Development of IoT-Based Accounting System for Automatic Environmental Data Monitoring

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ABSTRACT

This study aims to develop an IoT-based accounting system called Smart Eco Ledger to automatically monitor and record environmental data for use in environmental accounting reports. The system integrates sensors (e.g., temperature, humidity, CO_2), a microcontroller (ESP32), cloud storage (Firebase), and a user-friendly web dashboard. It enables real-time monitoring, automatic data logging, and simple report generation for environmental performance tracking. The results showed that the system works accurately, with high user satisfaction scores in usability testing. This innovation bridges the gap between environmental monitoring and accounting practices by eliminating manual input and increasing data reliability. The novelty of this research lies in the integration of IoT technology with environmental accounting in real-time, supported by cloud systems and interfaces accessible to accounting professionals. Although testing was limited to indoor conditions and a small sample size, the system shows potential for wider adoption. Future research may include sensor expansion, blockchain integration, mobile access, and AI-based forecasting. The Smart Eco Ledger contributes to sustainable accounting practices and demonstrates a practical solution for organizations committed to environmental responsibility and digital transformation.

Keywords: IoT-Based Accounting System; Environmental; Monitoring; Sustainability; Digital

Fields: Accounting; Environmental; Technology

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INTRODUCTION

Environmental sustainability has become a critical concern (Susanti et al., 2024) for businesses and governments worldwide (Elmar et al., 2024). Companies are increasingly required to monitor, manage, and report their environmental impact to comply with regulations and meet stakeholder expectations (Istiana et al., 2022). Traditional methods of environmental data collection and accounting are often manual, time-consuming, and prone to errors, which can hinder timely decision-making and reduce data accuracy.

With the rapid advancement of technology (Purwati et al., 2024), the Internet of Things (IoT) offers a promising solution for real-time, automatic monitoring of environmental parameters such as air quality, temperature, humidity, and pollutant levels (Ramadan et al., 2024). By integrating IoT technology into an accounting system, organizations can automate the collection and recording of environmental data, thereby improving the accuracy, transparency, and efficiency of environmental accounting processes (Renaldo et al., 2023).

This research aims to develop an IoT-based accounting system designed specifically for automatic environmental data monitoring. The system will enable continuous data acquisition from various environmental sensors, securely store the data, and provide reliable reports to support sustainable management practices. Through this innovation, companies can better comply with environmental regulations, reduce operational risks, and enhance their corporate social responsibility (CSR) initiatives.

Objectives of these research are:

1. To design and develop an IoT-based accounting system for automatic collection and recording of environmental data.
2. To integrate various environmental sensors (e.g., air quality, temperature, humidity) with the accounting system for real-time data monitoring.

3. To ensure data accuracy, security, and transparency in the environmental accounting process through the developed system.
4. To evaluate the effectiveness of the IoT-based accounting system in improving the efficiency and reliability of environmental data management.
5. To provide a user-friendly interface for companies to access, analyze, and report environmental data easily.

Novelty on this research are: (1) Most existing environmental accounting systems rely on manual input of data. This research introduces an automated system that uses IoT sensors to directly collect and record environmental data in real time, which is then linked to an accounting reporting system. (2) The system enables real-time tracking of environmental indicators (like temperature, humidity, and CO_2) using a cloud platform. This supports (Andra & Hajjah, 2020) timely reporting and enhances transparency, a feature rarely found in traditional environmental accounting approaches. (3) Unlike typical IoT projects aimed at engineers or technicians, this system features a simple web-based dashboard tailored for accountants and environmental officers, bridging the gap between IT and accounting functions.

LITERATURE REVIEW

Environmental Accounting and Monitoring

Environmental accounting is an essential process for organizations to track their impact on the environment and ensure sustainable practices. According to (Shakkour et al., 2018), environmental accounting integrates environmental costs (Wati et al., 2024) and impacts into traditional accounting systems to provide a clear picture of a company's ecological footprint. However, many companies still rely on manual data collection methods, which are prone to errors and inefficiencies.

Internet of Things (IoT) in Environmental Monitoring

The Internet of Things (IoT) refers to a network of connected devices that can collect, exchange, and analyze data in real time. IoT technology has been widely applied in environmental monitoring to automate the collection of data such as air pollution, temperature, humidity, and other environmental parameters (Wawoorundeng, 2024). IoT sensors reduce human error, increase data accuracy, and enable continuous monitoring, which is critical for timely decision-making.

Integration of IoT with Accounting Systems

Recent studies highlight the potential of integrating IoT with accounting and information systems (Renaldo et al., 2022) to improve data reliability and transparency (Renaldo et al., 2024). For instance, (Han et al., 2023) discussed how blockchain combined with IoT can enhance data security and trustworthiness in accounting systems (Hadi et al., 2024). Although the application of IoT in environmental accounting is still emerging, it offers promising opportunities to digitize and automate environmental data management (Mukhsin et al., 2024).

METHODOLOGY

Research Design

This research adopts a design and development approach (Putra et al., 2024), combining principles from accounting, environmental monitoring, and information technology (Saharan & Bougie, 2016). The study is conducted in four main stages: requirement analysis, system design, implementation, and evaluation.

Requirement Analysis

In this initial stage, a needs assessment is conducted through literature review and interviews with stakeholders (e.g., environmental officers, accounting staff, and IT personnel). The objective is to identify key environmental parameters to be monitored (e.g., temperature, humidity, CO_2 levels) and accounting data needs related to environmental reporting.

System Design

The Smart Eco Ledger system is designed using a modular architecture to integrate:

1. IoT sensors: for real-time environmental data collection.
2. Microcontroller (e.g., Arduino or ESP32): to process and transmit sensor data.
3. Cloud-based database: for storing sensor and accounting data.
4. Web-based dashboard: for data visualization, reporting, and export.

The system is designed to ensure:

1. Automatic data logging
2. Timestamped records
3. Secure data transmission

Implementation

Prototypes are developed using appropriate hardware (sensors and microcontrollers) and software platforms such as:

1. Firebase / MySQL for database
2. Python / JavaScript / Node.js for system logic
3. React / HTML-CSS for the user interface

The system is tested in a small-scale environment (e.g., a university lab or office setting) to simulate real-time environmental data monitoring and recording.

Evaluation

System functionality is evaluated based on:

1. Accuracy of collected data compared to manual measurements
2. Efficiency in data processing and reporting
3. Usability based on user feedback (via questionnaires)
4. Reliability of system performance over time

System Architecture Overview

The system architecture of the IoT-based accounting system integrates hardware and software components to collect, process, store, and present environmental data in a structured accounting format.

Main Components

1. IoT Sensor Layer

- Devices: Temperature sensor, humidity sensor, CO_2 sensor, pollutant sensors.
- Function: Measure environmental conditions in real-time.
- Example Hardware: DHT22, MQ135, BMP280.

2. Microcontroller Layer

- Device: Arduino Uno, ESP32, or Raspberry Pi.
- Function: Receives raw data from sensors, formats it, and transmits to the cloud.
- Communication: Wi-Fi / MQTT protocol for wireless data transfer.

3. Cloud Layer (Data Storage)

- Platform: Firebase, MySQL, or AWS IoT Core.
- Function: Stores timestamped environmental data in real-time.
- Feature: Data backup, scalability, access control (Renaldo et al., 2021).

4. Application Layer (Accounting Interface)

- Frontend: Web or mobile interface (React.js, Vue.js, Flutter).

- Backend: Node.js, Python Flask/Django.
- Function: Displays real-time data, generates environmental reports, and stores records for accounting purposes.

5. Reporting & Analysis Layer

- Tools: Integrated charts, data export to Excel/PDF.
- Function: Translates sensor data into accounting reports (e.g., emission logbook, CSR reports).
- Optional: Machine Learning module for prediction (future integration) (Jahrizal et al., 2024).

RESULT AND DISCUSSION

System Functionality Test

The IoT-based accounting system prototype was successfully developed using DHT22 (temperature and humidity) and MQ135 (air quality) sensors, integrated with an ESP32 microcontroller. The system continuously collected environmental data every 30 seconds and transmitted it to a Firebase cloud database. The web dashboard displayed real-time data, stored historical records, and generated simple accounting reports on environmental performance.

- Data collection was automated and required no manual input.
- Real-time transmission worked effectively within Wi-Fi range.
- Data logs were complete with timestamps and environmental categories.

Accuracy of Environmental Data

To assess accuracy, the sensor readings were compared with standard digital tools (e.g., handheld thermometers and commercial air monitors) (Purwati et al., 2023). The deviation was minimal:

Table 1. Accuracy of Environmental Data

Parameter	Sensor Reading	Reference Reading	Accuracy (%)
Temperature (°C)	27.5	27.8	98.90%
Humidity (%)	68	70	97.10%
CO_2 Level (ppm)	410	400	97.50%

This result indicates that the system provides reliable and sufficiently accurate data for environmental accounting purposes.

User Interface and Usability

A small user testing session was conducted with 5 users from an accounting and IT background. Feedback was collected using a Likert scale questionnaire (1 = strongly disagree, 5 = strongly agree). Average scores were:

Tabel 2. User Interface and Usability Perspective

Statement	Avg. Score
The interface is easy to understand and navigate	4.6
The system provides useful data for accounting	4.8
Real-time data is clearly presented	4.4
Report generation is simple and functional	4.2
The system improves efficiency in environmental logging	4.7

The positive feedback suggests that the system is user-friendly and valuable for environmental accountants.

Discussion

The development of the Smart Eco Ledger demonstrates the potential of IoT technology in transforming traditional environmental accounting systems (Nyoto et al., 2023). By automating the monitoring and logging process, organizations can significantly reduce manual workload and minimize human error. The integration of cloud storage ensures data availability and transparency, which is essential for corporate sustainability reporting (Mukhsin et al., 2023).

This system also supports the growing need for digital transformation in environmental management. Although still at the prototype stage, the system can be scaled by integrating more types of sensors and features such as automated alerts, mobile app access, or machine learning for predictive analysis.

CONCLUSION

Conclusion

This study successfully developed a prototype of an IoT-based accounting system named Smart Eco Ledger, designed to automatically monitor and record environmental data. The system integrates environmental sensors, microcontrollers, cloud databases, and a web interface to collect, store, and display real-time environmental data. Testing showed that the system works accurately, is user-friendly, and supports environmental accountability and reporting processes. The integration of IoT and accounting proves to be effective in increasing data reliability, timeliness, and efficiency.

Implication

The research has practical implications for organizations seeking to improve environmental transparency and reporting. By automating data collection, the system minimizes human error and administrative burden in environmental accounting. It also supports sustainability reporting, corporate social responsibility (CSR), and compliance with environmental regulations. Academically, this study bridges accounting and information technology (Sudarno et al., 2022), demonstrating the potential of cross-disciplinary innovations.

Limitation

The prototype was tested in a limited indoor environment and may not reflect complex real-world conditions (*e.g.*, factory sites or outdoor areas). Only a few environmental parameters were monitored (temperature, humidity, CO_2). The sample size for user testing was small (n = 5), limiting the generalizability of the usability findings.

Recommendation

Organizations should consider adopting similar IoT-based systems to enhance their environmental reporting practices. Further investment in training accounting staff to interpret real-time environmental data is recommended. Government and industry associations can support standardization of environmental data collection for accounting purposes.

Future Research

Future studies can scale the system by integrating more sensors (e.g., noise, water quality (Renaldo, 2023), PM2.5). Research on integrating this system with blockchain for secure audit trails is encouraged. Broader usability testing involving professionals from various industries would provide more comprehensive insights. Development of mobile app versions and AI-powered analytics can further improve user experience and functionality.

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