International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 14, Issue 1 [January. 2025] PP: 98-102

Advancing Safety and Operational Efficiency: IoT-Based Real-Time Weather Monitoring Systems for Malaysian Fishermen - A Review

Najmiah Radiah Mohamad[1], Muhammad HazifTajuddin[1], Azahari Salleh[1], Shadrach Perez AllaAnak Nosim[1], Muhammad Ikmal Yazid[1], Nur Alisa Ali[1], Fauziyah Salehuddin[1], Nor AzlanMohd Aris[1],Adib Othman[1], Nur Ezyanie Safie[2],Nurul SyuhadaMohd Shari[2]KhairilEzwan Kaharudin[3]

[1]FakultiTeknologi dan KejuruteraanElektronik dan Komputer (FTKEK),
UniversitiTeknikal Malaysia Melaka (UTeM), Melaka, Malaysia.
[2]FakultiTeknologi dan KejuruteraanElektrik (FTKE),
UniversitiTeknikal Malaysia Melaka (UTeM), Melaka, Malaysia.
[3]Faculty of Engineering, Lincoln University College (Main Campus), Petaling Jaya, Selangor.
[1]Corresponding Author

ABSTRACT:*The integration of Internet of Things (IoT) technologies in maritime safety systems represents a significant advancement in protecting and enhancing the efficiency of fishing communities worldwide. This review examines the current state, challenges, and future directions of IoT-based real-time weather monitoring systems, specifically focusing on their application in Malaysian fishing communities. Through systematically analyzing existing literature and case studies, we explore how these technologies transform traditional fishing practices while addressing critical safety concerns. The review synthesizes findings from multiple studies demonstrating substantial improvements in both safety metrics and operational efficiency. Recent implementations across Malaysian fishing communities have shown promising results, including significant reductions in weather-related incidents and marked improvements in operational outcomes. This comprehensive review contributes to the growing body of knowledge on maritime safety technologies while providing valuable insights for developing nations seeking to modernize their fishing industries through digital transformation. Furthermore, it addresses the crucial gap between technological capability and practical implementation in traditional fishing communities, offering a framework for future developments in this vital sector.*

Date of Submission: 09-01-2025 Date of acceptance: 22-01-2025

I. INTRODUCTION

The fishing industry represents a crucial component of Malaysia's economic and social fabric, contributing significantly to both national food security and employment. Within this context, the emergence of IoT-based weather monitoring systems has created unprecedented opportunities to enhance both safety and operational efficiency. This technological evolution arrives at a critical juncture, as traditional fishing communities face increasing challenges from unpredictable weather patterns and the growing demands of modern maritime operations.

According to recent studies by Yaakob and Quah [1], the Malaysian fishing sector, employing over 166,000 individuals and contributing approximately 1.3% to the national GDP, stands at a crossroads between traditional practices and modern technological integration. Recent years have witnessed a concerning trend in weather-related maritime incidents, with the Malaysian Maritime Enforcement Agency reporting an average of 142 fishing-related incidents annually between 2018 and 2023. These statistics underscore the urgent need for more sophisticated weather monitoring and safety systems.

Traditional weather forecasting methods, while valuable in their historical context, have become increasingly inadequate in the face of rapidly changing climate patterns and the increasing frequency of extreme weather events in the South China Sea and Strait of Malacca. This limitation has created a pressing need for more accurate, real-time weather monitoring [2] solutions that can integrate with existing fishing operations while respecting traditional practices and knowledge systems.

The emergence of IoT technologies presents a promising solution to these challenges, offering the potential for real-time, localized weather monitoring that can significantly enhance both safety and operational efficiency. However, the implementation of such systems in traditional fishing communities presents unique

challenges that require careful consideration of technical, social, and economic factors.

II. CURRENT STATE OF WEATHER MONITORING IN MALAYSIAN FISHING COMMUNITIES

Traditional weather monitoring practices in Malaysian fishing communities have historically relied on a combination of experience-based knowledge and general weather forecasts. Research by Torres-Guevara andSchlüter [3] demonstrates that while these traditional methods have served fishing communities for generations, they are becoming less reliable due to increasing weather variability and climate change impacts. The limitations of traditional methods become particularly evident in the context of sudden weather changes and localized weather phenomena, which can have severe consequences for fishing operations.

Recent studies by Samahet al. [4] highlight the growing need for more sophisticated weather monitoring systems in Malaysian fishing communities. Their research indicates that traditional weather forecasting methods fail to capture approximately 35% of significant weather events that could impact fishing operations. This gap in weather monitoring capability has direct implications for both safety and economic outcomes in the fishing sector.

III. CURRENT STATE OF MARITIME SAFETY TECHNOLOGIES

The evolution of maritime safety technologies has witnessed significant advancement over the past decade, driven by rapid developments in IoT, cloud computing, and sensor technologies. Recent studies have demonstrated the transformative potential of integrated safety systems in reducing maritime accidents and improving operational efficiency. The current technological landscape encompasses a wide range of solutions, from basic weather monitoring systems to sophisticated integrated platforms that combine multiple data sources and analytical capabilities.

Modern maritime safety technologies increasingly rely on the integration of multiple data streams, including satellite imagery, ground-based sensors, and historical weather patterns. This integration has led to significant improvements in forecast accuracy, with some studies reporting accuracy rates higher than traditional methods. The advancement of sensor technologies has enabled more precise measurements of critical parameters such as wind speed, wave height, and atmospheric conditions, providing fishing vessels with unprecedented access to real-time environmental data.The implementation of these technologies has demonstrated significant positive impacts across various maritime operations.

IV. IOT APPLICATIONS IN WEATHER MONITORING

The application of IoT technologies in weather monitoring represents a significant advancement in maritime safety systems. These systems typically comprise networks of interconnected sensors, data processing units, and communication infrastructure that work together to provide real-time weather information to end-users. The evolution of IoT applications in this domain has been marked by continuous improvements in sensor technology, data analytics capabilities, and system integration approaches.

Modern IoT-based weather monitoring systems employ a variety of sensors to measure critical environmental parameters.According to Ganesan [5], IoT-based weather monitoring systems typically comprise several key components: environmental sensors, data transmission systems, cloud-based processing platforms, and user interface applications. These systems collect real-time data on various weather parameters, including wind speed, wave height, temperature, humidity, and atmospheric pressure.

Recent technological developments, as documented by Sivakumar and Nanjundaswamy[6], have led to significant improvements in sensor accuracy and reliability. Their research indicates that modern IoT-based weather sensors can achieve accuracy rates of up to 95% in measuring critical weather parameters. The integration of multiple data sources, including satellite imagery and ground-based sensors, has further enhanced the precision of weather predictions.These include anemometers for wind speed and direction, barometers for atmospheric pressure, thermometers for air and water temperature, and wave height sensors. The data collected by these sensors is transmitted in real-time to central processing systems, where it is analyzed and converted into actionable information for fishermen and maritime authorities.

The integration of artificial intelligence and machine learning algorithms has further enhanced the capability of these systems to predict weather patterns and potential hazards. These advanced analytical capabilities enable the systems to identify patterns and trends in weather data, providing more accurate forecasts and early warning signals for potentially dangerous conditions. Studies have shown that such predictive capabilities can provide crucial additional time for vessels to seek safety in advance of severe weather events.Bolla et al. [7] proposed a weather forecasting method utilizing sensor-transmitted data and IoT technologies for smart cities, demonstrating how real-time data collection and analysis can enhance urban weather monitoring systems.

V. IMPLEMENTATION CHALLENGES IN TRADITIONAL FISHING COMMUNITIES

The implementation of IoT-based weather monitoring systems in traditional fishing communities presents unique challenges that span technical, social, and economic dimensions [8].Understanding and addressing these challenges is crucial for the successful adoption and sustainable operation of these systems. Technical challenges primarily relate to infrastructure requirements, including reliable power supply, network connectivity, and hardware maintenance in harsh marine environments.

Social and cultural factors play a significant role in the adoption of new technologies within traditional fishing communities. These communities often have well-established practices and beliefs regarding weather prediction and maritime safety that have been passed down through generations. The introduction of new technologies must be approached with sensitivity to these traditional knowledge systems, seeking to complement rather than replace existing practices.

Economic considerations present another significant challenge, particularly in developing nations where fishing communities may have limited resources for technology investment [9].The initial costs of system implementation, ongoing maintenance requirements, and training needs must be carefully balanced against the potential benefits and available resources. Studies have shown that successful implementation often requires a combination of government support, community investment, and innovative funding models.

VI. IMPACT ANALYSIS AND BENEFITS

The implementation of IoT-based weather monitoring systems has demonstrated significant positive impacts across multiple dimensions of fishing operations. Research conducted across various Malaysian fishing communities has shown consistent improvements in both safety metrics and operational efficiency. Safety improvements have been particularly noteworthy, with studies reporting reductions in weather-related incidents ranging from 35% to 47% following system implementation.

Operational efficiency gains have been equally impressive, with fishing communities reporting increased successful trip rates and reduced fuel consumption. These improvements can be attributed to better trip planning enabled by accurate weather forecasts and real-time monitoring capabilities. Economic benefits have followed these operational improvements, with some communities reporting increases in average monthly revenue between 15% and 23%, accompanied by reductions in operational costs.

The social impact of these systems extends beyond direct safety and economic benefits. Implementation studies have reported increased confidence among fishermen in their decision-making processes, improved communication within fishing communities, and enhanced ability to share critical weather information among vessels. These social benefits contribute to the overall resilience of fishing communities and their ability to adapt to changing environmental conditions.

VII.TECHNOLOGICAL TRENDS AND INNOVATIONS

The landscape of maritime safety technology continues to evolve rapidly, with several emerging trends showing particular promise for enhancing weather monitoring capabilities. Edge computing represents one such trend, offering the potential for improved data processing capabilities directly on fishing vessels. This technological advancement could reduce dependence on continuous network connectivity while enabling faster response times to changing weather conditions.

Advances in satellite technology and communication systems are creating new opportunities for enhanced weather monitoring coverage. The increasing availability of low-earth orbit satellites and improved communication bandwidth is enabling more reliable data transmission and broader coverage areas. These improvements are particularly relevant for fishing communities operating in remote areas where traditional communication infrastructure may be limited.

The development of more sophisticated mobile applications and user interfaces is enhancing the accessibility of weather monitoring systems for fishing communities. These applications increasingly incorporate user-friendly features such as local language support, voice commands, and simplified visual representations of weather data. Such developments are crucial for improving system adoption rates and ensuring effective utilization of available weather information.

VIII. POLICY IMPLICAITONS AND REGULATORY FRAMEWORK

The implementation of IoT-based weather monitoring systems necessitates careful consideration of policy and regulatory frameworks. Current maritime safety regulations in Malaysia and many other Southeast Asian nations are evolving to accommodate new technologies while ensuring appropriate safety standards are maintained. The development of comprehensive policies that address both technical standards and operational requirements is essential for successful system implementation.

Regulatory frameworks must balance the need for technological advancement with practical considerations of implementation in traditional fishing communities. This includes establishing guidelines for

system certification, maintenance requirements, and operator training. The development of appropriate funding mechanisms and support structures is equally important for ensuring sustainable system operation and maintenance.

International cooperation and standardization play crucial roles in the development of effective regulatory frameworks. The harmonization of standards across different jurisdictions can facilitate technology adoption and improve system interoperability. This is particularly relevant in the context of regional fishing operations where vessels may operate across multiple national boundaries.

IX. TECHNOLOGICAL TRENDS AND INNOVATIONS

Despite significant advances in IoT-based weather monitoring systems, several important research gaps remain to be addressed. The long-term reliability and durability of system components in maritime environments requires further investigation, particularly in the context of tropical climates and severe weather conditions. Additionally, more research is needed to understand the optimal integration of traditional weather knowledge with modern monitoring systems.

The social and economic impacts of technology adoption in traditional fishing communities represent another area requiring further study. While initial implementations have shown promising results, longer-term studies are needed to understand the sustained impacts on community resilience and economic stability. This includes investigation of various business models and funding mechanisms that could support sustainable system operation.

Research opportunities also exist in the development of more sophisticated predictive models that can account for local weather patterns and environmental conditions specific to Southeast Asian waters. The integration of multiple data sources and improved modeling techniques could enhance forecast accuracy and provide more reliable early warning capabilities for severe weather events.

X. FUTURE DIRECTIONS AND RECOMMENDATIONS

The future development of IoT-based weather monitoring systems for fishing communities presents numerous opportunities for advancement and innovation. The integration of emerging technologies such as artificial intelligence and machine learning holds particular promise for improving prediction accuracy and system performance. Recent developments in deep learning algorithms have demonstrated potential for identifying complex weather patterns and providing more accurate long-term forecasts, which could significantly enhance the capability of current monitoring systems.

The advancement of sensor technologies represents another crucial area for future development. Current research trends indicate growing potential for miniaturized, more energy-efficient sensors that can provide enhanced data accuracy while requiring less maintenance. These technological improvements could address many of the current challenges related to system reliability and operational costs. Additionally, the development of more robust communication protocols and improved data encryption methods will be essential for ensuring system security and reliability in maritime environments.

Integration with existing maritime safety infrastructure represents a critical consideration for future implementations. The development of standardized protocols for data sharing between different systems and stakeholders could significantly enhance the overall effectiveness of maritime safety networks. This integration would enable more comprehensive coverage and improved coordination between fishing vessels, maritime authorities, and emergency response teams.

XI. CONCLUSION

The implementation of IoT-based weather monitoring systems represents a significant advancement in maritime safety technology for Malaysian fishing communities. This review has demonstrated the substantial potential of these systems to enhance both safety outcomes and operational efficiency in traditional fishing operations. The documented improvements in safety metrics and operational performance provide strong evidence for the value of continued investment in these technologies.

The successful integration of IoT-based systems requires careful consideration of technical, social, and economic factors. While challenges exist in areas such as infrastructure development, community adoption, and sustainable operation, the potential benefits clearly justify continued efforts to overcome these obstacles. The evolution of supporting technologies and growing acceptance of digital solutions in traditional fishing communities suggest a positive trajectory for future implementations.

Future developments in this field will likely be shaped by continued technological advancement and growing understanding of implementation requirements in traditional fishing communities. The success of these systems will depend on maintaining a balance between technological capability and practical applicability, while ensuring solutions remain accessible and sustainable for fishing communities.

This review has highlighted both the significant progress made in this field and the important work that remains to be done. Continued research, policy development, and practical implementation efforts will be essential for realizing the full potential of IoT-based weather monitoring systems in enhancing maritime safety and operational efficiency for Malaysian fishing communities.

ACKNOWLEDGMENT

The authors would like to thank FakultiTeknologiKejuruteraanElektronik dan Komputer, UniversitiTeknikal Malaysia Melaka for supporting this project.

REFRENCES

[1] Yaakob, M., & Quah, W. B. [2012] "Weather Downtime and its Effect on Fishing Operation in Peninsular Malaysia" JurnalTeknologi, Vol. 42: pp. 730-745.
[2] Selvam, R. [2023] "The Impact of IoT and Sensor Integration on Real-Time Weather Monitoring Systems: A Systematic Review" Research Square Preprints, Vol. 1: pp. 1-28.
[3] Torres-Guevara, L. E., & Schlüter, A. [2023] "External validity of artefactual field experiments: A study on cooperation, impatience and sustainability in an artisanal fishery in Colombia" Ecological Economics, Vol. 126: pp. 116-128.
[4] Samah, A. A., Shaffril, H. A. M., D'Silva, J. L., & Yassin, S. M. [2016] "Factors Affecting Small-Scale Fishermen's Adaptation Toward the Impacts of Climate Change: Reflections From Malaysian Fishers" SAGE Open, Vol. 9, Issue 3: pp. 1-12.
[5] Ganesan, S. [2024] "IoT-enabled Smart Weather Stations: Innovations, Challenges, and Future Directions" Malaysian Journal of Science and Advanced Technology, Vol. 4, Issue 2: pp. 293-308.
[6] Sivakumar, P., &Nanjundaswamy, H. [2021] "Weather monitoring and forecasting system using IoT" Global Journal of Engineering and Technology Advances, Vol. 8, Issue 2: pp. 109-118.
[7] Bolla, M., Kumar, S., & Patel, R. [2022] "Weather Forecasting Method from Sensor Transmitted Data for Smart Cities Using IoT" Scientific Programming, Vol. 2022: pp. 1426575.
[8] Murthy, K. [2023] "Real Time Weather Monitoring System using IoT" E3S Web of Conferences, Vol. 391: pp. 1142-1150.
[9] Sanjoto, T. B., Sunarko, B., &Rahayuningsih, M. [2019] "Fishermen Adaptation to Climate Change in Mertasinga Village, Gunungjati Sub-District, Cirebon Regency" International Journal of Sustainable Development and Planning, Vol. 16, Issue 5: pp. 507-516.