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Design of a Low-Cost Vessel Monitoring System for Fishing Vessels

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Abstract

Indonesia, as the world's second-largest maritime country, has a fisheries sector that plays a crucial role in the economy with a contribution of nearly 5% to GDP. With 170,034 fishing vessels spread across Indonesia's entire territory, monitoring the movement of fishing vessels is essential to prevent illegal activities such as fish smuggling, territorial incursions, and maritime terrorism threats. This study aims to design an affordable, effective, and easy-to-use fish vessel monitoring system. The system includes monitoring of location, fuel, weather, and early warning features that can enhance surveillance efficiency. LoRa technology is used as a communication network module for long-distance data transmission at low cost, while the ESP32 microcontroller manages the system effectively. Initial testing in a laboratory-scale model, adjusted to field scenarios, showed satisfactory results: GPS accuracy reached 99.49%, fuel sensor 93.67%, and weather data above 97%, except for wind speed at 72.86% due to external factors during measurement and BMKG data update frequency. Field testing conducted on fishing vessels at the Brondong Nusantara Fishery Port, Lamongan, showed GPS accuracy above 98%, fuel sensor around 92%, and BMKG weather data above 94%. From an economic perspective, this system offers lower production and subscription costs compared to current commercial VMS.

Key Words : Ship Monitoring System, Fishing Vessel, LoRa, ESP32, Low-Cost Technology

1. INTRODUCTION

Indonesia is one of the largest maritime countries in the world, with an area of about 6.32 million km². With such vast waters, Indonesia is ranked as the second-largest fish producer in the world after China. The Indonesian fisheries sector plays an important role in the country's economy, contributing nearly 5% to the Gross Domestic Product (GDP) [1]. In 2023, the number of marine fishing vessels was recorded at 170,034 units spread across Indonesia [2].

Based on this indicator, it can be seen that the traffic in Indonesia's seas is quite high, requiring effective and efficient monitoring and tracking of vessel movements to prevent illegal activities such as fish smuggling, territorial sea invasions, and maritime terrorism. Currently, commercial Fishing Vessel Monitoring Systems (VMS) exist, but they still have high product purchase and subscription costs, which are not affordable for fishermen, resulting in limited use of such systems. Referring to previous research by [3], a vessel monitoring system using a combination of low-cost technology with artificial intelligence was developed for small fishing vessels at Ancona Port, Italy. This system is capable of collecting vessel trajectory data and predicting possible fishing efforts. The tested equipment included the Teltonika FMM640 as a Global Positioning System (GPS) device and used secure REST API over HTTPS to exchange information via the internet, combined with a LoRa module. The results showed that the system worked well but still required cellular data for data transmission. Further research is needed on the detailed fishing patterns to train the algorithm used in understanding the behavior and characteristics of fishing vessels in the study area.

Therefore, the author intends to research and design a vessel monitoring system with affordable equipment and subscription costs for fishermen in Indonesia. With an affordable monitoring system, fishing vessels in Indonesia will have better supervision and will be protected from potential illegal activities.

2. METHODS

2.1. Research Object

The research object is fishing vessels operating at the Brondong Nusantara Fishery Port (PPN), Lamongan Regency, East Java. The research data is obtained from two sources, namely:

1. Primary data, obtained through interviews with fishermen and staff at the Brondong Fishery Port (PPN), as well as direct surveys of the fishing vessels targeted in the research. This data includes the main size of the vessel, general arrangement, fuel tank capacity, vessel speed, and the condition of the equipment used on the vessel.
2. Secondary data, consisting of scientific literature, government reports, and relevant databases related to vessel monitoring systems and supporting technologies.

2.2. Treatment of the Research Object

In this study, the design and testing of a Low-Cost Vessel Monitoring System (VMS) are applied as the treatment to the research object. The fixed variables in this study include the type of vessel (traditional fishing vessels), operational location (Brondong Fishery Port, PPN), and the standard measurements for vessel positioning and weather data. The independent variables include variations in sensor usage (GPS, fuel sensor, ultrasonic sensor), data communication methods (LoRa), and trials on both model vessels and real vessels.

2.3. Research Location

The research was conducted at two main locations, namely:

1. Laboratory for the design, assembly, and calibration stages of the system prototype, including testing components such as the ESP-32, GPS module, LoRa, and ultrasonic sensors.
2. Field at the Brondong Nusantara Fishery Port, Lamongan, East Java, as the location for primary data collection and testing the system implementation on actual fishing vessels.

2.4. Research Method and Procedure

The method used in this study is an experimental method with a prototype development approach. The research procedure includes:

1. Problem identification and literature review.
2. Collection of primary and secondary data.
3. System design and development of the VMS prototype.
4. Integration of hardware (ESP-32, LoRa, GPS sensor, ultrasonic sensor) with software in the form of a user interface.
5. Calibration of sensors (GPS, fuel, and weather).
6. System testing on both model vessels and operational fishing vessels at Brondong Fishery Port (PPN).

This method has been widely used in research based on the Internet of Things (IoT). The advantage of this method is that it can produce prototypes that can be tested directly under real-world conditions, while the disadvantage is the limited scale of implementation and reliance on communication network conditions.

2.5. Research Tools and Materials

The main tools used in this study include the ESP-32 microcontroller, LoRa communication module, GPS sensor, HY-SRF05 ultrasonic sensor, as well as supporting testing equipment such as laptops and comparison GPS testing devices. The research materials consist of traditional fishing vessels as the test objects and software for designing the user interface.

3. RESULT AND DISCUSSION

3.1. Prototype Testing on Model Vessel

Testing on the Model Vessel was conducted to verify the performance of the Low-Cost Vessel Monitoring System before it is applied to fishing vessels. The testing was carried out at Danau Delapan ITS with a setup that mimicked real-world conditions while the vessel was in operation.

- Scheme 1: Sailing Vessel

This test was conducted on the Model Vessel to simulate the initial conditions when the vessel is about to set sail, with the fuel tank still full..

1. GPS

The following is the travel route history recorded during the testing:

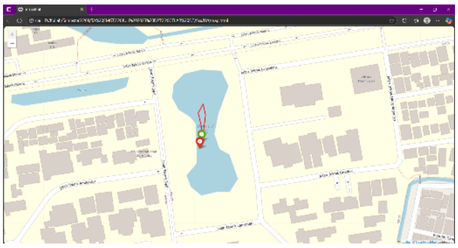

Figure 1. Recorded Travel Route History during Testing in Scheme 1 Model Vessel by the GPS System

Figure 2. The recorded travel route history during testing in Scheme 1 Model Vessel by the comparison GPS.

And below is Figure 3. Comparison Chart of Travel Routes Between the GPS System and Comparison GPS in Scheme 1 Fishing Vessel..

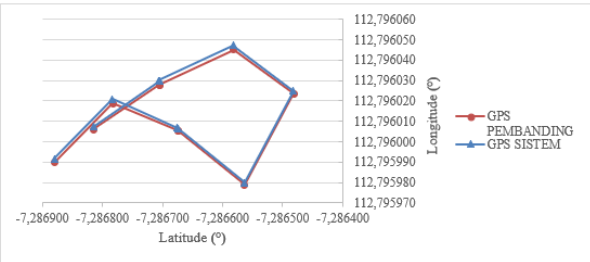

Figure 3. Comparison Chart of Travel Routes Between the GPS System and Comparison GPS in Scheme 1 Fishing Vessel.

Based on the graph and calculations, the GPS System has an error rate of 0.001% for the Latitude and Longitude parameters, with an accuracy of 99.999% compared to the Comparison GPS. For the Distance parameter, the error rate is 1.53%, with an accuracy of 98.47%.

2. Fuel Sensor

In this stage, fuel sensor monitoring was conducted by installing an ultrasonic sensor on the lid of a jar filled with water, representing the vessel's fuel tank. Comparative data was obtained by measuring the fuel height at the starting and ending points before the device was removed.

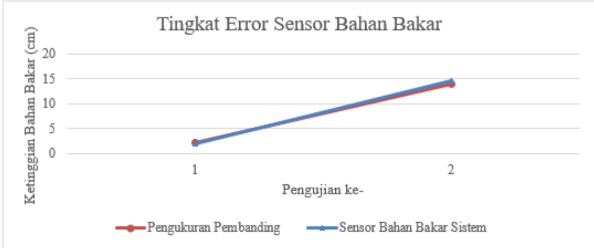

Figure 4. Fuel Sensor Error Rate Graph Scheme 1 on Model Vessel

Based on the calculations and graph, the error rate of the HY-SRF05 ultrasonic sensor is 6.73%, with an accuracy rate of 93.67%.

3. Weather

During the Scheme 1 model vessel testing, the BMKG weather forecast conditions were tested at Keputih Village, Sukolilo District, with the area code 35.78.09.1001. Below is Figure 5. Temperature Error Rate Graph Scheme 1 on Model Vessel.

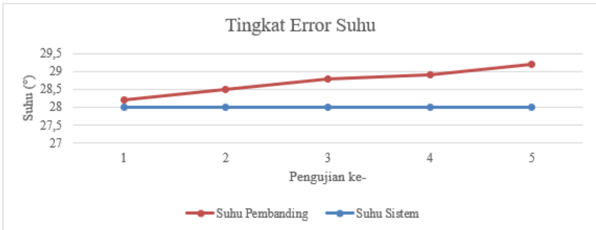

Figure 5. Temperature Error Rate Graph Scheme 1 on Model Vessel.

Based on the graph, the average error rate for the temperature parameter using BMKG weather data is 2.44%, with an accuracy rate of 97.56%. Meanwhile, Figure 6 shows the Humidity Error Rate Graph Scheme 1 on Model Vessel.

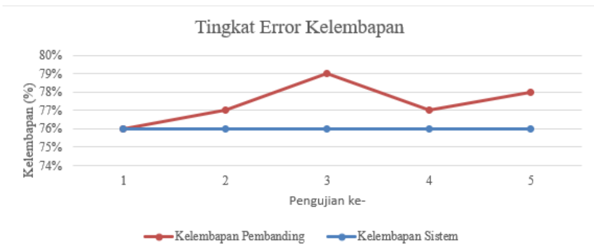

Figure 6. Humidity Error Rate Graph Scheme 1 on Model Vessel.

Based on the graph, the average error rate for the humidity parameter using BMKG weather data is 1.81%, with an accuracy rate of 98.19%. Meanwhile, below is Figure 7. Wind Speed Error Rate Graph Scheme 1 on Model Vessel.

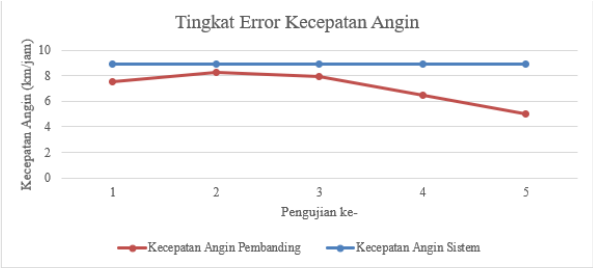

Figure 7. Wind Speed Error Rate Graph Scheme 1 on Model Vessel.

Based on the graph, the average error rate for the wind speed parameter using BMKG weather data is 27.14%, with an accuracy rate of 72.86%. The significant difference between the measurement data and the BMKG weather data is due to the difference in methods, where the anemometer directly measures in the field, while BMKG uses a meteorological model that considers multiple factors.

- Scheme 2 : Vessel in Emergency Condition

In Scheme 2 testing, the test was conducted when the vessel was nearly out of fuel. When the fuel level reached the threshold, the central monitoring system would receive information about the fuel level and the vessel's position, and send a warning through a buzzer sound.

Time Stamp	Latitude	Longitude	Jarak	EMG Button	EMG dari Kapal	Ketinggian BBM
2025-06-16 17:10:52	-7.286675	112.7960067	60,98	EMG Terdeteksi	-	12,3

Figure 8. Data Recorded on the System Data Storage Logger

3.2. Prototype Testing on Fishing Vessel

- Scheme 1 : Vessel Departure

In Scheme 1 testing, the test was conducted where the fishing vessel would depart from Brondong Fishery Port (PPN) Lamongan, with all components of the Low-Cost Vessel Monitoring System fully installed on the vessel.

1. GPS

Berikut merupakan riwayat rute perjalanan yang terekam saat pengujian,

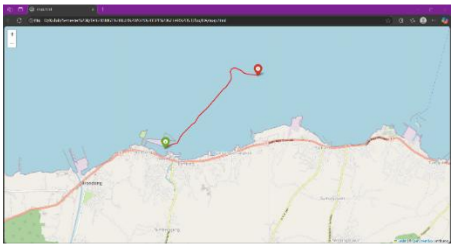

Figure 9. Recorded Travel Route History during Scheme 1 Testing on Fishing Vessel by the GPS System.

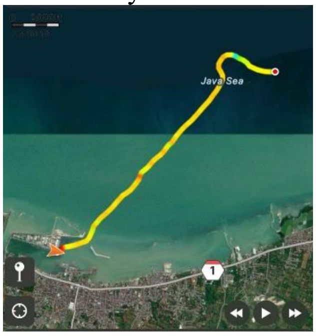

Figure 10. Recorded Travel Route History during Scheme 1 Testing on Fishing Vessel by the Comparison GPS.

And below is Figure 11. Comparison Chart of Travel Routes Between the GPS System and Comparison GPS in Scheme 1 Fishing Vessel.

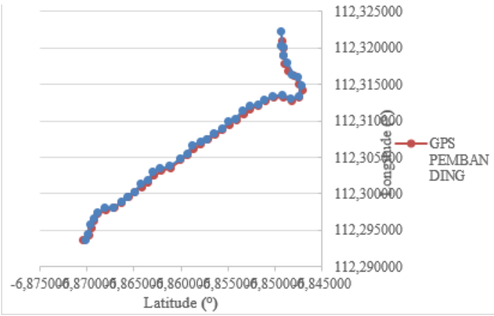

Figure 11. Comparison Chart of Travel Routes Between the GPS System and Comparison GPS in Scheme 1 Fishing Vessel.

Based on the calculations and graph, the GPS System has an error rate of 0.002% for Latitude (accuracy 99.998%) and 0.001% for Longitude (accuracy 99.999%). For the Distance parameter, the error rate is 3.857% with an accuracy of 96.143% compared to the Comparison GPS.

2. Fuel Sensor

In this stage, fuel sensor monitoring was conducted by installing an ultrasonic sensor on the fuel tank cover of the vessel. Scheme 1 tested the condition of a full fuel tank on a vessel with a capacity of 1000 liters. Comparative data was obtained from two water conditions: Test 1 at the dock with calm water, and Test 2 at sea, 4.8 km from the shore.

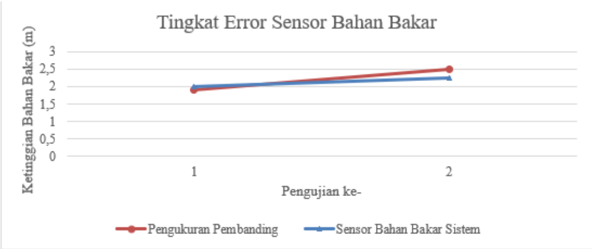

Figure 12. Fuel Sensor Error Rate Graph Scheme 1 on Fishing Vessel.

Based on the calculations and graph, the error rate of the HY-SRF05 ultrasonic sensor is 7.632%, with an accuracy rate of 92.368%.

3. Weather

During Scheme 1 testing, the BMKG weather forecast conditions were tested at Brondong Village, Lamongan City, with the area code 35.24.07.1010. Below is Figure 13. Temperature Error Rate Graph Scheme 1 on Fishing Vessel.

Figure 13. Temperature Error Rate Graph Scheme 1 on Fishing Vessel.

Based on the graph, the average error rate for the temperature parameter using BMKG weather data is 3.11%, with an accuracy rate of 96.89%.

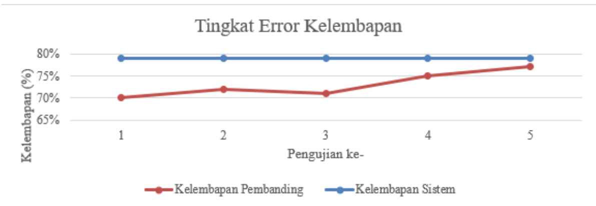

Figure 14. Humidity Error Rate Graph Scheme 1 on Fishing Vessel.

Based on the graph, the average error rate for the humidity parameter using BMKG weather data is 8.22%, with an accuracy rate of 91.78%.

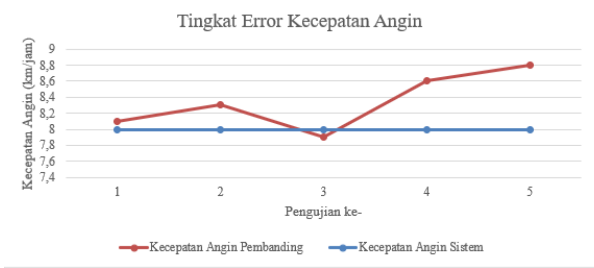

Figure 15. Wind Speed Error Rate Graph Scheme 1 on Fishing Vessel.

Based on the graph, the average error rate for the wind speed parameter using BMKG weather data is 3.61%, with an accuracy rate of 96.39%.

- Scheme 2 : Vessel Return

In Scheme 2 testing, the fishing vessel is on its way back to the dock after completing the journey. The vessel will begin the process of returning to the dock with the fuel level having decreased after being used during the trip.

1. GPS

The following is the travel history recorded during the testing,

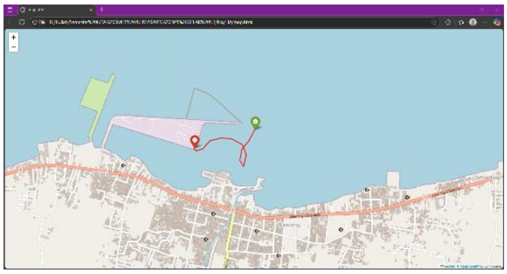

Figure 16. Recorded Travel Route History during Scheme 2 Testing on Fishing Vessel by the GPS System.

Figure 17. Recorded Travel Route History during Scheme 2 Testing on Fishing Vessel by the Comparison GPS.

And below is Figure 18. Comparison Chart of Travel Routes Between the GPS System and

Comparison GPS in Scheme 2 Fishing Vessel.

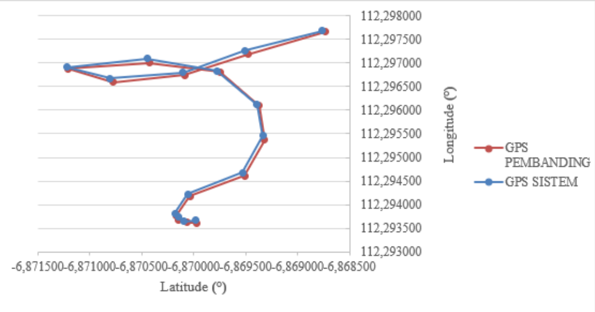

Figure 18. Comparison Chart of Travel Routes Between the GPS System and Comparison GPS in Scheme 2 Fishing Vessel.

Based on the calculations and graph, the GPS System has an error rate of 0.001% with an accuracy of 99.999% for the Latitude and Longitude parameters. For the Distance parameter, the error rate is 4.71% with an accuracy of 95.29%.

2. Fuel Sensor

In this stage, fuel sensor monitoring was conducted on the vessel that had been sailing to catch fish, with the fuel level reduced. The vessel's 1000-liter fuel tank was used as a test model. Comparative data was obtained by measuring at the starting and ending points before the device was removed.

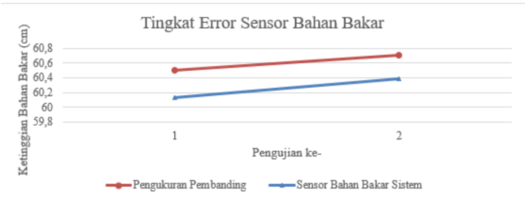

Figure 19. Fuel Sensor Error Rate Graph Scheme 2 on Fishing Vessel.

Based on the graph, the error rate of the HY-SRF05 ultrasonic sensor is 0.56%, with an accuracy rate of 99.44%. The testing conditions were conducted in relatively calm waters, which allowed for more stable and accurate measurements.

3. Weather

During Scheme 2 testing, the BMKG weather forecast conditions were tested at Brondong Village, Lamongan City, with the area code 35.24.07.1010. Below is.

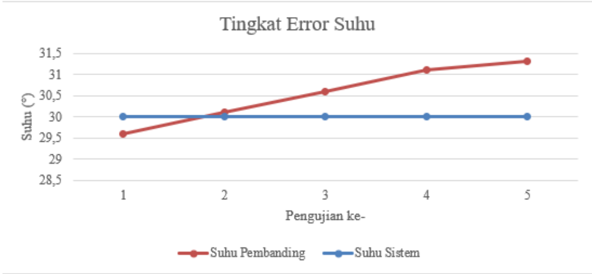

Figure 20. Temperature Error Rate Graph Scheme 2 on Fishing Vessel.

Based on the graph, the average error rate for the temperature parameter using BMKG weather data is 1.64%, with an accuracy rate of 98.36%.

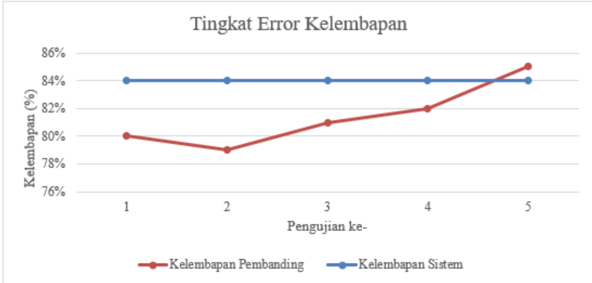

Figure 21. Humidity Error Rate Graph Scheme 2 on Fishing Vessel.

Based on the graph, the average error rate for the humidity parameter using BMKG weather data is 3.19%, with an accuracy rate of 96.81%.

Figure 22. Wind Speed Error Rate Graph Scheme 2 on Fishing Vessel.

Based on the graph, the average error rate for the wind speed parameter using BMKG weather data is 5.6%, with an accuracy rate of 94.4%.

4. Emergency Condition

In Scheme 2 testing, the SOS Button was tested to see if it functions correctly and if LoRa can transmit the last GPS coordinates when the SOS button is pressed.

Time Stamp	Latitude(°)	Longitude (°)	Jarak (m)	EMG Button	EMG dari Kapal	Ketinggian BBM (cm)
2025-06-26 15:28:58	-6.870091	112.293643	874,77	-	EMG From Ship	60,39

Figure 23 Data Recorded on the System Data Storage Logger.

3.3. Economic Analysis

In this stage, a comparison is made between the specifications of the device designed in this study and previously researched Vessel Monitoring Systems, as well as the existing Vessel Monitoring Systems.

Table 1 VMS Specification Comparison

Spesifikasi	***Low Cost Vessel Monitoring System***	**Sistem Pemantauan Kapal Skala Kecil oleh Tasseti et.al**	**VMS Komersial**
Power	5v DC	10 - 30 V DC	5v DC atau 8 - 24V *Input Cable with Regulator*
Baterai	-	12V Battery	AAA 1.5v Lithium
Jangkauan	5 km (+-3 mil) dengan kondisi di ruang terbuka	<20 km (12 mil)	Seluruh Indonesia
GPS	Ublox Neo 6M	Teltonika FMM640	16-channel Ublox Receiver
Transmitter	Lo-Ra	LoRaWAN dan *REST API* over HTTPS	Globalstar Certified Transmitter
Program	Computer Based	Computer Based	Smartphone and Computer Based
Biaya Langganan / bulan	-	Rp 665.000 untuk Data Seluler	Rp 525.000
Harga	Rp 1.147.500	Rp 3.400.000	Rp 7.425.000

The Low-Cost Vessel Monitoring System (VMS) offers an affordable vessel monitoring solution for small fishing vessels with limited budgets. This system includes basic features such as location, weather, fuel, and emergency alerts, providing operational efficiency without high costs. Compared to commercial VMS, this system is more economical, allowing small vessel owners to monitor their vessels at a low cost without sacrificing essential safety and operational features.

4. CONCLUSION

The design of the Low-Cost Vessel Monitoring System (VMS) for fishing vessels resulted in two main components: the user interface and the prototype. This system supports vessel position tracking, fuel monitoring, weather monitoring, and early warning alerts. Laboratory testing showed a GPS accuracy of 99.49%, fuel sensor accuracy of 93.66%, and weather data accuracy above 97%, although wind speed was only 72.86%. Field testing on fishing vessels at Brondong Nusantara Fishery Port demonstrated GPS accuracy of over 98%, fuel sensor accuracy of 92%, and BMKG weather data accuracy of over 91%. Based on the economic feasibility analysis, the system proves financially beneficial with a short payback period of around 8 trips. The low investment cost and minimal annual operating costs make it an affordable solution for fishermen. In addition to enhancing vessel safety and monitoring, this system also supports sustainability and efficiency in managing the fisheries sector.

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No	Type of Review	Mark
1	Abstract:	
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	Methods	
	Conclusion	
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	Objectives and Benefits of the Research	
3	Method:	
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	Treatment of the Research Object	
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	Tools and/or Materials Used in the Research	
4	Result:	
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	Comparison of Results from Different Variables	
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	Table (centered, in line with text, numbered starting from 1, title above the table, first letter capitalized, labels written in bold)	
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	Contains primary references (journals)	
	Format IEEE	