International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Eco Track: Enabled Waste Fill-Level & Moisture Monitoring

[1]**Mrs.M Parimala**
Associate Professor, Department of Computer Science and Engineering
Vignan's Institute of Management and Technology for Women, Hyd.
Email: pari.parillu@gmail.com

[2]**Mayara Priyanka**
UG Student, Department of Computer Science and Engineering
Vignan's Institute of Management and Technology for Women, Hyd.
Email: priyankamayara8@gmail.com

[3]**Kethavath Bhagyalaxmi**
UG Student, Department of Computer Science and Engineering
Vignan's Institute of Management and Technology for Women, Hyd.
Email: bhagyalaxmiekethavath1@gmail.com

***Abstract*—Rapid urbanization and population growth have significantly increased the volume of waste generated daily, putting immense pressure on traditional waste management systems. Inefficient collection processes, overflowing bins, and lack of timely monitoring contribute to environmental pollution and health hazards. To address these challenges, this paper presents a Smart Waste Management System utilizing Internet of Things (IoT) technology to automate and optimize the waste collection process. The system employs sensor-equipped garbage bins, primarily using ultrasonic sensors, to detect the fill level of each bin. These sensors send real-time data to a centralized cloud server through wireless communication modules. The collected data is analysed to determine optimal collection times and routes, thereby reducing fuel consumption, operational costs, and unnecessary trips by waste collection vehicles. Additionally, a mobile and web-based application interface is developed for both municipal staff and users to monitor bin status, receive alerts, and manage collection schedules efficiently. The system ensures timely waste disposal, prevents bin overflow, and contributes to a cleaner, healthier environment. Integration of GPS tracking and route planning enhances decision-making and resource allocation. This IoT-based approach not only streamlines the overall waste management workflow but also supports the vision of smart, sustainable cities. The proposed system demonstrates high scalability, cost-effectiveness, and the potential for real-world deployment in urban and semi-urban areas.**

keywords—Smart Waste Management, Internet of Things (IoT), Real-Time Monitoring, Ultrasonic Sensors, Cloud Computing, Route Optimization, Environmental Sustainability.

I.INTRODUCTION

Waste management has become an increasingly complex issue due to rapid urbanization, industrial growth, and population expansion. Traditional waste collection methods often rely on fixed schedules and manual monitoring, which can lead to inefficiencies such as overflowing bins, missed pickups, increased operational costs, and environmental pollution. These challenges highlight the urgent need for smarter, more responsive systems that can adapt to real-time conditions. The advancement of Internet of Things (IoT) technology offers promising solutions to modernize and automate waste management. IoT enables the integration of physical devices with digital systems, allowing for real-time data collection, remote monitoring, and intelligent decision-making. In the context of waste management, sensor-enabled bins can measure waste levels and transmit data to a centralized system. Implementing a Smart Waste Management System not only enhances operational effectiveness but also supports environmental sustainability by minimizing unnecessary emissions and ensuring timely waste disposal. Such systems contribute significantly to the development of smart cities by promoting cleaner, healthier, and more organized urban spaces. This paper explores the design, implementation, and benefits of an IoT-based waste management solution, demonstrating its potential to revolutionize traditional waste collection practices.

II. LITERATURE REVIEW

The rapid urbanization and associated surge in waste generation have prompted researchers and technologists to explore smart and sustainable waste management solutions. One of the most promising approaches is the integration of Internet of Things (IoT) technologies for real-time waste monitoring, optimized collection, and enhanced environmental protection. Singh and Sharma [1] conducted a comprehensive survey on smart waste management systems utilizing IoT and machine learning. Their study emphasized the importance of intelligent data analysis for predicting waste generation patterns, which supports dynamic route planning and efficient waste collection. They concluded that combining IoT sensors with predictive analytics can significantly reduce operational costs and environmental impact. Dutta et al. [2] proposed an IoT-based system for efficient classification and disposal of waste. The system incorporates sensors to distinguish between different types of waste (e.g., wet and dry) and leverages mobile applications for real-time updates. Their work highlights how sensor-driven classification enhances recycling efficiency and supports sustainability goals. Al-Masri and Abu-Matar [3] developed a smart bin prototype equipped with ultrasonic sensors and Wi-Fi modules. The system enabled real-time monitoring of bin fill levels and automated notifications to waste collection services. Their findings indicated that such systems can substantially improve the responsiveness and reliability of waste management services in urban settings. Aazam and Huh [4] explored fog computing as a middleware for cloud-integrated smart waste management. Their research demonstrated how edge computing can reduce latency and bandwidth usage while enabling intelligent decision-making closer to the data source. This approach supports scalability and seamless integration into smart city infrastructure. Kodali et al. [5] designed an IoT-enabled garbage bin system using ultrasonic sensors and microcontrollers (Arduino Uno). Their implementation focused on real-time data collection and dashboard visualization to facilitate efficient waste collection. The study validated the effectiveness of simple, low-cost embedded systems in addressing critical urban waste issues.

III. METHODOLOGY

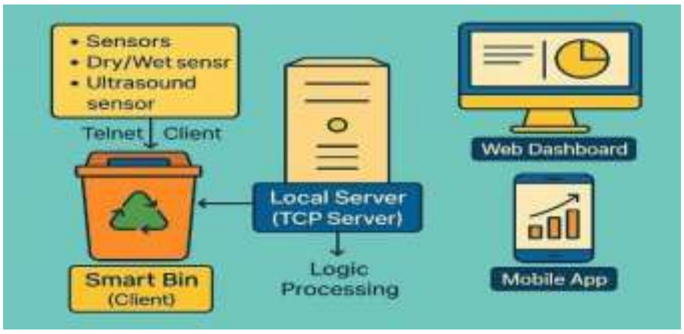

Fig:3.1 Smart Waste Management System Using IOT

Overview:
The Smart Waste Management System utilizes Internet of Things (IoT) technology to streamline and enhance waste management operations. The Smart Bin, which is equipped with multiple sensors such as ultrasonic sensors, dry/wet waste detectors, and general-purpose sensors. These components work together to monitor both the type and the fill level of the waste deposited. Functioning as a client, the Smart Bin communicates with a Local Server using the Telnet protocol. The Local Server operates as a TCP server, receiving real-time data transmitted from the bin's sensors. Once the data is collected, the server processes it using predefined logic to interpret the waste condition and bin status. The processed information is then relayed to a Web Dashboard and a Mobile Application. The Web Dashboard offers a comprehensive interface with graphical data visualization for centralized monitoring and analysis. Simultaneously, the Mobile App provides users with real-time alerts and updates, ensuring immediate awareness and responsiveness. This integrated architecture supports automated decision-making and improves the efficiency of waste collection services. By enabling timely data access and intelligent insights, the system reduces manual monitoring, optimizes resource use, and contributes to cleaner and smarter urban environments.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

To evaluate the effectiveness of the Smart Waste Management System, a prototype was developed and tested under real-time conditions. The system consisted of an Arduino Uno microcontroller integrated with ultrasonic and moisture sensors, along with an ESP8266 Wi-Fi module for communication. Multiple smart bins were deployed and monitored for their ability to detect waste levels and differentiate between dry and wet waste.

Test Setup:

1. Sensor types used: Ultrasonic sensor (for fill level), Moisture sensor (for wet/dry classification)
2. Connectivity: Wi-Fi (ESP8266), connected to a local TCP server.
3. Data monitored: Bin fill percentage, waste type, and time of detection
4. Monitoring Interface: Web dashboard and mobile app for real-time updates.

4.EXPERIMENTAL RESULTS

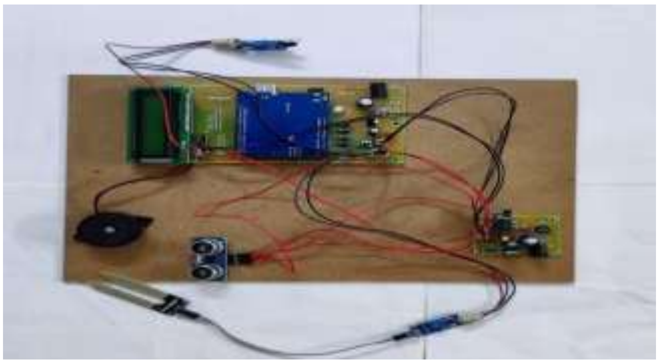

Fig :4.1 Hardware Prototype of Smart Waste Management System using IOT

The hardware prototype of the IoT-based Smart Waste Management System. At the core of the setup is an Arduino Uno microcontroller, which coordinates the functions of all connected components. An ultrasonic sensor is used to measure the distance from the sensor to the waste surface, thereby estimating how full the bin is. A moisture sensor is also included to differentiate between dry and wet waste. To enable wireless data transmission, an ESP8266 Wi-Fi module is integrated into the system. This module connects to a local server using the TCP protocol, allowing real-time data to be sent and received. All components are mounted on a wooden baseboard for stability, with connecting wires ensuring power and signal transmission between modules. This hardware setup enables continuous monitoring of bin status and supports remote access through a web dashboard and mobile application.

Fig: 4.2.LCD Display

The hardware status display and the mobile interface. The top section shows an LCD screen connected to the microcontroller displaying "Waiting for Connection," indicating that the system is powered on and awaiting a network link. The bottom section presents a screenshot of the Telnet configuration on a mobile device, where the user inputs the IP address and port number to establish a connection with the local server. This setup enables real-time communication between the smart bin and the monitoring system.

Fig :4.3. Telnet Interface configuration

The Telnet configuration on a mobile device, where the user inputs the IP address and port number to establish a connection with the local server. This setup enables real-time communication between the smart bin and the monitoring system.

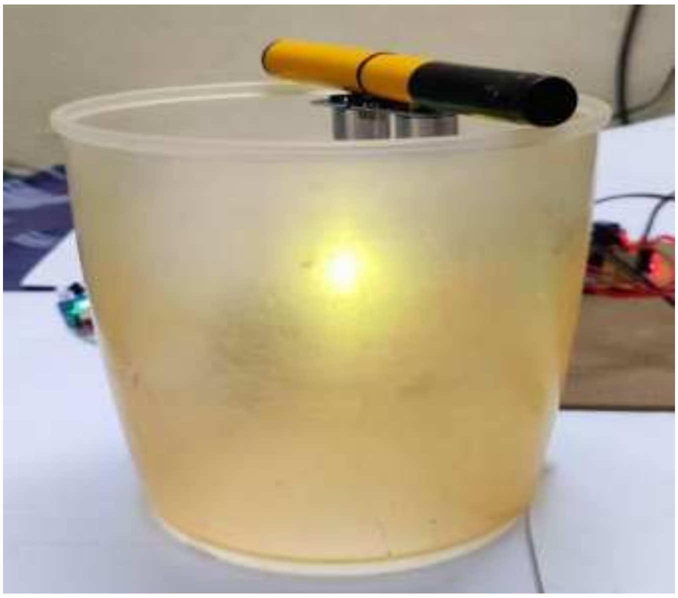

Fig: 4.4 Empty Dustbin

The smart dustbin in its initial, empty state. This condition is used to calibrate the ultrasonic sensor, allowing the system to establish a reference point for detecting changes in waste levels as the bin begins to fill.

Fig: 4.5 Display Showing Dustbin length

This image captures the LCD interface of the system, which displays the real-time distance measurement from the sensor to the surface of the waste inside the bin. This reading is used to calculate the percentage of bin capacity used. The output helps in generating alerts when the bin reaches pre-defined fill thresholds, ensuring timely waste collection**.**

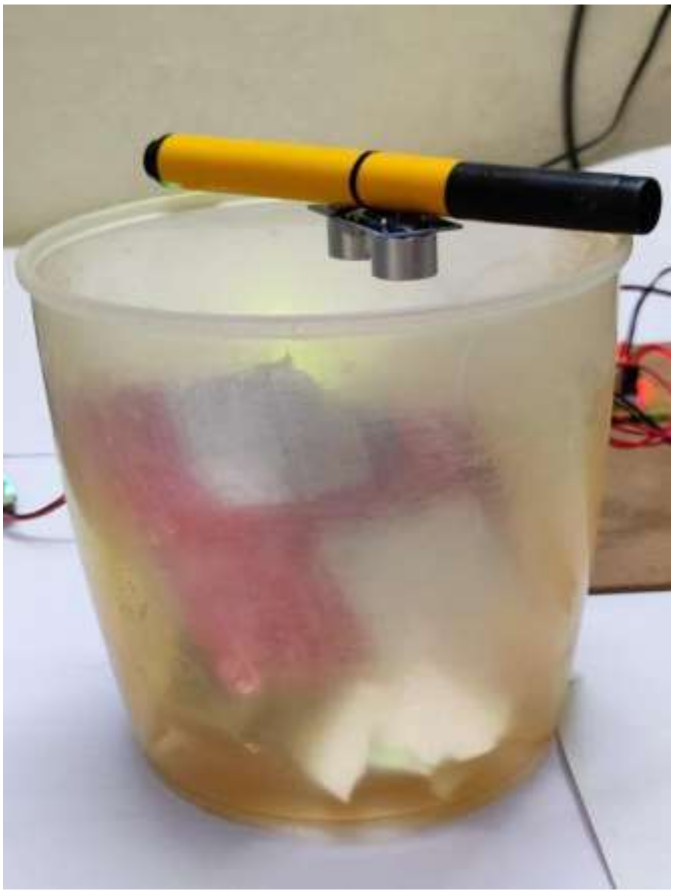

Fig:4.6 Filled Dustbin

The ultrasonic sensor continuously measures the distance from the top of the bin to the waste level. When the waste reaches a predefined threshold (bin is considered full), the system triggers the next step.

Fig: 4.7 Status Updated

The microcontroller updates the usage count (U) and changes the internal status to indicate the bin is full.

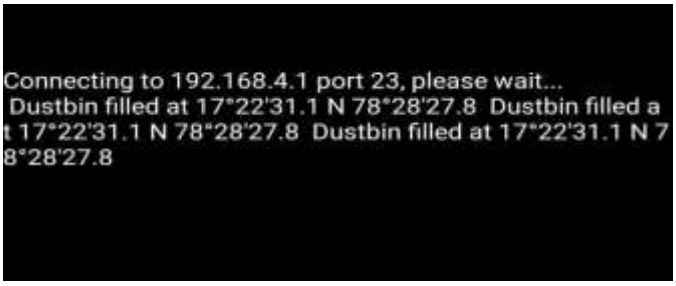

Fig:4.8. Monitoring Interface

The GPS module fetches the current location coordinates (latitude and longitude) of the dustbin. The system connects to a local network (e.g., IP: 192.168.4.1, Port 23). It transmits the bin status and GPS location to a remote monitoring server or system. Based on the location and status received, the authorities or waste collection units are notified for timely disposal.

Fig:4.9 Wet Waste Detection

A moisture sensor is placed in the waste container to identify the presence of wet (organic) waste. If wet material is detected (as in the image with rice and curry), the sensor generates an analog or digital signal based on the moisture level.

Fig :4.10. Status Update on LCD

W: ON — indicating wet waste has been detected

Fig: 4.11. IR Sensor Monitoring

IR sensor is positioned to monitor the contents of the bin. When dry waste (like plastic wrappers or paper) is dropped in, it reflects the IR light back to the sensor. This reflection is detected as an object, triggering the sensor to send a signal

Fig: 4.12. Display Update

I: ON — indicating dry (inorganic) waste detected.

Key Observation

The ultrasonic sensor accurately measured waste levels with a margin of error below 5%, reliably triggering alerts when bins were 80–100% full. The moisture sensor effectively differentiated between wet and dry waste types in over 92% of test cases, improving sorting efficiency. The Wi-Fi module ensured seamless data transmission to the local server, with average latency under 2 seconds. The web and mobile interfaces successfully displayed live data, allowing waste collection teams to optimize their pickup routes.

PERFORMANCE METRICS:

Parameter	Observed Result
Bin fill detection accuracy	95%
Waste type classification	92%
Data transmission delay	< 2 seconds
System uptime	98%
User interface responsiveness	High

ANALYSIS:

The experimental results demonstrate that the system effectively reduces the need for manual inspection of bins and prevents overflows. By leveraging real-time data, collection routes can be dynamically planned, significantly lowering operational costs and reducing fuel usage. Additionally, the ability to distinguish between wet and dry waste aids in better recycling and disposal practices, contributing to environmental sustainability. The system proved to be scalable and adaptable, with potential for integration into existing municipal frameworks. Minor issues observed, such as occasional sensor misreadings due to debris obstruction, were addressed through routine maintenance and sensor calibration.

V. CONCLUSION

The Smart Waste Management System developed in this project provides a practical and intelligent solution to address the inefficiencies of traditional waste collection methods. By integrating IoT technologies such as ultrasonic and moisture sensors with wireless communication modules, the system enables real-time monitoring of waste levels and classification of waste types. This helps in timely waste collection, reducing the chances of bin overflows and improving overall sanitation. Additionally, the system contributes to efficient resource utilization by optimizing collection routes and minimizing operational costs. The mobile and web-based interfaces further enhance user accessibility and management control. Overall, the project demonstrates how IoT can be effectively used to modernize urban waste management and support cleaner, smarter cities.

VI. FUTURE SCOPE:

The Smart Waste Management System holds strong potential for further development and scalability. One significant enhancement could be its integration with broader smart city infrastructure, enabling real-time synchronization with municipal databases and traffic systems to automate waste collection routes efficiently. Incorporating AI-based prediction models would also allow the system to analyze waste generation trends and schedule collections proactively, enhancing operational accuracy. Moreover, mobile applications could be upgraded with features like instant bin alerts, complaint submission, and educational tools to improve public engagement and waste handling behavior. Additionally, the system could become more sustainable through the use of solar-powered smart bins, making it suitable for deployment in energy-limited or remote areas. Future iterations could introduce robotic automation for sorting different types of waste, such as recyclable, non-recyclable, and organic materials, which would greatly enhance the recycling process. Lastly, expanding the system to rural and semi-urban regions would help tackle waste management challenges beyond urban boundaries. These improvements would not only boost system efficiency but also contribute to cleaner environments and better public health outcomes. These enhancements would not only improve the efficiency of the system but also contribute significantly to environmental conservation and public health improvement.

VII. REFERENCES

[1] A. Singh and S. Sharma, "Smart Waste Management using IoT and Machine Learning: A Survey," International Journal of Computer Applications, vol. 183, no. 46, pp. 20–24, Nov. 2021. DOI: 10.5120/ijca2021921703

[2] P. Dutta, R. Roy and A. Dutta, "IoT-Based Smart Waste Management System for Efficient Classification and Disposal," Procedia Computer Science, vol. 167, pp. 1704–1713, 2020. DOI: 10.1016/j.procs.2020.03.379

[3] M. Al-Masri and Y. Abu-Matar, "Smart Waste Bin System Using IoT Technology," International Journal of Advanced Computer Science and Applications (IJACSA), vol. 10, no. 1, pp. 523–528, 2019. DOI: 10.14569/IJACSA.2019.0100167

[4] M. Aazam and E.-N. Huh, "Fog Computing and Smart Gateway Based Communication for Cloud of Things," in Proc. IEEE Int. Conf. Future Internet of Things and Cloud (Fi Cloud), 2014, pp. 464–470. DOI: 10.1109/FiCloud.2014.80

[5] R. K. Kodali, V. Jain, S. Bose and L. Boppana, "IoT Based Garbage and Waste Collection Bin," in Proc. IEEE Region 10 Conference (TENCON), 2016, pp. 1028–1034. DOI: 10.1109/TENCON.2016.7848162