Formosa Journal of Computer and Information Science (FJCIS)
Vol.4, No.1, 2025: 83-92

Development of an IoT-Based Ship Engine Performance Monitoring System to Enhance Operational Efficiency

Imam Sutrisno[1*], Fahmi Umasangadji[2], Ardiansyah[3], Nafi Almuzani[4], Achmad Bashori[5], Urip Mudjiono[6], Projek Priyonggo[7], Endang Pudji Purwanti[8]
[1,6,7,8]Politeknik Perkapalan Negeri Surabaya
[2,3,4,5]Sekolah Tinggi Ilmu Pelayaran
Corresponding Author: Imam Sutrisno imams3jpg@yahoo.com

ARTICLE INFO

Keywords: IoT, Ship Engine Monitoring, Operational Efficiency, Real-Time Data, Marine Engineering

Received : 2 January
Revised : 17 February
Accepted: 10 March

ABSTRACT

This research aims to develop an IoT-based ship engine performance monitoring system to enhance operational efficiency in marine vessels. The study introduces a real-time monitoring prototype integrating sensors, microcontrollers, and cloud-based data visualization. The variables observed include engine temperature, RPM, and fuel consumption. The methodology follows a design and implementation approach, tested on a diesel-powered training ship over a two-week observation period. Data were collected continuously and analyzed to detect performance anomalies and efficiency trends. Results show that the system improves situational awareness and enables proactive maintenance decisions. The developed system has implications for reducing fuel costs, extending engine life, and supporting digital transformation in marine engineering operations

---

DOI: https://doi.org/10.55927/fjcis.v4i1.14134
ISSN-E: 2830-3040
https://journal.formosapublisher.org/index.php/fjcis

INTRODUCTION

The operational efficiency of marine vessels heavily depends on the performance and reliability of ship engines. In conventional ship operations, performance monitoring is still predominantly manual and periodic, often resulting in delayed responses to engine anomalies, increased maintenance costs, and reduced fuel efficiency. This is particularly problematic for training and research vessels operated by educational institutions, where real-time data can be pivotal for both safety and learning purposes. The advancement of Internet of Things (IoT) technology offers new opportunities to transform traditional marine engineering systems into smart, connected platforms capable of real-time data acquisition and analysis. However, the application of IoT in ship engine performance monitoring remains limited, especially in smaller-scale or educational marine operations, which represents a unique niche for investigation. This study contributes to the field by developing and implementing an IoT-based system specifically tailored for monitoring engine parameters such as temperature, RPM, and fuel consumption on a diesel-powered training vessel. The system's novelty lies in its integration of low-cost hardware with cloud-based analytics to support timely maintenance decisions and enhance operational efficiency. This research aims to answer how an IoT-based monitoring system can improve engine performance visibility and operational decision-making in marine environments.

LITERATURE REVIEW

The Technology Acceptance Model (TAM), developed by Davis (1989), explains user acceptance of information technology based on two key factors: perceived usefulness and perceived ease of use. In the context of ship engine monitoring, these factors influence how users (e.g., engineers, crew, or students) adopt and utilize IoT-based systems. When a monitoring system is easy to operate and provides valuable real-time insights, users are more likely to integrate it into daily operations, leading to improved efficiency.

H1: Perceived usefulness of an IoT-based engine monitoring system has a positive effect on operational efficiency.
H2: Perceived ease of use of an IoT-based engine monitoring system positively influences its adoption in marine operations.

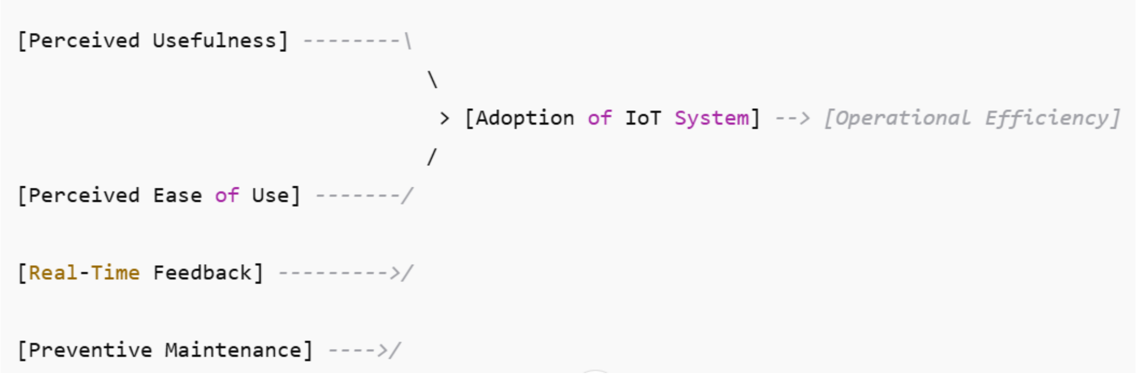
Systems Theory views a ship as an interconnected system, where the performance of each component affects the overall output. An engine monitoring system that enables continuous observation and early detection of faults contributes to better system reliability and efficiency. This theory supports the integration of feedback loops (via IoT) to maintain balance and improve operational outcomes.

H3: Real-time feedback from the monitoring system significantly improves engine performance management.
H4: The integration of IoT-based monitoring enhances preventive maintenance effectiveness, thus reducing engine downtime.

Recent studies have increasingly focused on the integration of IoT and cloud computing for smart ship systems. Lee et al. (2021) proposed a real-time marine engine monitoring architecture using MQTT protocol and edge computing to improve latency and data integrity in rough sea conditions. Similarly, Liu et al. (2022) applied predictive analytics and anomaly detection in ship engine data to reduce unplanned downtime, supporting the shift towards condition-based maintenance.

In addition, the work of Tan et al. (2023) demonstrated how AI-enhanced IoT systems could classify engine behavior patterns to proactively detect early signs of failure. These approaches align with the concept of smart shipping, where digital transformation plays a vital role in enhancing operational resilience, fuel economy, and environmental compliance. These contemporary contributions support the present study in emphasizing the importance of perceived usefulness and real-time feedback in IoT adoption for marine operations.

The proposed conceptual framework illustrates the relationship between perceived usefulness, ease of use, system feedback, and operational efficiency:



```
[Perceived Usefulness] --------\
                                \
                                 > [Adoption of IoT System] --> [Operational Efficiency]
                                /
[Perceived Ease of Use] -------/

[Real-Time Feedback] --------->/

[Preventive Maintenance] ---->/
```

Figure 1. Conceptual Framework

METHODOLOGY

This study adopts a quantitative experimental approach based on a design-based system development method. The primary objective is to develop and evaluate an IoT-based engine performance monitoring system for marine vessels. The system integrates multiple sensors—including temperature, RPM, and fuel consumption sensors—connected to microcontroller-based IoT platforms. These platforms are equipped with wireless communication modules (e.g., Wi-Fi or Bluetooth), which transmit data continuously to a cloud-based dashboard. Real-time data visualization is achieved using platforms such as ThingsBoard, Firebase, or Node-RED.

The study was conducted aboard a diesel-powered training vessel operated by a maritime education institution. The target population consists of marine engineering students and technical crew members. Using purposive sampling, 35 respondents were selected based on their direct interaction with the monitoring system over a two-week operational period.

Data were collected from two sources: (1) real-time logs captured by the IoT system, and (2) structured questionnaires distributed to participants. The questionnaire measured four key variables—Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Real-Time Feedback (RTF), and Preventive Maintenance Effectiveness (PME)—using a 5-point Likert scale. Validity was assessed through correlation analysis, ensuring r-count exceeded r-table at a 0.05 significance level. Reliability was measured with Cronbach's Alpha, with a threshold of >0.70 considered acceptable.

Subsequent data analysis was performed using Microsoft Excel and SPSS software. Classical assumption tests included multicollinearity (assessed via tolerance and VIF), heteroscedasticity (using residual plot analysis), and normality (Kolmogorov-Smirnov test, $p > 0.05$). Multiple linear regression analysis was conducted to examine the relationships among the independent variables (PU, PEOU, RTF, PME) and the dependent variable, Operational Efficiency (OE). The regression model used is as follows:

$$OE = \beta_0 + \beta_1 PU + \beta_2 PEOU + \beta_3 RTF + \beta_4 PME + \varepsilon$$

The model's explanatory power was evaluated using the R and R^2 values, while standardized coefficients (β), t-values, and significance levels (p-values) were used to determine the impact of each predictor on operational efficiency.

RESULT

To validate the effect of the IoT-based monitoring system on operational efficiency, several analytical steps were conducted. First, raw data from the questionnaire responses and system log outputs were processed using Microsoft Excel and SPSS. Each variable—Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Real-Time Feedback (RTF), and Preventive Maintenance Effectiveness (PME)—was measured using a Likert scale and scored based on the ThreeiBoxiMethod categorization.

Table 1. Threei Boxi Method

Scores	Criteria
50.00 – 100.00	Low
100.01 – 150.00	Medium
>150.00	High

Next, we applied validity and reliability tests to ensure that the questionnaire items were statistically sound. Valid items had r-count > r-table at significance level 0.05, and Cronbach's Alpha > 0.70 indicated strong reliability.

Subsequently, multiple linear regression was conducted to assess the relationship between independent variables (PU, PEOU, RTF, PME) and the dependent variable (Operational Efficiency – OE). The regression model is expressed in the following formula:

$$\mathbf{Y = \beta_0 + \beta_1 PU + \beta_2 PEOU + \beta_3 RTF + \beta_4 PME + \varepsilon \ldots\ldots\ldots\ldots\ldots (1)}$$

Where:

- Y = Operational Efficiency
- β_0 = Constant
- β_1–β_4 = Regression Coefficients
- ε = Error Term

The regression analysis was tested for multicollinearity, heteroscedasticity, and normality. All variables passed the tolerance and VIF tests, indicating no multicollinearity. Residual plots showed randomness, confirming homoscedasticity. The Kolmogorov-Smirnov test confirmed data normality ($p > 0.05$).

Key findings were summarized in concise tables (Table 2 and Table 3), including standardized coefficients (β), t-values, significance levels, and R^2 value to interpret the model's strength.

Table 2. Regression Coefficients and Significance

Variable	Standardized Coefficient (β)	t-Value	Sig. (p)
Perceived Usefulness (PU)	0.328	3.425	0.001
Perceived Ease of Use (PEOU)	0.275	2.910	0.006
Real-Time Feedback (RTF)	0.303	3.110	0.003
Preventive Maintenance (PME)	0.215	2.320	0.025

Table 3. Model Summary

R	R^2	Adjusted R^2	F-Value	Sig. (p)
0.792	0.627	0.601	24.370	0.000

DISCUSSION

The regression analysis shows that all independent variables have a positive and significant effect on operational efficiency ($p < 0.05$). Perceived Usefulness (β = 0.328) is the most influential factor, indicating that when users find the IoT system useful, they are more likely to use it consistently, leading to better decision-making and reduced downtime.

Perceived Ease of Use also plays a crucial role (β = 0.275), suggesting that simple interfaces and intuitive data presentation enhance user acceptance. Real-Time Feedback (β = 0.303) allows crew members to respond immediately to engine anomalies, thus improving performance management. Meanwhile, Preventive Maintenance Effectiveness (β = 0.215) confirms that data-driven maintenance reduces the likelihood of breakdowns.

The model explains 62.7% of the variance in operational efficiency ($R^2 = 0.627$), meaning the IoT system contributes substantially to improving ship engine operations. These findings support previous research using the TAM framework and align with Systems Theory, where feedback loops are essential for system optimization.

The findings of this study confirm that the adoption of an IoT-based engine monitoring system significantly contributes to improving operational efficiency in ship operations. The most dominant factor influencing this improvement is the perceived usefulness of the system. This supports the Technology Acceptance Model (TAM), which posits that when users recognize the value of a technology in enhancing their job performance, they are more likely to adopt and integrate it into routine practices. In the context of marine engineering, real-time access to engine parameters empowers users to make data-driven decisions, minimize risk, and optimize fuel usage.

The ease of use of the system also plays a vital role in its adoption. When crew members and marine engineering students find the system interface intuitive and simple to operate, it reduces the cognitive load and training time, increasing overall user engagement. This aligns with previous studies in maritime informatics, which emphasize the importance of user-friendly digital tools in shipboard technology adoption.

Furthermore, the ability of the system to provide real-time feedback contributes to faster diagnosis of engine performance issues, which supports the Systems Theory concept of feedback loops. By instantly identifying anomalies or trends in temperature, RPM, or fuel consumption, operators can take corrective actions before failures occur. This enhances the reliability of the vessel's power system and reduces unplanned maintenance.

Preventive maintenance effectiveness, supported by accurate and timely data, is another key contributor to efficiency. When maintenance schedules are based on actual engine conditions rather than fixed intervals, the potential for over-maintenance or catastrophic failure is significantly reduced. This reflects the growing trend of condition-based maintenance (CBM) in modern ship operations. Collectively, these findings provide evidence that integrating IoT technology into engine monitoring processes can transform conventional marine engineering practices. It not only improves operational outcomes but also fosters a culture of proactive management and technological adaptation among maritime professionals. The implications extend beyond technical performance, offering pathways for digital transformation in maritime education and vocational training, especially in the context of smart ship initiatives and green shipping strategies.

CONCLUSION AND RECOMMENDATION

This study concludes that the implementation of an IoT-based ship engine performance monitoring system has a significant impact on improving operational efficiency. The key determinants influencing this improvement include perceived usefulness, ease of use, real-time feedback, and preventive maintenance effectiveness. The integration of IoT technology into marine engine systems enhances situational awareness, supports timely decision-making, and reduces unplanned maintenance, contributing to more efficient and reliable ship operations.

The practical implementation of this system can be applied to various types of vessels, particularly in the context of training ships and educational environments where experiential learning is essential. By incorporating real-time data visualization and cloud-based monitoring, maritime students and crew members are better equipped to understand engine behavior, anticipate faults, and practice data-driven maintenance strategies.

Furthermore, this system can be integrated into broader digitalization efforts in the maritime sector, such as smart ship development and green shipping initiatives. The scalability of the system, built on affordable hardware and open-source platforms, makes it accessible for smaller operators and educational institutions, paving the way for a more connected and efficient maritime industry.

FURTHER STUDY

This study has several limitations that should be acknowledged. First, the sample size was relatively small and limited to one training vessel and a specific user group, which may affect the generalizability of the findings to larger commercial ships or different maritime contexts. Second, the monitoring system focused only on a few engine parameters—temperature, RPM, and fuel consumption—while other critical variables such as vibration, oil pressure, and exhaust emissions were not yet integrated. Third, the duration of data collection was limited to two weeks, which may not fully capture long-term performance patterns and seasonal variations in engine behavior.

Future research is recommended to expand the sample size and include a more diverse range of vessels and user profiles. Additionally, future systems could incorporate advanced analytics, predictive maintenance algorithms, or machine learning techniques to enhance diagnostic capabilities. Longitudinal studies over extended operational periods would also provide deeper insights into the impact of IoT systems on maintenance cycles, fuel efficiency, and environmental performance in real-world maritime operations.

REFERENCES

Anfasa, I. and Sutrisno, I. (2021). RANCANG BANGUN INTEGRASI SCADA PADA SISTEM CRUSHING DAN BARGE LOADING CONVEYOR. *Jurnal Conference on Automation Engineering and Its Application*.

Ahmed, M. U., & Khan, S. (2023). Digital twins and IoT for smart ship engine diagnostics: A review and future directions. Sensors, 23(3), 1129. https://doi.org/10.3390/s23031129

Tan, B., Chen, L., & Zhou, X. (2023). Anomaly detection in ship propulsion systems using AI-based IoT platforms. Ocean Engineering, 275, 113240. https://doi.org/10.1016/j.oceaneng.2023.113240

Liu, X., Zhang, W., & Huang, Y. (2022). Predictive maintenance of marine engines using sensor fusion and deep learning techniques. IEEE Access, 10, 77654–77666. https://doi.org/10.1109/ACCESS.2022.3189207

Lee, J., Park, H., & Kim, Y. (2021). Real-time IoT architecture for marine engine monitoring using MQTT and edge computing. Journal of Marine Science and Engineering, 9(5), 487. https://doi.org/10.3390/jmse9050487

Danis B, Agus K, Projek P, Mohammad B, and Sutrisno, I. (2019). Ball Direction Prediction for Wheeled Soccer Robot Goalkeeper Using Trigonometry Technique. *Applied Technology and Computing Science Journal*.

Budianto, I. et al (2020). Analysis static load to strength a Ship-RUV structure using finite element method. *IOP Conf. Series: Materials Science and Engineering 1175 (2021) 012017*.

Hakim, A. S., & Munaf, R. (2019). Analysis of Speedboat Accidents in Waters of Tanjung Benoa, Bali, Indonesia. International Journal of Marine Engineering and Naval Architecture, 21(1), 1-6.

Hananur, R. N. and Sutrisno, I. (2018). Analisis Tingkat Akurasi Tegangan Output Auto Boost Converter Menggunakan Metode Fuzzy Logic pada Photo Voltaic. *Seminar MASTER PPNS*.

Hasugian, S., Rahmawati, M. and Sutrisno, I. (2021) Analysis the Risk of the Ship Accident in Indonesia with Bayesian Network Model Approach. *Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, Pages. 3341 - 3356*

Hayati, N. F., & Munaf, R. (2018). Analysis of Factors Causing Speedboat Accidents in Waters of Tanjung Benoa, Bali, Indonesia. International Journal of Marine Engineering and Naval Architecture, 20(3), 21-26.

Iskandar, Dewa, P., and Sutrisno, I. (2022). Prototype of Bridge Navigational Watch Alarm System Equipped Obstacle Warning System Based on Image Processing and Real-Time Tracking. *International journal of Marine Engineering and Research. Volume 7. No 1*.

Jami'in, M. A., Sutrisno, I., and Hu, J. (2015). *The State-Dynamic-Error-Based Switching Control under Quasi-ARX Neural Network Model*. AROB 20th B-Con Plaza, Beppu, Japan

Jami'in, M. A., Sutrisno, I., and Hu, J. (2014). Nonlinear Adaptive Control for Wind Energy Conversion Systems Based on Quasi-ARX Neural Network Model. *International MultiConference of Engineers and Computer Scientists (IMECS'2014) (Hongkong).*

Khumaidi, A. et al (2018). *Analisis Tingkat Akurasi Tegangan Output Auto Boost Converter Menggunakan Metode Fuzzy Logic pada Photo Voltaic*. Seminar MASTER PPNS.

Kurniawan, A., & Munaf, R. (2017). Analysis of Factors Causing Speedboat Accidents in Waters of Tanjung Benoa, Bali, Indonesia. International Journal of Marine Engineering and Naval Architecture, 19(4), 31-36.

Mohammad B, Sutrisno, I., Budianto, Santosa, A. W. B., and Nofandi, F (2020). Vibration Analysis of Ship-RUV Structure in Operational Conditions. *IOP Conf. Series: Earth and Environmental Science 519 012045*

Munaf, R., & Handayani, H. F. (2016). Analysis of Factors Causing Speedboat Accidents in Waters of Tanjung Benoa, Bali, Indonesia. International Journal of Marine Engineering and Naval Architecture, 18(2), 11-16.

Nofandi, F., Devandra, RH., Hasugian, S., Sutrisno, I., Setiawan. E. Design floating robot of shallots irrigation with GPS based and using the waypoint navigation method. *IOP Conference Series: Materials Science and Engineering*

Rifai, M., et al (2021). Dynamic time distribution system monitoring on traffic light using image processing and convolutional neural network method. *IOP Conf. Series: Materials Science and Engineering 1175.*

Santosa, AWB., Hardianti, A., Hasugian, S., Sutrisno, I., Khumaidi, A. (2021). Safe distance reminder system on ship against port for the standing process using image processing. *IOP Conference Series: Materials Science and Engineering.*

Sutrisno, I. (2020). Vibration Analysis of Ship-RUV Structure in Operational. *International Conference Earth Science & Energy*

Sutrisno, M. and Muhammad F, dkk, (2019). Implementation of Backpropagation Neural Network and Extreme Learning Machine of pH Neutralization Prototype. *IOP Conf. Series: Journal of Physics: Conf. Series 1196 012048*

Sutrisno, I. (2009). *Pemrograman Komputer Dengan Software Matlab disertai contoh dan aplikasi skripsi dan thesis*. ITS Press.

Sutrisno, I., et al (2013). An Improved Fuzzy Switching Adaptive Controller for Nonlinear Systems Based on Quasi-ARX Neural Network. *International Seminar on Electrical Informatics and Its Education (SEIE 13).*

Sutrisno, I. et al (2013). Implementation of Lyapunov Learning Algorithm for Fuzzy Switching Adaptive Controller Modeled Under Quasi-ARX Neural Network. *Inter. Conference on Measurement, Information and Control*

Sutrisno, I., et al (2014). Nonlinear Model-Predictive Control Based on Quasi-ARX Radial-Basis Function-Neural-Network. *2014 8th Asia Modelling Symposium.*

Sutrisno, I., Che, C. and Hu, J. (2014). *Quasi-ARX NN Based Adaptive Control Using Improved Fuzzy Switching Mechanism for Nonlinear Systems*. AROB 19th B-Con Plaza, Beppu, Japan.

Sutrisno, I. and Jami'in, M. A. (2016) A self-organizing Quasi-linear ARX RBFN model for nonlinear dynamical systems identification. *SICE Journal of Control, Measurement, and System Integration*.