METHOMIKA: Jurnal Manajemen Informatika & Komputerisasi Akuntansi
Vol. 9 No. 1 (April 2025)
ISSN: 2598-8565 (media cetak)
ISSN: 2620-4339 (media online)

SELECTION OF AUTONOMOUS VEHICLE FOR MARINE PATROL: A MULTI CRITERIA ANALYSIS DECISION MAKING ANALYSIS IN THE NORTH NATUNA SEA

[1]Anang Prasetia Adi✉, [1]Syaiful Anwar, [1]Aris Sarjito, [1]Sovian Aritonang, [2]Eko Prasetyo
[1]Republic of Indonesia Defense University, Bogor, Indonesia
[2]Director of Maritime Meteorology BMKG, Jakarta, Indonesia
Email: anang8088@gmail.com

DOI: https://doi.org/10.46880/jmika.Vol9No1.pp106-111

ABSTRACT

The North Natuna Sea has high strategic and economic importance because it is an important trade route and has abundant fishery resources. However, the region is prone to illegal fishing and border violations. In 2020-2022, there were 162 violations, while 2023 recorded 14 warship contacts. The Indonesian Navy has organized security operations with warships and maritime patrol aircraft. However, budget constraints are a major obstacle. Autonomous vehicles are a potential solution due to their lower cost, high efficiency, and advanced monitoring capabilities. This research aims to determine the priorities and criteria of Autonomous vehicles suitable for patrolling the North Natuna Sea. This research uses a quantitative method with Analytic Network Process (ANP) to analyze the relationship between system elements. The data was analyzed with a Multi Criteria Decision Making approach using Super Decision version 3.10 software to generate objective decisions. The main criteria included Performance, Operational, Maintenance, and Cost. The ANP model allows the evaluation of interrelated factors, determining the priority of Autonomous Vehicles in patrolling the North Natuna Sea. The results showed that the main criteria in the selection of Autonomous Vehicles for patrolling in the North Natuna Sea were Performance (0.441), followed by Cost (0.267), Operational (0.181), and Maintenance (0.111). At the sub-criteria level, Endurance has the highest priority (0.151), followed by Acquisition Cost (0.118) and Range (0.098). For vehicle alternatives, UAV ranked first (0.509), followed by AUV (0.281), UCAV (0.136), and USV (0.074). These results show that UAV is the best choice for maritime patrol based on the factors of performance, cost, and operational range.

Keyword: Autonomous Vehicle, ANP, North Natuna Sea.

INTRODUCTION

The North Natuna Sea has significant strategic and economic importance because its existence positions Indonesia as an archipelago with strategic control over important trade routes in Southeast Asia. The North Natuna Sea is known as an area that is very vulnerable to illegal fishing due to the huge potential of fisheries resources and its location on the border with international waters so that foreign fishermen can easily enter Indonesian waters (Juanita & Setiani, 2022; Situmorang et al., 2022). Throughout 2020 - 2022 there were 162 violations of the sea border area and in 2023 there were at least 14 incidents of warship contact in the North Natuna Sea area (Indonesian Navy Staff of Operation, Fleet Command I, 2023). The North Natuna Sea has significant strategic and economic importance because its existence positions Indonesia as an archipelago with strategic control over important trade routes in Southeast Asia. The North Natuna Sea is known as an area that is very vulnerable to illegal fishing due to its huge potential fishery resources and its location on the border with international waters, making it easy for foreign fishermen to enter Indonesian waters (Gunawan et al., 2022; Suhanto & Putri, 2023). Throughout 2020-2022 there were 162 violations of the sea border area and in 2023 there were at least 14 incidents of warship contact in the North Natuna Sea area (Indonesian Navy Staff of Operation, Fleet Command I, 2023).

Based on Article 7 paragraph 2, sub point 4, Law Number 34 of 2004 concerning the Indonesian National Army, it is explicitly written that the TNI's duty is to secure border areas. To overcome territorial violations in the North Natuna Sea, the Indonesian Navy has conducted Sea Combat Standby Operations and North Natuna Sea Security Operations involving various kinds of Indonesian Warships (KRI), helicopters, and maritime patrol aircraft. For KRI, the Navy deployed 2 Fregate type ships and 2 Corvette type ships (Indonesian Navy Staff of Operation, Fleet

Command I, 2023) (Manumoyoso, 2023). As for maritime patrol aircraft, the Navy deployed CN235-220 MPA and NC212-200 MPA aircraft (Sops Puspenerbal, 2023). On the other hand, Indonesian Coast Guard also prepared 7 units of High-Speed Craft (HSC) patrol vessels with a length of 15 meters and a width of 3.3 meters to strengthen security in the North Natuna Sea (Novarina, 2024). However, the operation costs a lot of money and is not enough to be able to patrol thoroughly. One of the problems related to patrols in the North Natuna Sea is the limited budget available to provide fuel oil logistics (Nirmala Maulana Achmad, 2023). The North Natuna Sea region is shown in Figure 1.

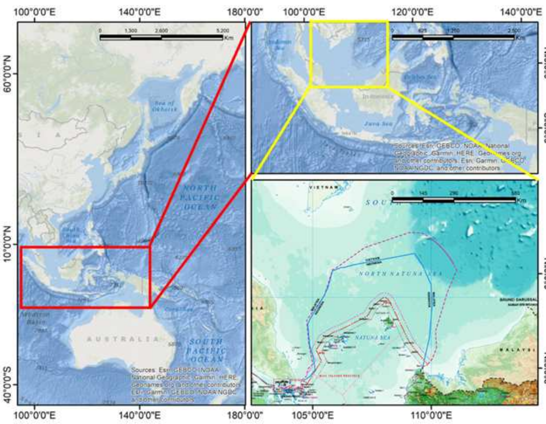

Figure 1. Research Area in the North Natuna Sea

Based on this background, the use of autonomous vehicle systems as an assistance option for patrolling the North Natuna Sea. This is based on several things such as lower operational costs of autonomous vehicles or not using fuel oil (Bauk et al., 2019), easier organization and maintenance (Klein, 2021), more consistent performance (McCullough et al., 2020), and high monitoring and data analysis capabilities (Mahapatra et al., 2016). In recent years, autonomous vehicle (AV) technology has developed rapidly, offering great potential for various sectors, including defense and security. Autonomous vehicles are vehicles that can operate without direct human intervention, using advanced technologies such as sensors, algorithms, and navigation systems to control the vehicle autonomously (Xu et al., 2021). Among the various types of autonomous vehicles, there are Unmanned Aerial Vehicles (UAV), Unmanned Surface Vehicles (USV), and Autonomous Underwater Vehicles (AUV). Each of these types of autonomous vehicles has the potential to provide efficient solutions for surveillance and patrolling of territories. Faced with efficiency, Autonomous Vehicle operational costs that tend to be cheaper accompanied by not too significant costs in their procurement are advantages in themselves. For comparison, the cost incurred by the government in procuring warships results in a cost value equivalent to 10 autonomous vehicles (National & Press, 2005). Of course, faced with Indonesia's defense budget, which is less than 1% of Indonesia's Gross Domestic Product (GDP) (Surahman et al., 2024), the use of AV is one alternative that greatly helps reduce the costs incurred by the state in protecting the border area in the waters of the North Natuna Sea.

The application of autonomous vehicles in patrolling Indonesia's marine territory can be part of the effort to strengthen Indonesia's position as a maritime nation. With lower operational costs, the ability to operate for longer periods of time, and high flexibility, autonomous vehicles can increase the effectiveness of patrols and surveillance and strengthen the overall security of Indonesia's marine border areas (Aliyah et al., 2024; Slamet et al., 2018). Along with ongoing technological developments, autonomous vehicles have great potential to become an integral part of Indonesia's modern and effective sea defense system. By considering the potential of Autonomous Vehicle technology, this research aims to provide strategic solutions to improve the effectiveness of surveillance and defense in the North Natuna Sea. Specifically, the research objectives are: Determine the main priorities of Autonomous Vehicles used in supporting the sea patrol system (National & Press, 2005); and determine the criteria and sub-criteria of Autonomous Vehicle capabilities that are most suitable for dealing with geographical conditions in the North Natuna Sea region (Adi et al., 2024).

RESEARCH METHODOLOGY

This research uses a quantitative method with a new Analytic Network Process (ANP) approach to analyze the relationship between elements in a system. The data is analyzed using the Super Decision tool, which allows quantitative assessment and calculation. This approach aims to obtain values or views that represent consensus from experts, so as to provide more objective and valid results. The hierarchy of criteria consists of: Performance, with sub-criteria of endurance, range, cruising speed and payload capacity; Operational, with sub-criteria of sensor system, communication system, data security, navigation system; Maintenance, including sub-criteria of spare parts, human resources, repair and maintenance facilities; and Cost, including sub-criteria of acquisition cost, operational cost, maintenance cost. The results of

ISSN: 2598-8565 (media cetak)
ISSN: 2620-4339 (media online)

the ANP analysis are used to determine the main priorities of Autonomous Vehicle equipment used in supporting the marine patrol system in the North Natuna Sea.

Table 1. Criteria and Sub-criteria for Autonomous Vehicle (AV) Determination

Num.	Criteria AV	Sub-Criteria	Code
1.	Performance	Endurance	1.1
		Range	1.2
		Cruise Speed	1.3
		Payload Capacity	1.4
2.	Operational	Sensors System	2.1
		Communication System	2.2
		Data Security	2.3
		Navigation System	2.4
3.	Maintenace	Spare Part	3.1
		Human Resources	3.2
		Facilities	3.3
4.	Cost	Acquisition Cost	4.1
		Operational Cost	4.2
		Maintenance Cost	4.3

ANP is a mathematical theory that allows decision makers to systematically deal with interconnected and reciprocal factors. This decision-making method uses a Multi Criteria Decision Making (MCDM) approach with Super Decision software version 3.10 and applies a general framework in a multi-criteria selection process without preconceived notions. The advantage of the ANP method lies in its ability to assist decision makers in measuring and combining various factors in a network. Components in a cluster can affect other components in the same cluster (internal linkage) and also have an impact on components in other clusters (external linkage). The stages in MCDM data analysis are as follows:

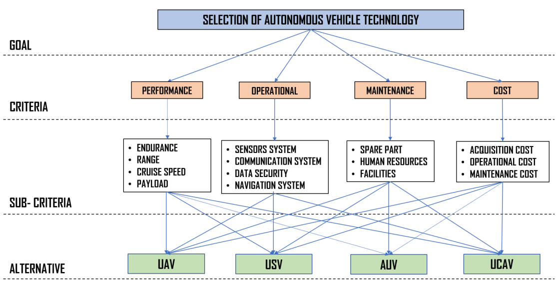

Figure 2. Hierarchical Model of Autonomous Vehicle Technology Selection

Step 1: Determine the desired criteria and sub-criteria, to determine the problem to be solved clearly, in detail and easily understood, making it easier to calculate. From these problems will be determined solutions that may be suitable.

Step 2: Determining the hierarchical structure starting with the main objective (goals) regarding the selection of AV technology in supporting sea patrols in the North Natuna Sea region, followed by arranging the hierarchical levels of criteria and sub-criteria. The results of data processing produce Geometric Mean values in each criterion and sub-criteria, and are followed by ranking. The hierarchical structure in this study can be seen in Figure 2.

Step 3: Compile a pairwise comparison matrix between criteria, sub-criteria and alternatives, followed by entering the weighted value of relative importance based on the preferences of the decision maker using a scale-based value.

Table 2. Relative Level of Importance Scale (Saaty, 1980)

Relative Level of Importance	Definition
1	both elements are equally important
3	one element is slightly more important than the other
5	one element is more important than the other
7	one element is certainly more important than the other
9	one element is absolutely more important than the other
2, 4, 6, 8	Intermediate values between two adjacent preferences

RESULTS AND DISCUSSION

The ANP Multi Criteria Decision Making model is used to make decisions on the selection of Autonomous Vehicle technology, which in this study consists of four criteria: Performance, Operational, Maintenance, and Cost. Hierarchical modeling as shown in Figure 3.

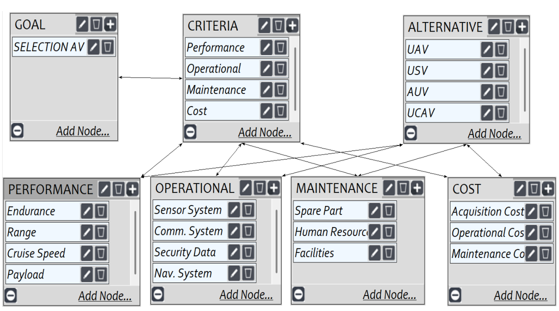

Figure 3. Hierarchical modeling of ANP Multi Criteria Decision Making.

ISSN: 2598-8565 (media cetak)
ISSN: 2620-4339 (media online)

The results of hierarchical modeling are followed by a judgment process in each criterion, sub-criteria, and alternative. The results obtained are in the form of Geometric Mean values and rankings. At the Criteria level, the results obtained are the Ability Criteria ranked first with a priority of 0.441 and a global priority of 0.147. Cost criteria are ranked second with priority 0.267 and global priority 0.089. Operational criteria ranked third with priority 0.181 and global priority 0.060, while Maintenance criteria ranked fourth with priority 0.111 and global priority 0.037, as shown in Table 3.

Table 3. Criterion Level Results on AV Selection

Criteria	Priority	Global Priority	Rank
Performance	0.441	0.147	1
Operational	0.181	0.060	3
Maintenance	0.111	0.037	4
Cost	0.267	0.089	2

The results of the analysis using the ANP super decission model, at the Sub Criteria level, obtained the following results:

a. At the Performance sub-criteria level, Endurance ranks first with a weight of 0.521, followed by range (0.282), cruising speed (0.120), and payload capacity (0.077). With an inconsistency of 0.022 (≤ 0.10), these results are consistent and can be used in decision making.
b. Operational sub-criteria level, data security ranks first with a weight of 0.574, followed by sensor system (0.262), communication system (0.110), and navigation system (0.054). With an inconsistency of 0.046 (≤ 0.10), these results are consistent and can be used in decision making.
c. Maintenance sub-criteria level, spare parts rank first with a weight of 0.642, followed by human resources (0.254), and facilities (0.105). With an inconsistency of 0.005 (≤ 0.10), these results are highly consistent and reliable for decision making; and
d. Cost sub-criteria level, acquisition cost ranks first with a weight of 0.615, followed by operational cost (0.307), and maintenance cost (0.078). With an inconsistency of 0.008 (≤ 0.10), these results are highly consistent and can be used in decision making.

Table 4. Results of Capability, Operational, Maintenance, and Cost Sub-Criteria

a. Sub Criteria Performance		b. Sub Criteria Operational	
Inconsistency	0.022	Inconsistency	0.046
Name	Priority	Name	Priority
1.1 Endurance	0.521	2.1 Sensors System	0.262
1.2 Range	0.282	2.2 Comm. System	0.110
1.3 Cruise Speed	0.120	2.3 Security Data	0.574
1.4 Payload	0.077	2.4 Navigation System	0.054
c. Sub Criteria Maintenance		**d. Sub Criteria Cost**	
Inconsistency	0.005	Inconsistency	0.008
Name	Priority	Name	Priority
3.1 Spare Part	0.642	4.1 Acquisition Cost	0.615
3.2 Human Resources	0.254	4.2 Operational Cost	0.307
3.3 Facilities	0.105	4.3 Maintenance Cost	0.078

The overall ranking results at the Sub Criteria level with the following results: At the Sub criteria level, Endurance ranks first globally with priority 0.151 and global priority 0.050. Followed by Acquisition Cost in second place with priority 0.118 and global priority 0.039. Reach is ranked third with a priority of 0.098 and a global priority of 0.033, while Data Security is ranked fourth with a priority of 0.088 and a global priority of 0.029. Operating Cost ranked fifth with a priority of 0.077 and a global priority of 0.026, followed by Spare Parts ranked sixth with a priority of 0.071 and a global priority of 0.024. Cruising Speed ranked seventh with priority 0.062 and global priority 0.021, while Sensor System ranked eighth with priority 0.059 and global priority 0.020.

Payload ranks ninth with priority 0.053 and global priority 0.018, followed by Human Resources at tenth with priority 0.050 and global priority 0.017. Communication System ranked eleventh with priority 0.046 and global priority 0.015, while Maintenance Cost ranked twelfth with priority 0.046 and global priority 0.015. Navigation System is ranked thirteenth with priority 0.041 and global priority 0.014, and Facilities close at fourteenth with priority 0.042 and global priority 0.014. The overall results of the ranking of Sub Criteria, as shown in Table 5.

Table 5. Overall Ranking Results of Sub Criteria Levels on AV Selection.

Sub Criteria	Priority	Global Priority	Rank
Endurance	0.151	0.050	1
Range	0.098	0.033	3
Cruise Speed	0.062	0.021	7
Payload	0.053	0.018	9
Sensors System	0.059	0.020	8
Communication System	0.046	0.015	11
Security Data	0.088	0.029	4
Navigation System	0.041	0.014	13
Spare Part	0.071	0.024	6
Human Resources	0.050	0.017	10
Facilities	0.042	0.014	14
Acquisition Cost	0.118	0.039	2
Operational Cost	0.077	0.026	5
Maintenance Cost	0.046	0.015	12

Results at the Alternative Level, the UAV ranked first with priority 0.509 and global priority 0.085, making it the best choice based on the analysis conducted. Followed by AUV in second place with priority 0.281 and global priority 0.047. UCAV is ranked third with priority 0.136 and global priority 0.023, while USV is ranked fourth with priority 0.074 and global priority 0.012. Results at the Alternative level, as shown in Table 6.

Table 6. Alternative Level Results on AV Selection

Alternative	Priority	Global Priority	Rank
UCAV	0.136	0.023	3
UAV	0.509	0.085	1
USV	0.074	0.012	4
AUV	0.281	0.047	2

In general, the results of the recapitulation graph at the Goal/Goal, Alternative Level, Criteria Level and Sub Criteria Level along with the Global Priority value are shown in Figure 4.

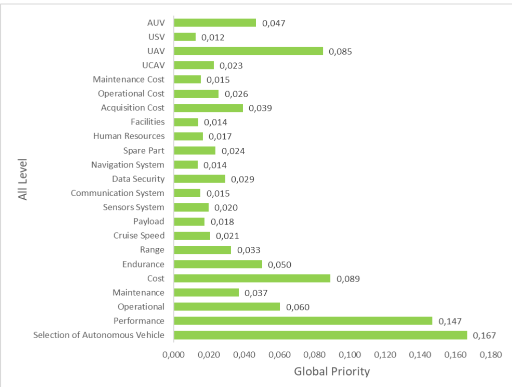

Figure 4. Result Graph of Overall Goal, Alternative, Criteria, and Sub Criteria

CONCLUSIONS

The results showed that Unmanned Aerial Vehicle (UAV) is the best choice for marine patrol in the North Natuna Sea region, with the highest priority score (0.509) compared to AUV (0.281), UCAV (0.136), and USV (0.074). UAVs have better endurance, greater range, and lower operational costs than other alternatives. These factors make UAVs a more efficient solution in supporting surveillance of large maritime areas with limited budgets. Of the four main criteria analyzed, Performance (0.441) and Cost (0.267) are the main determining factors in the selection of autonomous vehicles for patrol. The sub-criteria Endurance (0.151) and Acquisition Cost (0.118) have the most influence, indicating that technological reliability and budget efficiency are crucial elements in supporting a sea defense system. Other factors such as data security (0.088), sensor system (0.059), and navigation (0.041) also play a role in ensuring the operational effectiveness of autonomous vehicles in detecting border threats.

The main obstacle in marine patrols in the North Natuna Sea region is the limited budget for operational warships and maritime patrol aircraft. With 162 territorial violations (2020-2022) and 14 warship contacts (2023), a more cost-effective solution is needed to maintain maritime sovereignty. UAVs offer a more economical alternative to warships and manned aircraft, enabling wider surveillance without heavy reliance on fuel and human resources. The Analytic Network Process (ANP) method used in this research enables more strategic decision-making by considering the relationships between complex elements. Using Super Decision 3.10 software, the model produces data-driven analysis with a high degree of consistency (≤ 0.10), ensuring the accuracy and validity of the results obtained. The evaluation of internal and external factors in the patrol system enables the selection of the most suitable AV technology for the geographical conditions and security challenges in the North Natuna Sea; and the integration of UAVs with AUVs and USVs can be a long-term strategy in strengthening Indonesia's marine surveillance system. By utilizing advanced sensor technology and integrated communication systems, autonomous vehicles can improve the effectiveness of early detection and response to threats at the border. As technology develops, the use of AVs in the maritime defense sector could become an integral part of Indonesia's defense system modernization, enabling the country to safeguard its sovereign waters more efficiently and adaptively to regional security challenges.

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ISSN: 2598-8565 (media cetak)
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