



AHP-Based Evaluation of UAV Platforms for Maritime Surveillance Across Indonesia's Archipelagic Sea Lanes

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ABSTRACT

Indonesia's vast archipelagic waters and strategic Archipelagic Sea Lanes (ALKI I, II, and III) demand effective maritime surveillance. This study applies the Analytic Hierarchy Process (AHP) to evaluate Fixed-Wing, Rotary-Wing, and Hybrid VTOL UAVs across six criteria: range, endurance, payload, launch flexibility, weather resilience, and communication. Results indicate Hybrid VTOL UAVs as the most suitable overall, particularly for ALKI II and III, while Fixed-Wing UAVs best fit ALKI I, and Rotary-Wing UAVs serve tactical short-range needs. A region-specific UAV deployment strategy is recommended to strengthen maritime security and guide defense procurement.

INTRODUCTION

Indonesia, the world's largest archipelago, is made up of over 17,000 islands spread across a vast span of sea between the Indian and Pacific oceans. (Lestari, 2021). The country's unique geography positions it as a crucial hub for both international shipping routes and regional defense. Therefore, maintaining effective surveillance, security, and sovereignty over its maritime territory is not only a necessity but also a complex operational challenge. (Ministry of Defence of the Republic of Indonesia, 2015). To facilitate international navigation while ensuring national security, Indonesia has established three Indonesian Archipelago Sea Lines (ALKI) - ALKI I, ALKI II, and ALKI III - which function as official routes for foreign vessels and aircraft under international law of the sea. (Kusumoprojo Wahyuno. S, 2007). These corridors traverse various oceanographic and atmospheric conditions, each presenting different geopolitical and logistical considerations. This division emphasizes the necessity for defense strategies tailored to the distinct characteristics of each ALKI region.

As one of the world's maritime nations, the use of Unmanned Aerial Vehicles (UAVs) has emerged as a transformative asset in defense and surveillance operations (Shafira Karunia Hildawati et al., 2024). Their versatility, rapid deployment, and cost-effectiveness make them particularly attractive to countries like Indonesia, where conventional air patrols are limited by geography and cost. However, not all UAVs are suitable for every operational environment-performance can vary significantly based on platform type, payload capacity, endurance, weather resistance, and communications infrastructure (Ariante & Del Core, 2025).

The strategic utilization of UAVs within Indonesia's maritime defense architecture must consider not only their technical specifications but also the distinct operational demands of each maritime zone. Indonesia's vast archipelagic geography means that surveillance missions must adapt to varying sea conditions, weather patterns, and levels of accessibility. UAVs that perform well in open and relatively stable waters, such as those found in ALKI I, may not be suitable for narrow straits or storm-prone areas in ALKI II and III (Stokes et al., 2023). Therefore, an analytical framework that aligns UAV capabilities with environmental and logistical variables is essential for ensuring mission success and maximizing the return on defense investment. Furthermore, the increasing geopolitical interest in Indonesia's surrounding seas – from the South China Sea disputes to the intensifying military presence in the Indo-Pacific region – demands that Indonesia enhance its maritime domain awareness and rapid response capabilities (Sadov & Sharp, 2025). UAVs equipped with real-time imaging, automatic target recognition, and BVLOS (Beyond Visual Line of Sight) systems can significantly enhance Indonesia's ability to monitor unauthorized movements and respond promptly to maritime incidents. However, without a clear strategic framework, the deployment of such technologies may remain sporadic and inefficient.

In addition to military considerations, UAV-based surveillance also plays a vital role in safeguarding economic resources. Illegal, unreported, and unregulated (IUU) fishing, smuggling, and marine pollution are persistent

threats that drain Indonesia's economic potential and undermine environmental sustainability. Deploying UAVs with adaptive sensors and modular payloads can provide continuous monitoring of exclusive economic zones (ZEE) and environmentally sensitive areas, thereby reinforcing both national defense and sustainable development goals (Bartlett et al., 2025). While UAVs have gained traction in Indonesia's defense strategy, there is a lack of systematic analysis of the types of drones and technical specifications best suited for operations in ALKI I, II and III. Without such tailored guidance, the risk of procurement inefficiencies, operational failures and underutilized capabilities will remain high.

This study addresses the current gap in UAV deployment strategy by proposing a structured method for evaluating and selecting UAV platforms based on multi-criteria analysis. By applying the Analytic Hierarchy Process (AHP), this research integrates technical performance indicators with Indonesia's strategic maritime needs across ALKI I, II, and III. The ultimate goal is to support policymakers, defense planners, and procurement authorities in making informed decisions that are operationally effective, economically efficient, and aligned with the long-term vision of national maritime security.

THEORETICAL REVIEW

Several studies have looked into the use of Unmanned Aerial Vehicles (UAVs) in marine defense operations. Unmanned Aerial Vehicles (UAVs) are playing an increasingly important role in border surveillance and anti-smuggling operations, especially in countries with large maritime boundaries where traditional patrol tactics are limited in terms of logistics and cost. Drones provide an agile and cost-effective solution for border authorities, enhancing situational awareness and enabling the detection of cross-border illegal activities – including smuggling and unauthorized vessel movement – particularly during nighttime operations through the use of advanced infrared sensors. (Athanasakis et al., 2025).

A study conducted by (Sarjito, 2024) used a sustainable marine defense model in archipelagic environments and found that incorporating UAV platforms considerably improved situational awareness and maritime domain control. The UAVs were demonstrated to increase real-time surveillance coverage, minimize response latency, and improve operational coordination across geographically separated coastal zones. These findings are especially pertinent for countries such as Indonesia and the Philippines, where retaining sovereignty over broad maritime territories presents difficult logistical challenges. The study supports the view that UAV systems are not only supplemental but fundamental elements in the modernization of maritime security infrastructures.

(Ramesh & Muruga Lal Jeyan, 2022) conducted a thorough comparative analysis of fixed-wing, rotary-wing, and hybrid UAVs for military and civilian purposes, with a focus on performance characteristics such as endurance, range, payload, and deployment flexibility. Their organized, multidimensional evaluation closely reflects the analytical approach of this research, which further

extends the concept by using the Analytic Hierarchy Process (AHP) to systematically evaluate UAV types throughout ALKI I, II, and III.

(ULUKAVAK & MIMAN, 2021) Using the Analytic Hierarchy Process (AHP), a detailed multi-criteria evaluation was undertaken to establish the ideal marine surveillance assets. Their study evaluated a variety of intervention vehicles, including UAVs, ships, and helicopters, using seven important operational criteria: range, endurance, payload, communication systems, weather resilience, maneuverability, and responsiveness. The use of AHP enabled a transparent and hierarchical comparison of platform choices, which the authors argued was crucial for decision-making in complex marine zones.

In a similar vein, (Marwanto et al., 2023) applied the Analytic Hierarchy Process (AHP) to support maritime security operations, evaluating UAV alternatives on criteria including operational range, endurance, sensor quality, and communications reliability. By involving maritime security experts in pairwise comparison judgments, their study prioritized UAV platforms most suitable for early detection missions at sea. This methodology aligns closely with the current research, which extends this approach by focusing exclusively on UAV platforms—fixed-wing, rotary-wing, and hybrid VTOL—tailored to the distinct geographic and environmental demands of Indonesia’s ALKI corridors.

Regarding drone types, UAVs can be broadly categorized into fixed-wing, rotary-wing, and hybrid VTOL (Vertical Take-Off and Landing). Fixed-wing UAVs like the Boeing ScanEagle are known for their long endurance and range, making them suitable for wide-area patrols. Rotary-wing drones such as the DJI Matrice 300 RTK excel in agility and vertical lift, which is advantageous for confined operations. Hybrid VTOL platforms, including the Trinity F90+, combine the strengths of both fixed and rotary systems, offering flexibility in launch and operational endurance.



Figure 1. Fixed Wing ScanEagle (I), Rotary-Wing DJI Matrice 300 RTK (II), Hybrid VTOL Trinity F90+ (III)

METHODOLOGY

This study uses a hybrid qualitative-quantitative approach, integrating UAV technical specification analysis with the Analytic Hierarchy Process (AHP) for structured decision-making. The method is divided into the following stages: 1. Criteria Identification: The UAV evaluation is based on seven key criteria: range, endurance, payload capacity, launch flexibility, weather resilience, and communication system (e.g., BVLOS capability). 2. AHP Framework: AHP is employed to structure the decision-making process. The eigenvector method is

used to calculate consistency and derive normalized weights for each criterion. 3. UAV Scoring: Three UAV types—fixed-wing, rotary-wing, and hybrid VTOL—are assessed against each criterion on a scale of 1 to 5 based on their known specifications from manufacturers and academic sources. 4. Aggregated Evaluation: A weighted sum model combines the UAV scores with AHP-derived weights to produce a final ranking of UAV types for general ALKI deployment (Vukić et al., 2024). This methodological approach ensures objectivity, transparency, and reproducibility in UAV selection, particularly in the context of archipelagic maritime defense.

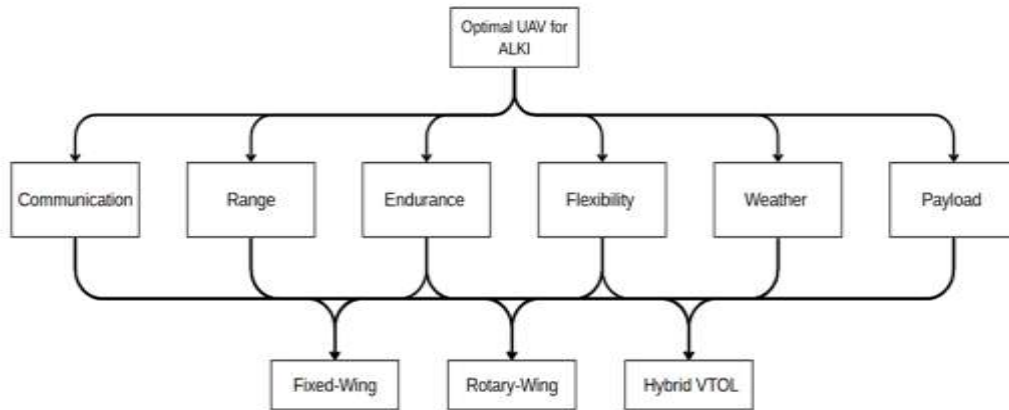


Figure 2. Analytic Hierarchy Process (AHP) Framework

RESULTS AND DISCUSSION

Based on the Analytic Hierarchy Process (AHP), each evaluation criterion was assigned a priority weight, where range (26%) and endurance (24%) emerged as the most significant factors in determining UAV suitability. These were followed by payload capacity (15%), launch flexibility (13%), weather resilience (12%), and communication system (10%). The three UAV types evaluated—Fixed-Wing (e.g., Boeing ScanEagle), Rotary-Wing (e.g., DJI Matrice 300 RTK), and Hybrid VTOL (e.g., Trinity F90+)—demonstrated different strengths.

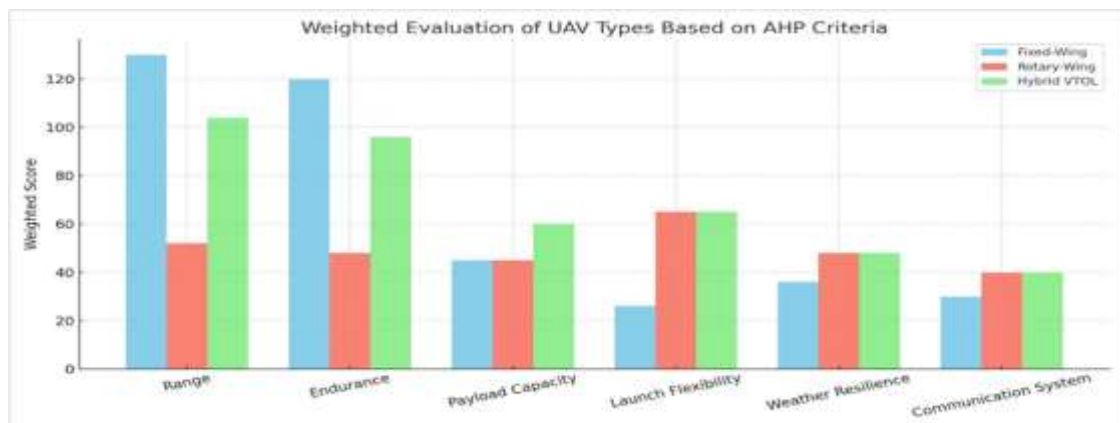


Figure 3. Weighted Evaluation of UAV Types Based on AHP Criteria Diagram

Fixed-wing UAVs showed superior range and endurance but lacked flexible launch options. Rotary-wing UAVs offered excellent maneuverability and vertical lift capabilities, though limited in range and endurance. In contrast, Hybrid VTOL UAVs provided a balanced performance across all criteria and were highly adaptable to Indonesia’s archipelagic terrain. Table 1 presents the final AHP-weighted scores for each UAV type.

Table 1. Final AHP-Weighted Scores

UAV Type	Weighted Score
Hybrid VTOL (Trinity F90+)	4.23
Fixed-Wing (ScanEagle)	4.09
Rotary-Wing (Matrice 300)	3.05

From these results it can be concluded that the Hybrid VTOL has the highest score, showing its most balanced and adaptive performance to Indonesia’s geographical conditions. It combines good range with vertical take-off capability, making it ideal for infrastructure-constrained areas such as ALKI II and ALKI III. Meanwhile, Fixed-Wing UAVs such as ScanEagle have advantages in range and endurance, making them ideal for ALKI I, a relatively stable and open sea lane, with better infrastructure support. Rotary-Wing UAVs, while limited in terms of range and endurance, have advantages in maneuverability and hovering capabilities that are very useful for close-range tactical operations, such as port inspections, ship monitoring, or SAR (Search and Rescue) missions.

Each sea corridor in the Indonesian Archipelago Sea Route (ALKI) system has different geographical characteristics, operational environments and infrastructure levels, requiring a special approach in the selection of UAV types to be used to support maritime surveillance and defense. ALKI I, which covers the Malacca Strait and North Natuna Sea, is characterized as an open sea with very active international shipping lanes. The region is relatively geographically stable and has sufficient supporting infrastructure, such as ports and military bases (Fenton, 2024). Therefore, the most suitable UAV for use in this region is the Fixed-Wing type, as it is able to cover a very large area and stay in the air for a long duration. This capability is essential for strategic patrol missions that require large area coverage and high fuel efficiency.

Meanwhile, ALKI II, which stretches from the Java Sea to the Flores Sea, is an area with narrower seas, high density of ship traffic, and complex island topography. The many small islands and intense geographical dynamics make a Hybrid VTOL type UAV the most appropriate choice (Ambroziak et al., 2022). This type of UAV has the flexibility to take off and land vertically without the need for a large runway, while being able to cover dispersed areas. These characteristics make Hybrid VTOL ideal for continuous operations and dynamic situational monitoring in infrastructure-constrained environments.

ALKI III, which covers the Banda Sea to the Aru Sea, is a deep-sea area with often extreme weather conditions and minimal availability of supporting

infrastructure. In this region, the main needs are maneuvering flexibility, precise short-term mission capabilities, and a long-range communication system (Beyond Visual Line of Sight/BVLOS) to maintain control of the UAV in conditions of minimal signal or direct access (Nomikos et al., 2023). Therefore, Hybrid VTOL and Rotary-Wing UAVs are considered most suitable for operation in ALKI III. Hybrid VTOL offers a balance between range and launch flexibility, while Rotary-Wing has advantages in hovering and vertical mobility that are important for incidental missions such as evacuation, search and rescue (SAR), and surveillance of critical points in a short time.

Table 2. UAV Types and Suitability for Indonesian ALKI Corridors

UAV Type	ALKI I	ALKI II	ALKI III	Notes
Fixed-Wing	Yes	Yes	No	Needs long runway or mobile launcher
Hybrid VTOL	Yes	Yes	Yes	Balanced: good for all regions
Rotary-Wing	Yes, for Short Operation	Yes	Yes	Tactical missions, ship-launched

CONCLUSION AND RECOMMENDATION

Indonesia's vast and diverse maritime landscape demands a strategic and adaptive approach to surveillance and defense operations. Through the application of the Analytic Hierarchy Process (AHP), this study has identified the most suitable Unmanned Aerial Vehicle (UAV) platforms for each Indonesian Archipelagic Sea Lane (ALKI) based on six prioritized criteria: range, endurance, payload capacity, launch flexibility, weather resilience, and communication capabilities.

The analysis revealed that Hybrid VTOL UAVs offer the most balanced performance across all operational criteria, achieving the highest overall AHP-weighted score (4.23). Their combination of moderate range, endurance, and vertical takeoff and landing capabilities makes them highly effective in infrastructure-limited and geographically complex regions, such as ALKI II and ALKI III. Fixed-Wing UAVs, exemplified by the Boeing ScanEagle, scored slightly lower (4.09) but are optimal for ALKI I, where wide-area coverage and prolonged endurance are critical, supported by better infrastructure and relatively stable operating conditions. Rotary-Wing UAVs, such as the DJI Matrice 300, scored lowest overall (3.05) due to limited range and endurance, yet they offer unique advantages in maneuverability, precision hovering, and vertical mobility—making them ideal for tactical missions in ALKI III, including port surveillance and search-and-rescue operations.

This study underscores the importance of aligning UAV platform capabilities with the distinct environmental and operational challenges of each ALKI corridor. A tailored, zone-specific UAV deployment strategy will enhance

Indonesia's maritime domain awareness, strengthen national defense, and improve the cost-effectiveness of future UAV procurements.

This study recommends that Indonesia adopt a region-specific approach to UAV deployment, aligning each platform's capabilities with the unique characteristics of ALKI I, II, and III. Fixed-Wing UAVs should be prioritized for ALKI I due to their superior range and endurance, which are suitable for monitoring the wide and relatively stable maritime zones of the Malacca Strait and North Natuna Sea. For ALKI II, which features complex topography and limited infrastructure, Hybrid VTOL UAVs offer the optimal combination of vertical takeoff capability and sufficient range, making them highly adaptable for dynamic surveillance environments. In ALKI III, where extreme weather and sparse infrastructure present significant operational challenges, a combination of Hybrid VTOL and Rotary-Wing UAVs is most appropriate. Hybrid VTOL UAVs provide operational flexibility, while Rotary-Wing UAVs enable precision hovering and short-range missions in difficult-to-access areas.

Furthermore, it is recommended that defense procurement processes integrate multi-criteria decision-making tools such as the Analytic Hierarchy Process (AHP) to ensure that UAV acquisitions are efficient, transparent, and aligned with mission requirements. Strengthening supporting infrastructure—including control centers, BVLOS communication systems, and maintenance hubs—is also critical for sustained UAV operations, particularly in ALKI II and III. Lastly, improving interagency collaboration and investing in operator training and technical capacity will be essential for maximizing the strategic impact of UAV deployment in Indonesia's maritime defense architecture.

FURTHER STUDY

Despite the comprehensive analysis provided in this study, several limitations must be acknowledged. First, the evaluation of UAV platforms was primarily based on publicly available specifications and literature-based assessments. Real-world performance, particularly under dynamic maritime conditions and operational constraints unique to each ALKI region, may differ significantly from these projections. Therefore, future research should incorporate field trials and empirical testing to validate the AHP-based rankings in actual maritime surveillance missions. Second, the criteria weights in the AHP model were derived from general operational priorities. Incorporating expert judgment from military operators, naval personnel, and UAV manufacturers through structured interviews or Delphi methods would enhance the model's precision and contextual relevance. Additionally, the AHP framework used in this study could be expanded by integrating fuzzy logic or other multi-criteria decision-making tools such as TOPSIS or PROMETHEE to handle ambiguity and uncertainty in stakeholder preferences.

Another potential area for further investigation involves the integration of UAVs into a broader command-and-control architecture, including satellite communication systems, maritime patrol aircraft, and naval surface assets. Future studies could explore how interoperability between UAVs and other maritime surveillance technologies can be optimized to create a robust and

resilient maritime domain awareness network. economic feasibility and lifecycle cost analysis—including maintenance, training, infrastructure investment, and potential export or dual-use applications—should be examined in future research to support long-term procurement and deployment strategies. As the strategic environment in the Indo-Pacific continues to evolve, ongoing evaluation of emerging UAV technologies and their applicability to Indonesia's archipelagic defense posture will remain critical.

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REFERENCES

- Ambroziak, L., Ciężkowski, M., Wolniakowski, A., Romaniuk, S., Bożko, A., Ołdziej, D., & Kownacki, C. (2022). Experimental tests of hybrid VTOL unmanned aerial vehicle designed for surveillance missions and operations in maritime conditions from ship-based helipads. *Journal of Field Robotics*. <https://doi.org/10.1002/rob.22046>
- Ariante, G., & Del Core, G. (2025). Unmanned Aircraft Systems (UASs): Current State, Emerging Technologies, and Future Trends. *Drones*, 9(1). <https://doi.org/10.3390/drones9010059>
- Athanasakis, I., Myttas, D., Katsilieris, T. D., Bellou, E., Zervakis, M., Antonakakis, M., Koutras, N., Boulougaris, G., Georgiou, M., Salom, I., Todorovic, D., Salajster, I., Nico, G., Masci, O., Kontopodis, I., Iriarte, F., & Leskovsky, P. (2025). BorderUAS Project: Semiautonomous Border Surveillance Platform Combining a Lighter-Than-Air (LTA) Unmanned Aerial Vehicle (UAV) with Ultra-High-Resolution Multisensor Surveillance Payload: A Comprehensive Overview. In I. Gkotsis, D. Kavallieros, N. Stoianov, S. Vrochidis, D. Diagourtas, & B. Akhgar (Eds.), *Paradigms on Technology Development for Security Practitioners* (pp. 401–414). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-62083-6_32
- Bartlett, B., Santos, M., Dorian, T., Moreno, M., Trsllic, P., & Dooly, G. (2025). Real-Time UAV Surveys with the Modular Detection and Targeting System: Balancing Wide-Area Coverage and High-Resolution Precision in Wildlife Monitoring. *Remote Sensing*, 17(5). <https://doi.org/10.3390/rs17050879>
- Fenton, A. J. (2024). Preventing Catastrophic Cyber-Physical Attacks on the Global Maritime Transportation System: A Case Study of Hybrid Maritime

- Security in the Straits of Malacca and Singapore. *Journal of Marine Science and Engineering*, 12(3). <https://doi.org/10.3390/jmse12030510>
- Kusumoprojo Wahyuno. S. (2007). *Indonesia Negara Maritim. Teraju (Anggota IKAPI)*.
- Lestari, M. M. (2021). WHAT IS THE RIGHT, ARCHIPELAGIC SEA LANES AND PASSAGE? (ACCORDING TO UNCLOS 1982 AND PRACTICE). *Indonesian Journal of International Law*. <https://doi.org/10.17304/ijil.vol18.2.809>
- Marwanto, M., Darmawan, B., & Pandjaitan, M. B. (2023). Analysis of Selection of Unmanned Aircraft in Supporting Security Operations at Sea. *Journal of Industrial Engineering & Management Research*, 4(4), 20–27. <https://doi.org/10.7777/jiemar.v4i4.483>
- Ministry of Defence of the Republic of Indonesia. (2015). *Indonesian Defence White Paper*. Ministry of Defence of the Republic of Indonesia.
- Nomikos, N., Gkonis, P. K., Bithas, P. S., & Trakadas, P. (2023). A Survey on UAV-Aided Maritime Communications: Deployment Considerations, Applications, and Future Challenges. *IEEE Open Journal of the Communications Society*, 4, 56–78. <https://doi.org/10.1109/OJCOMS.2022.3225590>
- Ramesh, P. S., & Muruga Lal Jeyan, J. V. (2022). Comparative Analysis of Fixed-Wing, Rotary-Wing and Hybrid Mini Unmanned Aircraft Systems (UAS) from the Applications Perspective. *INCAS Bulletin*. <https://doi.org/10.13111/2066-8201.2022.14.1.12>
- Sadov, T., & Sharp, T. (2025). A prize-dependent loitering time approach to UAS routing: application to South China Sea maritime domain awareness. *Journal of Defense Modeling and Simulation*, 0(0), 15485129241312712. <https://doi.org/10.1177/15485129241312711>
- Sarjito, A. (2024). Sustainable Maritime Defense Modeling : An Archipelagic Approach to Adaptability and Flexibility. 05(01), 656–671.
- Shafira Karunia Hildawati, Susilo Adi Purwantoro, Editha Praditya Duarte, Fachmi Khoiruddin, & Hikmat Zakky Almubaroq. (2024). The Role of Unmanned Aerial Vehicles (UAVs) in Indonesian Air Defense Management. *International Journal Of Humanities Education and Social Sciences (IJHESS)*. <https://doi.org/10.55227/ijhess.v3i4.768>
- Stokes, H. J., Mortimer, J. A., Laloë, J. O., Hays, G. C., & Esteban, N. (2023). Synergistic use of UAV surveys, satellite tracking data, and mark-recapture to estimate abundance of elusive species. *Ecosphere*. <https://doi.org/10.1002/ecs2.4444>
- ULUKAVAK, M., & MİMAN, M. (2021). Selection of The Most Proper Unmanned Aerial Vehicle for Transportation in Emergency Operations by Using Analytic Hierarchy Process. *International Journal of Environment and Geoinformatics*. <https://doi.org/10.30897/ijgeo.760758>
- Vukić, L., Vidov, J., & Karin, I. (2024). Method in Selecting Vehicles for Interventions and Surveillance of Navigation Safety at Sea. *Journal of Marine Science and Engineering*, 12(6). <https://doi.org/10.3390/jmse12060979>