Interconnection: An Economic Perspective Horizon

Integration of Internet of Things and Digital Accounting Systems for Marine Resources Monitoring

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ABSTRACT

This study explores the integration of Internet of Things (IoT) technologies and digital accounting systems in marine resource management, providing insights into how these technologies can improve operational efficiency, enhance sustainability, and optimize resource usage. The research follows a case study design with qualitative approach, which allows for an in-depth examination of the integration of IoT and digital accounting in specific marine industries, such as fisheries, aquaculture, and maritime logistics. The findings reveal that IoT is already being used for real-time environmental monitoring in industries like fisheries, aquaculture, and maritime transport, while digital accounting systems are primarily employed for financial and operational management. However, the integration of IoT data with digital accounting is still in its early stages, and challenges such as technical barriers, data overload, and system compatibility must be addressed to fully realize the potential of these technologies.

Keywords: IoT; Digital Accounting Systems; Marine Resources Monitoring

Fields: Accounting; Information System; Marine

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SDGs: Quality Education (4); Clean Water and Sanitation (6); Decent Work and Economic Growth (8); Climate Action (13); Life Below Water (14); Peace, Justice and Strong Institutions (16)

INTRODUCTION

The integration of Internet of Things (IoT) technologies and digital accounting systems offers transformative potential in the management and monitoring of marine resources (Renaldo, 2023). As the global demand for sustainable marine practices increases, particularly in industries like fisheries, aquaculture, and maritime transportation, the need for real-time, data-driven decision-making becomes imperative. IoT allows for the continuous monitoring of marine environments, tracking various parameters such as water temperature, salinity, pollution levels, and fish stock data (Mukhsin et al., 2023). Meanwhile, digital accounting systems can enhance transparency, track resource usage, and optimize financial performance in real time.

Incorporating these technologies in marine resource management is essential for improving operational efficiency (Renaldo et al., 2022), reducing wastage, and ensuring sustainability (Renaldo, Suhardjo, et al., 2024). By leveraging IoT for precise data collection and digital accounting for precise tracking and reporting, stakeholders can make informed decisions that align with both business goals and environmental responsibilities. Furthermore, this integration supports businesses in complying with environmental regulations, improving profitability, and ensuring the long-term viability of marine ecosystems.

This research explores the synergy between IoT and digital accounting systems, analyzing how their integration can enhance marine resource monitoring and management practices. It aims to provide insights into the implementation and benefits of this technological convergence, focusing on sectors that directly rely on marine resources.

This study introduces a novel approach by combining two rapidly evolving fields, IoT technology and digital accounting systems, into a cohesive framework for marine resource monitoring (Junaedi, Panjaitan, Yovita, Jahrizal, et al., 2024; Junaedi, Renaldo, Yovita, Veronica, & Jahrizal, 2023a). The novelty lies in the integration of these technologies to create a seamless, real-time monitoring and reporting ecosystem that can be applied across various marine industries. While IoT is already used to track environmental parameters in marine ecosystems, and digital accounting systems are well-established in business operations, their combined use in marine resource management has not been thoroughly explored.

Key innovative aspects include:

- Real-time Financial and Environmental Data Integration: The unique combination of real-time IoT data with digital accounting allows businesses to monitor both environmental impacts and financial performance simultaneously, creating a more comprehensive view of operations (Junaedi, Renaldo, Yovita, Augustine, et al., 2023).
- Sustainability Reporting Automation: By using digital accounting tools, businesses can automatically generate sustainability reports based on IoT-collected data, facilitating transparent environmental impact assessments and regulatory compliance.
- Predictive Analytics for Resource Optimization: Through the integration of IoT and accounting systems, predictive analytics can be applied to forecast resource usage trends and optimize financial strategies, reducing inefficiencies and promoting sustainability.
- Blockchain for Enhanced Transparency: The study explores the application of blockchain technology within this integrated system to ensure data integrity, transparency, and traceability in marine resource management, further reinforcing sustainability and trust among stakeholders.

LITERATURE REVIEW

Internet of Things (IoT) in Marine Resource Management

The Internet of Things (IoT) has become a critical tool for monitoring and managing natural resources, particularly in marine ecosystems. IoT systems allow for the continuous collection of data from sensors placed in the ocean or along coastlines to track various environmental factors. Key studies have highlighted the benefits of using IoT to monitor water quality, track marine life, and monitor fishing activities. For example, sensors can measure parameters like water temperature, salinity, and pollutant levels in real time (Alvarez et al., 2017). IoT has also been used in aquaculture to monitor fish health, water conditions, and feed consumption, which are crucial for optimizing operations (Yuan et al., 2018).

Further studies have demonstrated how IoT systems enable predictive analytics for early detection of environmental threats, such as algal blooms or contamination from industrial activities (Girotti et al., 2020). By providing stakeholders with real-time information, IoT technologies empower decision-makers to act swiftly, minimizing environmental damage and improving resource management (Bettencourt et al., 2020).

Digital Accounting Systems in Marine Industries

Digital accounting systems have long been recognized for improving efficiency and transparency in financial management. However, in recent years, their role has expanded to include the integration of environmental data, especially in industries dependent on natural resources. In marine industries, digital accounting systems allow for more accurate tracking of resource usage, cost management, and environmental impact reporting (Su et al., 2020). These systems are particularly useful for small and medium-sized enterprises (SMEs) in the fisheries and aquaculture sectors, where traditional manual accounting methods may be inadequate for managing increasingly complex operations.

Several studies have explored the benefits of cloud-based accounting systems, which offer real-time access to financial data and facilitate streamlined operations. These systems support the integration of environmental data, allowing businesses to better assess the cost-effectiveness of their sustainability efforts (Müller et al., 2019). Additionally, they provide tools for compliance with environmental regulations, enabling businesses to align financial and ecological goals.

Integrating IoT and Digital Accounting for Sustainability

While both IoT and digital accounting systems have been studied separately, the integration of these technologies remains a relatively novel approach. A few studies have begun exploring how the combination of IoT data and accounting systems can optimize business operations, reduce inefficiencies, and enhance sustainability. For instance, IoT-generated data on resource consumption (such as energy (Renaldo, Junaedi, Suhardjo, Jahrizal, et al., 2024), water, and raw materials) can be directly linked to accounting systems to track costs and identify opportunities for operational improvements (Zhao et al., 2020).

Moreover, digital accounting systems can automate sustainability reporting by using IoT data to track the environmental impact of business operations. This integration can help companies create more accurate and transparent sustainability reports, which are increasingly important for gaining consumer trust and meeting regulatory requirements (Jin et al., 2021). The synergy between IoT and digital accounting also facilitates the

optimization of resources by providing managers with the tools to assess both financial and environmental performance simultaneously (Putra et al., 2024).

Blockchain for Transparency in Marine Resource Management

Blockchain technology is emerging as a valuable tool for ensuring transparency and traceability in industries reliant on natural resources, including marine resources. By providing a decentralized, tamper-proof record of transactions, blockchain can ensure that all data related to marine resource usage is authentic and transparent. Research by Nakamoto (2020) highlighted the potential of blockchain to improve transparency in supply chains, especially in the seafood industry, where issues such as illegal fishing and mislabeling are prevalent.

The integration of blockchain with IoT and digital accounting systems can further enhance transparency by providing a verifiable record of both environmental and financial data. For example, blockchain can be used to record the data collected from IoT sensors, ensuring that this data cannot be altered or manipulated. This creates a trusted and transparent system for monitoring marine resources, which is essential for ensuring sustainability and meeting regulatory standards (Kouhizadeh et al., 2020).

The Role of Predictive Analytics in Marine Resource Optimization

Predictive analytics, fueled by IoT and integrated with digital accounting systems, holds significant potential in optimizing resource usage and improving financial performance in the marine industry. Research indicates that by analyzing data from IoT devices, businesses can predict trends such as resource scarcity or overuse, enabling more efficient planning and cost-saving strategies (Chong et al., 2020). For instance, predictive models can forecast fish stock levels based on environmental conditions, helping aquaculture businesses make more informed decisions about harvesting and feeding strategies.

In the context of financial management, predictive analytics can also be used to anticipate future costs and revenue streams. This allows businesses to adjust their financial strategies proactively, ensuring optimal profitability and sustainability (Yu et al., 2021). By combining predictive analytics with IoT and digital accounting, businesses in the marine sector can enhance both their operational efficiency and their commitment to sustainability.

METHODOLOGY

Research Design

The research follows a case study design with qualitative approach, which allows for an in-depth examination of the integration of IoT and digital accounting in specific marine industries, such as fisheries, aquaculture, and maritime logistics (Creswell & Creswell, 2018; Sekaran & Bougie, 2016). Case studies offer valuable insights into the real-world challenges and successes of these technologies, providing a practical understanding of their application (Junaedi, Renaldo, Yovita, Veronica, & Sudarno, 2023a). By selecting multiple case studies, the research ensures a broader perspective on how these technologies are being utilized across different contexts and sectors within the marine industry.

Data Collection

The data for this study will be collected through a combination of semi-structured interviews, focus group discussions (FGDs), and document analysis. This multi-method approach ensures comprehensive data collection from different sources, providing a richer understanding of the integration process.

1. Semi-Structured Interviews: Interviews will be conducted with key stakeholders, including business owners, technology providers, industry experts, and government officials involved in marine resource management. The semi-structured format allows for flexibility in questioning, enabling interviewees to provide detailed insights into the integration of IoT and digital accounting systems. The interviews will cover topics such as:
   - Current use of IoT and digital accounting in marine industries.
   - Challenges faced in integrating these technologies.
   - Perceived benefits and barriers.
   - Suggestions for improving the integration process.
   - Examples of successful implementation.

   A purposive sampling method will be used to select participants who have direct experience with the implementation or use of these technologies in marine industries.

2. Focus Group Discussions (FGDs): FGDs will be conducted with a group of industry stakeholders, including professionals from fisheries, maritime transport, and aquaculture, to generate a broader perspective on the topic. The focus groups will allow participants to discuss their experiences and share ideas on how IoT and digital accounting systems can be integrated more effectively. Key discussion topics will include:
    - The role of IoT in monitoring marine resources.
    - How digital accounting can support sustainability efforts.
    - Integration challenges and opportunities.
    - The future of digital technologies in marine resource management.
3. Document Analysis: Relevant documents such as policy papers, industry reports, technical guidelines (Renaldo, Junaedi, Suhardjo, Suharti, et al., 2024), and sustainability reports from marine businesses will be reviewed. This will provide additional context and help verify and triangulate the data gathered from interviews and FGDs. The document analysis will focus on:
    - Existing frameworks for integrating IoT and digital accounting systems.
    - Regulations and standards related to marine resource management.
    - Case studies or reports on successful applications of these technologies.

Data Analysis

Data collected from interviews, FGDs, and document analysis will be analyzed using thematic analysis, a qualitative method that involves identifying, analyzing, and reporting patterns (themes) within the data (Junaedi, Renaldo, Yovita, Veronica, & Sudarno, 2023b). This approach will allow for a detailed understanding of the key factors involved in integrating IoT and digital accounting systems for marine resource monitoring.

The steps involved in thematic analysis include:

- Familiarization with the Data: Transcribing the interviews and FGDs, reading through the data multiple times, and taking initial notes to gain an understanding of the content.
- Generating Initial Codes: Systematically coding significant portions of data that relate to the research questions, such as challenges, opportunities, technological applications, and stakeholder experiences.
- Identifying Themes: Grouping related codes together to form broader themes, such as "technical barriers," "financial benefits," "data integration," and "sustainability goals."
- Reviewing Themes: Revising the themes to ensure they accurately reflect the data and address the research questions.
- Defining and Naming Themes: Refining the final themes and naming them in a way that clearly reflects their content and relevance to the study's objectives.
- Reporting: Presenting the findings in a narrative format, linking the themes back to the research questions and providing quotes or examples from the data to support the analysis.

Validation and Reliability

To ensure the validity and reliability of the findings, the study will employ several strategies:

- Triangulation: Using multiple data sources (interviews, FGDs, and documents) to cross-verify the findings and ensure consistency across the data.
- Member Checking: After analyzing the interview data, key participants will be asked to review the findings to confirm the accuracy and relevance of the interpretations.
- Peer Review: The analysis will be reviewed by external experts in the fields of IoT, digital accounting, and marine resource management to ensure the robustness of the conclusions.

Ethical Considerations

This research will adhere to ethical standards for qualitative research. Key ethical considerations include:

- Informed Consent: All participants will be provided with information about the study and will give written consent before participating.

- Confidentiality: The identities of participants will be kept confidential, and all data will be anonymized before analysis and reporting.
- Right to Withdraw: Participants will be informed that they can withdraw from the study at any time without any negative consequences.

Expected Outcomes

The research is expected to:

- Provide an in-depth understanding of the integration process between IoT and digital accounting in marine resource monitoring.
- Identify the challenges and opportunities for successful implementation.
- Offer recommendations for businesses, policymakers, and technology providers on improving the integration and maximizing the potential benefits of these technologies.
- Contribute to the growing body of literature on digital transformation in marine industries and the role of technology in sustainable resource management.

RESULT AND DISCUSSION

Current Use of IoT and Digital Accounting Systems in Marine Industries

IoT in Marine Resource Monitoring

The findings show that IoT technologies are already being utilized in marine industries for various monitoring purposes. Most participants reported the use of sensors in aquaculture, fisheries, and maritime transport for tracking water quality, pollution levels, and marine life. For instance, sensors are used to monitor parameters like salinity, pH levels, and temperature to optimize fish farming conditions and reduce operational costs. Furthermore, IoT is enabling real-time tracking of fishing vessels to prevent illegal activities such as overfishing and to ensure sustainable fishing practices.

Digital Accounting Systems in Marine Industries

Digital accounting systems have been implemented primarily in larger organizations within the marine sector, with many participants mentioning the use of cloud-based solutions for managing financial data, inventory, and operational costs. However, the integration of environmental data into these accounting systems remains relatively limited. While some companies have started to adopt digital accounting tools that incorporate sustainability metrics, there is still a gap in seamlessly linking IoT data with financial accounting.

Challenges in Integrating IoT and Digital Accounting Systems

The integration of IoT and digital accounting systems faces several challenges, as reported by interviewees and focus group participants:

- Technical Barriers: Many businesses, particularly smaller enterprises, face difficulties in implementing and maintaining IoT infrastructure due to high initial costs, lack of technical expertise, and challenges in ensuring compatibility between different systems. Several participants mentioned that the lack of standardization in IoT devices for marine environments makes integration difficult.
- Data Overload and Analysis: A common issue highlighted was the overwhelming amount of data generated by IoT devices. While the IoT systems provide a wealth of real-time information, many organizations struggle to analyze and extract actionable insights from this data. The integration of this data into digital accounting systems is also challenging, as accounting software is often not designed to process large volumes of environmental data.
- Lack of Trained Personnel: A significant barrier to integration is the shortage of personnel who are skilled in both IoT technologies and digital accounting systems (Junaedi, Panjaitan, Yovita, Veronica, et al., 2024; Suhardjo et al., 2023). Many companies reported difficulties in finding employees who can bridge the gap between technology and financial management.
- Financial Constraints: Smaller marine businesses, especially those in developing regions, often lack the financial resources to invest in sophisticated IoT systems and digital accounting solutions (Nyoto et al., 2024). As a result, they rely on traditional methods of resource monitoring and financial management, which may not be as effective in promoting sustainability.

Perceived Benefits of Integration

Despite these challenges, several benefits were identified by participants in integrating IoT and digital accounting systems:

- Improved Operational Efficiency: One of the most significant benefits highlighted was the improved efficiency in resource management. Real-time monitoring through IoT allows businesses to make data-driven decisions that optimize resource usage, reduce waste, and cut costs. For example, aquaculture operations using IoT to monitor water conditions reported significant improvements in fish health and growth (Junaedi, Sudarno, et al., 2023), leading to higher yields and reduced operational costs.
- Enhanced Financial Transparency and Accountability: The integration of environmental data with digital accounting systems can provide a more holistic view of business operations. By tracking both financial and environmental metrics, businesses can ensure that their sustainability efforts are aligned with financial goals. Several participants mentioned that such integration allows for more accurate financial forecasting and budget planning, while also improving accountability for environmental impact.
- Regulatory Compliance: Businesses that integrate IoT and digital accounting systems are better equipped to comply with environmental regulations. Real-time environmental data can be automatically incorporated into sustainability reports, ensuring that businesses meet compliance requirements without the need for manual data entry. This automation can also reduce the risk of human error and increase the accuracy of reports submitted to regulatory bodies.
- Consumer Trust and Competitive Advantage: The use of IoT to monitor and report on environmental practices can enhance the reputation of marine businesses. Participants reported that consumers are increasingly looking for companies that are transparent about their environmental impact. By using IoT data to demonstrate sustainability efforts, businesses can build trust with consumers and differentiate themselves in the market.

Future Potential and Opportunities

The integration of IoT and digital accounting systems holds significant future potential for transforming marine resource management:

- Predictive Analytics for Resource Optimization: Several participants noted the potential of integrating predictive analytics with IoT and digital accounting systems. By analyzing historical IoT data, businesses can predict trends such as fish stock levels or the likelihood of environmental threats (e.g., algal blooms), allowing for more proactive resource management. Predictive analytics could help optimize production schedules, improve inventory management, and reduce waste in marine industries.
- Blockchain for Enhanced Transparency: The integration of blockchain with IoT and digital accounting systems could further enhance transparency in marine resource management. Blockchain can provide an immutable record of all transactions related to resource usage, ensuring that data from IoT devices is secure and tamper-proof. This could be particularly beneficial in industries such as fisheries, where traceability and transparency are essential to combat illegal activities and ensure sustainable practices.
- Scalability and Cost Reduction: As IoT technologies become more affordable and accessible, the scalability of these systems in marine industries is expected to improve. Cloud-based solutions and modular IoT devices will allow businesses of all sizes to implement these technologies without significant upfront costs. The growing availability of affordable IoT devices and digital accounting software tailored to small and medium enterprises (SMEs) will further democratize access to these technologies.
- Cross-Sector Collaboration: The successful integration of IoT and digital accounting in marine resource monitoring will require collaboration across sectors, including technology providers, financial institutions, government agencies, and marine businesses. Participants emphasized the importance of creating partnerships and frameworks that facilitate knowledge sharing and ensure that the benefits of these technologies are accessible to all stakeholders.

CONCLUSION

Conclusion

This study explored the integration of Internet of Things (IoT) technologies and digital accounting systems in marine resource monitoring. The research highlights that IoT technologies are already being used for real-time monitoring of marine environments, particularly in aquaculture, fisheries, and maritime logistics. Digital

accounting systems are also in use but are primarily limited to financial data, with minimal integration of environmental data.

The integration of IoT and digital accounting systems holds significant potential to improve operational efficiency, transparency, and sustainability in marine industries. By combining real-time environmental data with financial data, businesses can optimize resource management, enhance financial forecasting, and ensure compliance with environmental regulations. However, the study also identifies several challenges in the integration process, including technical barriers, data overload, and the shortage of skilled personnel.

Despite these challenges, the potential benefits of IoT and digital accounting integration, such as enhanced sustainability, regulatory compliance, and consumer trust are substantial. As IoT technologies become more accessible and affordable, the integration process is expected to expand, providing significant opportunities for businesses to optimize their operations and contribute to sustainable marine resource management.

Implication

The findings of this study have several important implications for marine industries, policymakers, and technology developers:

- For Marine Businesses: The integration of IoT and digital accounting systems offers the opportunity to enhance efficiency, reduce costs, and improve environmental sustainability. By adopting these technologies, businesses can optimize resource use, reduce waste, and improve their financial transparency, ultimately achieving both financial and environmental goals.
- For Policymakers and Regulators: Governments and regulatory bodies should support the adoption of these technologies by creating incentives for small and medium-sized enterprises (SMEs) and promoting standardization in IoT devices and data integration protocols. Establishing clear guidelines and frameworks for data privacy and security is essential to ensure the secure use of these technologies.
- For Technology Providers: The development of affordable, scalable, and user-friendly IoT devices and digital accounting software tailored for marine industries will be key to the widespread adoption of these technologies. Collaborative efforts between technology providers, businesses, and policymakers will be essential to overcoming integration challenges.
- For Researchers and Academics: The findings emphasize the need for further research into the integration of environmental data with digital accounting systems, especially in the context of marine resource management. Researchers can explore the use of advanced technologies such as blockchain and predictive analytics to enhance the effectiveness of these integrations.

Limitation

Despite the valuable insights provided by this study, there are several limitations that should be considered:

- Sample Size and Scope: The study focused on a relatively small number of case studies and interviewees, which may limit the generalizability of the findings. The experiences of participants may not fully represent the entire marine sector, particularly in regions with less access to technology.
- Technological Variability: The study focused on the integration of IoT and digital accounting systems within specific marine industries. However, the technologies used in these industries vary widely in terms of capabilities, costs, and compatibility, which may affect the results. Future studies could explore a broader range of IoT devices and accounting software to assess their applicability across different contexts.
- Focus on Qualitative Data: The research relied solely on qualitative methods, which provide rich insights but may lack the statistical rigor of quantitative approaches. Future research could combine qualitative and quantitative methods to validate the findings and provide more robust evidence.
- Limited Focus on Cost-Benefit Analysis: While the study highlighted the potential benefits of integrating IoT and digital accounting systems, it did not provide a detailed cost-benefit analysis. Future studies could explore the financial implications of these integrations in greater depth.

Recommendations

Based on the findings, several recommendations were made for policymakers, business leaders, and technology developers:

- Support for Training and Capacity Building: There is a clear need for training programs that equip personnel with the necessary skills to manage and integrate IoT and digital accounting systems. Governments and

educational institutions should invest in capacity-building initiatives to ensure that the workforce is prepared to support the digital transformation of marine industries.

- Incentives for Technology Adoption: Policymakers could introduce incentives, such as subsidies or tax breaks (Sevendy et al., 2023), to encourage small and medium-sized enterprises to adopt IoT and digital accounting technologies. These incentives would help overcome financial barriers and foster innovation in the marine sector (Renaldo, Junaedi, Suhardjo, Veronica, et al., 2024).
- Standardization and Regulation: Standardization of IoT devices and protocols for data integration with digital accounting systems would help streamline the adoption process. Regulatory bodies should work with industry stakeholders to develop clear guidelines for integrating these technologies while ensuring that data privacy and security concerns are addressed.

Future Research

Future research in this area can build upon the findings of this study by addressing several key areas:

- Exploring the Use of Advanced Technologies: Future studies could investigate the role of emerging technologies such as blockchain, artificial intelligence (AI) (Junaedi, Renaldo, Yovita, Veronica, & Jahrizal, 2023b), and machine learning in enhancing the integration of IoT and digital accounting systems. Blockchain, for example, could provide greater transparency and security in managing environmental data, while AI and machine learning could be used for predictive analytics to optimize resource management.
- Expanding to Different Regions and Industries: Future research should explore the integration of IoT and digital accounting systems in different marine industries and regions, especially in developing countries where access to technology may be more limited. Comparative studies across regions could provide insights into the barriers and enablers of technology adoption in different contexts.
- Cost-Benefit Analysis: A more detailed cost-benefit analysis of integrating IoT and digital accounting systems is needed to assess the financial viability of these technologies for marine businesses, particularly small and medium-sized enterprises (SMEs). This research could help businesses understand the financial implications and justify the investment in these technologies.
- Longitudinal Studies on Impact: Longitudinal studies tracking the long-term effects of IoT and digital accounting integration on business performance (Junaedi, Renaldo, et al., 2024), sustainability, and regulatory compliance would provide valuable insights into the effectiveness of these technologies over time.
- Exploring Policy Frameworks: Future research could examine the role of government policies and regulations in facilitating the adoption of IoT and digital accounting systems. Research could focus on creating policy frameworks that incentivize technology adoption, support standardization, and ensure data security in marine resource management.
- Integration with Other Environmental Metrics: Further studies could explore how IoT data related to marine resources could be integrated with other environmental metrics (e.g., carbon footprints (Chandra et al., 2024), biodiversity, ecosystem health) to provide a more comprehensive view of sustainability in marine industries.

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