3.1 Ship Ability Data

Patrol ships assigned to the western Indonesian territorial waters consist of 7 types of vessels, totaling 20 ships. This data is obtained from the Coalarm Patrol Ship Unit. Existing ship data will be used in determining the operating costs of each ship as well as input in the preparation of the optimization model, namely the anchorage (radar).

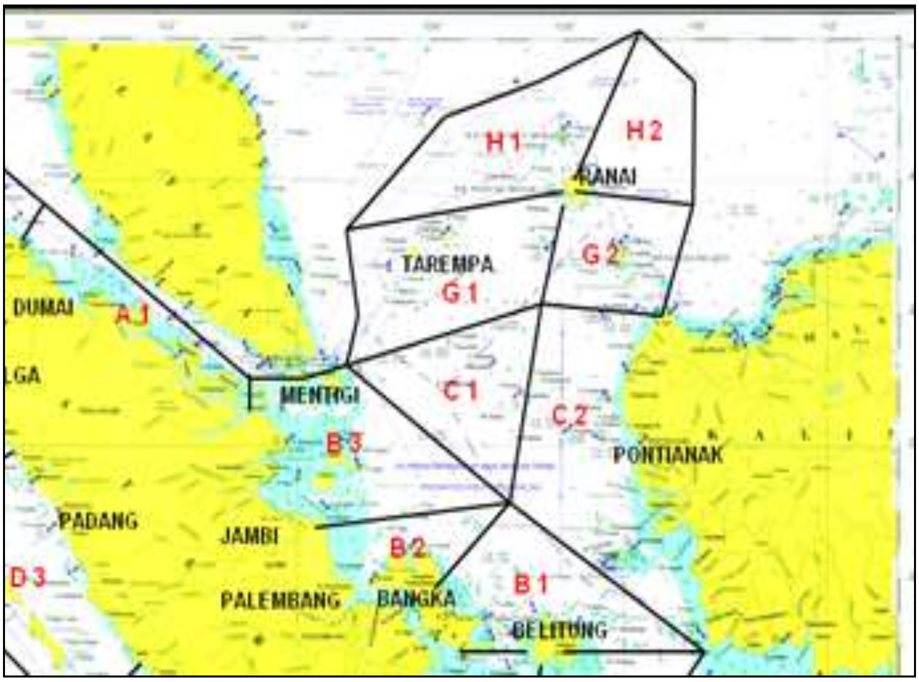

Fig.1 Hazard Point Data for Riau Islands Waters Region

3.2 Ship operating cost

The amount of operating costs for each ship is determined by the size of the unit cost, which is the cost needed per unit which will be used in the calculation of each ship

Table 1. Optimization of Assignment of Indonesian Navy ships in Marine Security Operations for the Riau Islands Waters Region

Ship's name	Endurance (Day)	Person number	Cost (Rp)
A1	9	26	883.791.000
B1	5	38	754.181.500
B2	5	38	754.181.500
C1	3	30	312.124.800
C2	3	30	312.124.800
C3	3	30	312.124.800
C4	3	30	312.124.800
C5	3	30	312.124.800
C6	3	30	312.124.800
C7	3	30	312.124.800
C8	3	30	312.124.800
D1	3	27	388.746.000
D2	3	27	388.746.000
D3	3	27	388.746.000
E1	3	20	330.497.400
E2	3	20	330.497.400
E3	3	20	330.497.400
E4	3	20	330.497.400
F	3	23	148.449.000
G	3	20	314.312.400

3.3. Decicions Variable

The decision variable is whether to place one ship at one vulnerable point or not to place the ship. The total number of existing vessels is 20 and 37 vulnerable points.

Table 2. Sectors of Assignment of Indonesian Navy ships
in Marine Security Operations for the Riau Islands Waters Region

Point	KRI Group						
	A	B	C	D	E	F	G
1	A1	B1	C1	D1	E1	F1	G1
2	A2	B2	C2	D2	E2	F2	G2
3	A3	B3	C3	D3	E3	F3	G3
4	A4	B4	C4	D4	E4	F4	G4
5	A5	B5	C5	D5	E5	F5	G5
6	A6	B6	C6	D6	E6	F6	G6
7	A7	B7	C7	D7	E7	F7	G7
8	A8	B8	C8	D8	E8	F8	G8
9	A9	B9	C9	D9	E9	F9	G9
10	A10	B10	C10	D10	E10	F10	G10
11	A11	B11	C11	D11	E11	F11	G11
12	A12	B12	C12	D12	E12	F12	G12
13	A13	B13	C13	D13	E13	F13	G13
14	A14	B14	C14	D14	E14	F14	G14
15	A15	B15	C15	D15	E15	F15	G15
16	A16	B16	C16	D16	E16	F16	G16
17	A17	B17	C17	D17	E17	F17	G17
18	A18	B18	C18	D18	E18	F18	G18
19	A19	B19	C19	D19	E19	F19	G19
20	A20	B20	C20	D20	E20	F20	G20
21	A21	B21	C21	D21	E21	F21	G21
22	A22	B22	C22	D22	E22	F22	G22
23	A23	B23	C23	D23	E23	F23	G23
24	A24	B24	C24	D24	E24	F24	G24
25	A25	B25	C25	D25	E25	F25	G25
26	A26	B26	C26	D26	E26	F26	G26
27	A27	B27	C27	D27	E27	F27	G27
28	A28	B28	C28	D28	E28	F28	G28
29	A29	B29	C29	D29	E29	F29	G29
30	A30	B30	C30	D30	E30	F30	G30
31	A31	B31	C31	D31	E31	F31	G31
32	A32	B32	C32	D32	E32	F32	G32
33	A33	B33	C33	D33	E33	F33	G33
34	A34	B34	C34	D34	E34	F34	G34
35	A35	B35	C35	D35	E35	F35	G35
36	A36	B36	C36	D36	E36	F36	G36
37	A37	B37	C37	D37	E37	F37	G37

1. A1 is worth 1 if the ship from group A is placed in critical point 1 worth 0 if the ship from group A is not placed in the critical point 1
2. A2 value 1 if the ship from group A is placed in point 2 of the value of 0 if the ship from group A is not placed in the point
3. A3 is worth 1 if the ship from group A is placed in point 3 of the value of 0 if the vessel from group A is not placed in the point

so on for each group of ships up to the decision variable G37

4. G37 is worth 1 if the ship from group G is placed at point 37 of value 0 if the vessel of group G is not placed in the point of 37

3.4 Objective function

The purpose of the function is to minimize the total costs required for operations for a year, by minimizing the number of vessels used in operations. along with the costs, but can still reach all vulnerable points

The operating costs required for each group of vessels are different. In addition, each ship also has a different endurance. With information that in one year there are 3 months rest period, then in a year there is a total operating time of 275 days. From the number of days in a year it can be known how many times each vessel operates in a year. Furthermore, it can be seen the costs required for each vessel to operate in a year by multiplying the number of operations carried out by each ship with the cost of each vessel in a single operation, then the formulation of the objective function is as follows:

$$Minimize = 27397521000 \sum_{i=1}^{37} Ai + 41497982500 \sum_{i=1}^{37} Bi + 28715481600 \sum_{i=1}^{37} Ci + 35764632000 \sum_{i=1}^{37} Di + 30405760800 \sum_{i=1}^{37} Ei + 13657308000 \sum_{i=1}^{37} Fi + 28900180800 \sum_{i=1}^{37} Gi$$

3.5 Constraint determination

There are 4 restrictions used in this study:

a. Guarding Limits for Each Prone Point. Each vulnerable point will be reached by at least one ship.

1. G1 + G2 + F1 + F2 + F3 + F4 + E1 + E2 + D1 + D2 + C1 + C2 + B1 + B2 + B3 + B4 + A1 + A2 + A3 + A4 >= 1 ;
2. G1 + G2 + G3 + F1 + F2 + F3 + F4 + E1 + E2 + E3 + D1 + D2 + D3 +C1 +C2 + C3 + B1+B2+B3 + B4 + A1 + A2 + A3 + A4 >= 1 ;
3. G2 + G3 + G4 + F1 + F2 + F3 + F4 + F5 + E2 + E3 + E4 +D2 + D3 + D4 + C2 + C3 + C4 + B1 + B2 + B3 + B4 + A1 + A2 + A3 + A4 >= 1 ;
4. G3 + G4 + F1 + F2 + F3 + F4 + F5 + F6 + F7 + E3 + E4 + D3 + D4 + C3 + C4 + B1 + B2 + B3 + B4 + B5 + B6 + A1 + A2 + A3 + A4 + A5 + A6 >= 1 ;
5. G5 + G6 + G7 + F3 + F4 + F5 + F6 + F7 + F8 + E5 + E6 + E7 + D5 + D6 + D7 + C5 + C6 + C7 + B4 + B5 + B6 + B7+ B8+A4 +A5 +A6 + A7+ A8 >= 1 ;
6. G5 + G6 + G7 + F4 + F5 + F6 + F7 + F8 + E5 + E6 + E7 + D5 + D6 + D7 + C5 + C6 + C7 + B4 + B5 + B6 + B7 + A4 + A5 + A6 + A7 >= 1 ;
7. G5 + G6 + G7 + G8 + F4 + F5 + F6 + F7 + F8 + F9 + E5 + E6 + E7 + E8 + D5 + D6 + D7 + D8 + C5 + C6 + C7 + C8 + B5 + B6 + B7 + B8 + B9 + A5 + A6 + A7 + A8 + A9 >= 1 ;
8. G7 + G8 + F5 + F6 + F7 + F8 + F9 + F10 + F11 + E7 + E8 + D7 + D8 + C7 + C8 + B5 + B7 + B8 + B9 + B10 + A5 + A7 + A8 + 9 + A10 >= 1 ;
9. G9 + G10 + F7 + F8 + F9 + F10 + F11 + F12 + E9 + E10 + D9 + D10 + C9 +C10 + B7 + B8 + B9 + B10 + B11 +A7 +A8 +A9 +A10 +A11 >= 1 ;
10. G9 + G10 + G11 + F8 + F9 + F10 + F11 + F12 + F13 + F27 + E9 + E10 + E11 + D9 + D10 + D11 + C9 + C10 + C11 + B8 + B9 + B10 + B11 + B12+ B13+B27+A8 +A9 +A10+ A11 + A12 + A13 + A27 >= 1 ;
11. G10 + G11 + G12 + F8 + F9 + F10 + F11 + F12 + F13 + F27 + F28 + E10 + E11 + E12 + D10 + D11 + D12 + C10 + C11 + C12 + B9 + B10 + B11+B12+B13 +B27+A9 +A10 + A11+ A12 +A13 + A27 >= 1 ;
12. G11 + G12 + G13 + G27 + F9 + F10 + F11 + F12 + F13 + F14 + F25 + F26 + F27 + F28 + E11 + E12 + E13 + E27 + D11 + D12 + D13 + D27 + C11 + C12 + C13 + C27 + B10 + B11 + B12 + B13 + B25 + B26 + B27 + B28 + A10 + A11 + A12 + A13 + A25 + A26 + A27 + A28 >= 1 ;
13. G12 + G13 + F10 + F11 + F12 + F13 + F14 + F26 + E12 + E13 + D12 + D13 + C12 + C13 + B10 + B11 + B12 + B13 + B14 + A10 + A11 + A12 + A13 + A14 >= 1 ;
14. G14 + F12 + F13 + F14 + F15 + E14 + D14 + C14 + B13 + B14 + B15 + A13 + A14 + A15 >= 1 ;
15. G15 + F14 + F15 + F16 + F17 + E15 + D15 + C15 + B14 + B15 + B16 + A14 + A15 + A16 >= 1 ;
16. G16 + G17 + F15 + F16 + F17 + F18 + E16 + E17 + D16 + D17 + C16 + C17 + B15 + B16 + B17 + A15 + A16 + A17 >= 1 ;
17. G16 + G17 + F15 + F16 + F17 + F18 + F19 + F21 + F22 + E16 + E17 + D16 + D17 + C16 + C17 + B16 + B17 + B18 + B19 + A16 + A17 + A18 + A19 >= 1 ;
18. G18 + G19 + F16 + F17 + F18 + F19 + E18 + E19 + D18 + D19 + C18 + C19 + B17 + B18 + B19 + A17 + A18 + A19 >= 1 ;
19. G18 + G19 + F17 + F18 + F19 + E18 +E19 +D18 +D19 + C18 + C19 + B17 + B18 +B19 +A17 + A18 + A19 >= 1 ;
20. G20 + F20 + F21 + F22 + E20 + D20 +C20 +B20 + B21 + A20 + A21 >= 1 ;

21. G21 + G22 + F17 + F20 + F21 + F22 + F23 + F24 + E21 + E22 + D21 + D22 + C21 + C22 + B20 + B21 + B22 +B23 +A20 + A21 + A22 + A23 >= 1 ;

22. G21 + G22 + F17 + F20 + F21 + F22 + F23 + F24 + E21 + E22 + D21 + D22 + C21 + C22 + B21 + B22 + B23 + B24 + A21+A22 + A23 + A24 >= 1 ;

23. G23 + G24 + F21 + F22 + F23 + F24 + E23 + E24 + D23 + D24 + C23 + C24+B21+B22+B23 + B24 + A21 + A22 + A23 + A24 >= 1;

24. G23 + G24 + F21 + F22 + F23 + F24 + F25 + E23 + E24 + D23 + D24 + C23 + C24 + B22 + B23 + B24 + A22 + A23 + A24 >= 1 ;

25. G25 + G26 + F12 + F24 + F25 + F26 + F27 + F28 + E25 + E26 + D25 + D26 + C25 + C26 + B12 + B25 + B26 + B27 + B28 + A12 + A25 + A26 + A27 + A28 >= 1 ;

26. G25 + G26 + G28 + F12 + F13 + F25 + F26 + F27 + F28 + F29 + E25 + E26 + E28 + D25 + D26 + D28 + C25 + C26 + C28 + B12 + B25 + B26 + B27 + B28 + A12 + A25 + A26 + A27 + A28 >= 1 ;

27. G12 + G27 + G28 + F10 + F11 + F12 + F25 + F26 + F27 + F28 + F29 + E12 + E27 + E28 + D12 + D27 + D28 + C12 + C27 + C28 + B10 + B11 + B12 + B25 + B26 + B27 + B28 + A10 + A11 + A12 + A25 + A26 + A27 + A28 >= 1 ;

28. G26 + G27 + G28 + F11 + F12 + F25 + F26 + F27 + F28 + F29 + F30 + E26 + E27 + E28 + D26 + D27 + D28 + C26 + C27 + C28 + B12 + B25 + B26 + B27 + B28 + B29 + B30 + A12 + A25 + A26 + A27 + A28 + A29 + A30 >= 1 ;

29. G29 + G30 + F26 + F27 + F28 + F29 + F30 + E29 + E30 + D29 + D30 + C29 + C30 + B28 + B29 + B30 + A28 + A29 + A30 >= 1 ;

30. G29 + G30 + F28 + F29 + F30 + F31 + E29 + E30 + D29 + D30 + C29 + C30 + B28 + B29 + B30 + A28 + A29 + A30 >= 1 ;

31. G31 + G32 + F30 + F31 + F32 + F33 + E31 + E32 + D31 + D32 + C31 + C32 + B31 + B32 + A31 + A32 >= 1 ;

32. G31 + G32 + F31 + F32 + F33 + E31 + E32 + D31 + D32 + C31 + C32 + B31 + B32 + A31 + A32 >= 1 ;

33. G33 + F31 + F32 + F33 + F34 + F35 + E33 + D33 + C33 + B33 + B34 + A33 + A34 >= 1 ;

34. G34 + G35 + F33 + F34 + F35 + F36 + E34 + E35 + D34 + D35 + C34 + C35 + B33 + B34 + B35 + A33 + A34 + A35 >= 1 ;

35. G34 + G35 + F33 + F34 + F35 + F36 + F37 + E34 + E35 + D34 + D35 + C34 + C35 + B34 + B35 + B36 + A34 + A35 + A36 >= 1 ;

36. G36 + G37 + F34 + F35 + F36 + F37 + E36 + E37 + D36 + D37 + C36 + C37 + B35 + B36 + B37 + A35 + A36 + A37 >= 1 ;

37. G36 + G37 + F35 + F36 + F37 + E36 + E37 + D36 + D37 + C36 + C37 + B36 + B37 + A36 + A37 >= 1 ;

b. Limitation of Ship Placement at Prone Points

Each ship from the existing group of vessels can only occupy one vulnerable point, to prevent one vulnerable point from being occupied by more than one ship.

$$\sum_{i=1}^{37} (Ai + Bi + Ci + Di + Ei + Fi + Gi) \leq 1$$

A1+B1+C1+D1+F1+G1 ≤ 1

A2+B2+C2+D2+F2+G2 ≤ 1

A3+B3+C3+D3+F3+G3 ≤ 1

A37+B37+C37+D37+F37+G37 ≤ 1

c. Limitation of the number of vessels per vessel group

A1+ A2+A3+ . . . + A37 ≤ 1

B1+ B2+B3+ . . . + B37 ≤ 2

C1+ C2+C3+. . . + C37 ≤ 8

D1+D2+ D3+ . . .+ D37 ≤ 3

E1+E2+ E3+ . . . + E37 ≤ 4

F1+ F2+F3+ . . . + F37 ≤ 1

G1+G2+G3+. . . + G37 ≤ 1

d. Limitation of Binary Numbers

If the selected ship is worth 1 while if it is not then it is worth 0. $A_i, B_i, C_i, D_i, E_i, F_i, G_i \in \{0,1\} \quad \forall i$

3.6 Optimizing process

The process of optimizing the assignment of Indonesian Navy ships in the territorial waters of Riau Islands was assisted by the use of Lingo 11 software. After the model was entered into Lingo 11, the optimization process was carried out using the solve command. The Value column shows whether the decision variable in question is selected or not in the model. The total number of ships used is 12 ships ; A17, B14, B28, D4, D7, D36, E1, E31, E33, E34, F21, dan G10.

3.7 Optimization result

From the optimization results, it was found that the ships assigned were 12 ships. Of the total 20 ships, 12 ships were able to cover all the critical points, so there were savings on the costs of the operations carried out.

The total number of ships used is 12 ships A17, B14, B28, D4, D7, D36, E1, E31, E33, E34, F21, and G10. So the cost needed is Rp. 381,831,914,000, - with details listed in the following table:

Table 3. Result Optimization of Assignment of Indonesian Navy ships

KRI Group	Amount Use	Operating cost 1 year (Rp)	Operating cost total (Rp)
A	1	27.397.521.000	27.397.521.000
B	2	41.479.982.500	82..959.965.000
C		28.715.481.600	0
D	3	35.764.632.000	107.293.896.000
E	4	30.405.760.800	121.623.043.200
F	1	13.657.308.000	13.657.308.000
G	1	28.900.180.800	28.900.180.800

This cost is more economical than assigning all ships, namely as many as 20 ships which cost Rp. 611,555,766,800 in one year of operation.

This optimization model has drawbacks, namely the protected hotspots are derived from historical data and from intelligence data. There is a possibility of criminal acts occurring at the vulnerable points that are not recorded on this model. Therefore if there is a new critical point that is not present in this model, then it is necessary to form a new model again by entering the new critical point.

3.8 Model verification

Model verification is carried out by manually plotting patrol boat assignments at the hotspots. Assigned ships will reach vulnerable points based on known radar range. This model verification is done by entering the optimization results, namely A17, B14, B28, D4, D7, D36, E1, E31, E33, E34, F21, and G10 at the existing critical points. Furthermore, each cell that is affordable by the ship in question will be blocked with certain colors that represent the group of ships. The group A ship is blue. Group B is green. Group D ships are red. Group E is yellow. The group of ships F is purple. The group of G ships is orange. This is done continuously until all ships have been plotted at the assigned point of vulnerability. The results of the verification can be seen in the following table 4

Table 4. The results of the model verification

KRI	Point	AFFORDABLE VULNERABLE POINTS																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
E	1	0	28	49	82	165	174	201	234	292	322	347	390	415	495	560	638	678	741	767	892	615	600	590	475	510	471	416	448	518	540	655	673	773	852	874	705	729
	2	28	0	21	54	137	146	173	206	264	294	319	362	387	467	532	610	650	713	739	607	597	574	562	542	447	443	388	394	464	486	601	619	719	798	820	771	747
	3	49	21	0	33	116	125	152	185	243	273	298	341	366	446	511	589	629	692	718	646	561	551	541	521	426	422	367	399	469	491	606	624	724	803	825	750	726
D	4	82	54	33	0	83	92	119	152	210	240	265	308	333	413	478	556	596	659	685	613	528	518	508	488	393	389	334	366	436	458	573	591	691	770	792	717	693
	5	165	137	116	83	0	9	36	69	127	157	182	225	250	330	395	473	513	576	602	530	445	435	425	405	310	306	251	283	353	375	490	508	608	687	709	634	610
	6	174	146	125	92	9	0	27	118	176	206	231	274	299	379	444	522	562	625	651	579	494	484	474	454	359	355	300	332	402	424	539	557	657	736	758	683	659
D	7	201	173	152	119	36	27	0	33	91	121	146	189	214	294	359	437	477	540	566	494	409	399	389	369	274	270	215	247	317	339	454	472	572	651	673	588	564
	8	234	206	185	152	69	118	33	0	58	88	113	156	181	261	326	404	444	507	533	461	376	366	356	336	241	237	215	247	317	339	454	472	572	651	673	265	241
	9	292	264	243	210	127	176	91	58	0	30	55	98	123	203	268	346	386	449	475	403	318	308	298	278	183	179	124	156	226	248	363	381	481	560	582	412	388
G	10	322	294	273	240	157	206	121	88	30	0	25	68	93	173	238	316	356	419	445	373	288	278	268	248	153	149	94	126	196	218	333	351	451	530	552	382	358
	11	347	319	298	265	182	231	146	113	55	25	0	43	68	148	213	291	331	394	420	348	263	253	243	223	128	124	69	101	171	193	308	326	426	505	527	452	428
	12	390	362	341	308	225	274	189	156	98	68	43	0	25	105	170	248	288	351	377	310	220	210	200	180	85	81	26	58	128	243	261	279	379	458	480	314	290
	13	415	387	366	333	250	299	214	181	123	93	68	25	0	80	145	223	263	326	352	315	230	213	210	205	145	106	131	163	233	255	370	388	488	567	589	374	350
B	14	495	467	446	413	330	379	294	261	203	173	148	105	80	0	65	143	183	246	272	340	255	255	260	258	180	145	196	228	298	320	435	453	553	632	654	409	385
	15	560	532	511	478	395	444	359	326	268	238	213	170	145	65	0	78	118	181	207	306	233	223	250	260	200	185	175	207	277	299	414	432	532	611	633	429	405
	16	638	610	589	556	473	522	437	404	346	316	291	248	223	143	78	0	40	103	129	225	155	180	185	190	165	155	150	182	252	274	389	407	507	586	608	394	370
A	17	678	650	629	596	513	562	477	444	386	356	331	288	263	183	118	40	0	63	89	235	110	120	155	165	170	168	167	199	269	291	406	424	524	603	625	319	295
	18	741	713	692	659	576	625	540	507	449	419	394	351	326	246	181	103	63	0	26	151	151	130	190	203	233	231	193	225	295	317	432	450	550	629	651	357	333
	19	767	739	718	685	602	651	566	533	475	445	420	377	352	272	207	129	89	26	0	125	122	135	199	222	212	215	219	251	321	343	458	476	576	655	677	376	352
	20	892	607	646	613	530	579	494	461	403	373	348	310	315	340	306	225	235	151	125	0	85	110	174	197	297	336	381	413	483	505	407	425	525	604	626	351	327
F	21	615	597	561	528	445	494	409	376	318	288	263	220	230	255	233	155	110	151	122	85	0	25	89	112	212	251	306	291	361	322	325	425	525	604	626	266	242
	22	600	574	551	518	435	484	399	366	308	278	253	210	213	255	223	180	120	130	135	110	25	0	64	87	187	226	281	313	383	405	297	315	415	494	516	241	217
	23	590	562	541	508	425	474	389	356	298	268	243	200	210	260	250	185	155	190	199	174	89	64	0	23	123	162	217	210	280	302	233	251	351	430	452	177	153
	24	475	542	521	488	405	454	369	336	278	248	223	180	205	258	260	190	165	203	222	197	112	87	23	0	100	139	194	184	254	276	210	228	407	486	508	154	130
	25	510	447	426	393	310	359	274	241	183	153	128	85	145	180	200	165	170	233	212	297	212	187	123	100	0	39	94	75	145	167	282	300	400	479	501	229	205
	26	471	443	422	389	306	355	270	237	179	149	124	81	106	145	185	155	168	231	215	336	251	226	162	139	39	0	55	40	110	132	247	265	365	444	466	268	244
	27	416	388	367	334	251	300	215	215	124	94	69	26	131	196	175	150	167	193	219	381	306	281	217	194	94	55	0	32	102	124	239	257	357	436	458	323	299
B	28	448	394	399	366	283	332	247	247	156	126	101	58	163	228	207	182	199	225	251	413	291	313	210	184	75	40	32	0	70	92	207	225	325	404	426	304	280
	29	518	464	469	436	353	402	317	317	226	196	171	128	233	298	277	252	269	295	321	483	361	383	280	254	145	110	102	70	0	22	137	155	255	334	356	374	350
	30	540	486	491	458	375	424	339	339	248	218	193	243	255	320	299	274	291	317	343	505	322	405	302	276	167	132	124	92	22	0	115	133	233	312	334	396	372
E	31	655	601	606	573	490	539	454	454	363	333	308	261	370	435	414	389	406	432	458	407	325	297	233	210	282	247	239	207	137	115	0	18	118	197	219	294	270
	32	673	619	624	591	508	557	472	472	381	351	326	279	388	453	432	407	424	450	476	425	425	315	251	228	300	265	257	225	155	133	18	0	100	179	201	299	275
E	33	773	719	724	691	608	657	572	572	481	451	426	379	488	553	532	507	524	550	576	525	525	415	351	407	400	365	357	325	255	233	118	100	0	79	101	270	294
E	34	852	798	803	770	687	736	651	651	560	530	505	458	567	632	611	586	603	629	655	604	604	494	430	486	479	444	436	404	334	312	197	179	79	0	22	110	134
	35	874	820	825	792	709	758	673	673	582	552	527	480	589	654	633	608	625	651	677	626	626	516	452	508	501	466	458	426	356	334	219	201	101	22	0	88	112
D	36	705	771	750	717	634	683	588	265	412	382	452	314	374	409	429	394	319	357	376	351	266	241	177	154	229	268	323	304	374	396	294	299	270	110	88	0	24
	37	729	747	726	693	610	659	564	241	388	358	428	290	350	385	405	370	295	333	352	327	242	217	153	130	205	244	299	280	350	372	270	275	294	134	112	24	0

3.9 Sensitivity analysis

Sensitivity analysis is done on this model due to uncertain real conditions. The real uncertain condition that often occurs in marine security operations is that the availability of fuel received by operating vessels is sometimes less than the capacity required by the ship. This will result in the ship's endurance also decreasing too. So that the time the ship operates on the sea is shorter than normal conditions. Because the operating time is shorter then the operations needed in a year are more so that the costs incurred will be greater.

Sensitivity analysis is carried out on the objective function coefficient which is the cost needed in a year. Sensitivity analysis in the form of post optimality analysis, namely sensitivity analysis carried out after obtaining the optimal solution. The objective function coefficient, which is operating costs in a year, will increase due to the increasing number of operations caused by the reduced endurance of the ship. Calculations performed will see to what extent the cost changes reach the greatest value due to the reduction in fuel received.

From the sensitivity analysis conducted, it is known that the model produces the highest cost output if the fuel received by the ship is 89.14% of the fuel capacity on the ship. The resulting cost is Rp. 463,621,411,040, -. Where this cost is greater than the optimal solution without any reduction in fuel received by the ship, which is Rp. 381,831,914,000 This higher cost is caused by the frequency of operations carried out by ships which are getting bigger in a year.

4. CONCLUSION

a. The number of ships needed to cover all vulnerable points is 12 ships

b. The total cost needed in a 1-year operation is Rp. 381,831,914,000, -. This fee is smaller than using the entire ship, which is 20 ships at a cost of Rp. 611,555,766,800 a year

c. This model is flexible, where the existing vulnerable points can change. So if there is a new critical point or there is a vulnerable point removed in this model then it is necessary to formulate the model again because the new optimization results obtained will likely be different

d. In this study, the problems are discrete. Namely formulating the existing critical points as a priority for safeguards. The more optimal condition is to use a continuous approach because the existing problems are the selection of locations in the continuous area, namely the territorial waters, where the placement location can be placed at all points in the waters

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