IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 14, Issue 4, April 2025

DOI: 10.17148/IJARCCE.2025.14461

SMART WASTE MANAGEMENT: IoT-ENABLED DUSTBIN WITH MULTI-SENSOR FUSION FOR AUTOMATED WASTE SEGREGATION AND REAL-TIME MONITORING

Dr. P. Boobalan[1], Mr.Vishal.SK[2]

Professor, Information Technology, Puducherry Technological University, Puducherry, India[1]

M. Tech Student, Internet of Things, Puducherry Technological University, Puducherry, India[2]

Abstract: This project presents an IoT-powered Smart Dustbin system designed to automate waste management and improve cleanliness in urban areas. It uses a combination of ultrasonic, infrared (IR), and metallic proximity sensors, all connected to a NodeMCU microcontroller, to monitor how full the bin is and to help sort different types of waste. The system can detect and separate metallic from non-metallic waste, using servo motors to guide each type into its own mini compartment.

To keep things efficient, the dustbin is also equipped with GSM and GPS modules. These allow it to send SMS alerts when the bin is full and share its real-time location, helping city workers collect waste on time and plan better collection routes. All sensor data is sent to a web dashboard built with Python Flask, giving authorities the ability to monitor everything remotely.

By combining intelligent waste segregation with location tracking, this system offers a smarter, more scalable solution for managing waste. It reduces the need for manual handling, encourages cleaner surroundings, and supports broader smart city goals. Overall, it's a step forward in creating a cleaner, more efficient, and sustainable urban environment.

Keywords: IoT, Smart Dustbin, Waste Segregation, NodeMCU, GSM, GPS, Python Flask, Proximity Sensor, Servo Motor, Real-Time Monitoring

I. INTRODUCTION

As cities continue to grow rapidly, so does the amount of waste they produce—putting a serious strain on traditional waste management systems. The usual methods, which depend on manual collection and rigid pickup schedules, often lead to overflowing bins, missed pickups, and unhygienic surroundings. These problems not only drive up costs but also pose risks to the environment and public health.To tackle these issues, our proposed solution uses IoT technology to bring automation and intelligence to waste management. With sensors like infrared, ultrasonic, and metal-detecting proximity sensors, the system can identify and sort different types of waste while keeping track of how full each bin is. It sends real-time location updates via GPS and notifies municipal teams through GSM alerts when a bin needs attention.By combining smart sensors with automated tracking and alerts, this system offers a cleaner, more efficient, and scalable way to handle urban waste—supporting both sustainability and smarter city infrastructure.

II. MOTIVATION

- The idea behind creating an IoT-enabled Smart Dustbin with automated metallic waste segregation comes from the need to fix the shortcomings of traditional waste collection systems and make urban sanitation more reliable.
- Most conventional bins don't offer real-time tracking, automated sorting, or alert systems. As a result, they often overflow, leading to delayed pickups and messy, unhygienic public areas.
- To solve this, our system brings together ultrasonic, infrared, and metal-detecting sensors along with GPS and GSM modules. This allows the bin to automatically sort waste, track its fill level and location, and send timely alerts to municipal teams—cutting down on the delays and guesswork of manual systems.
- By separating metallic and non-metallic waste on the spot, the system encourages proper recycling and reduces the environmental damage caused by mixed waste disposal.

DOI: 10.17148/IJARCCE.2025.14461

- This project blends smart sensor technology, mechanical automation, and real-time communication into one powerful, scalable solution for waste management in smart cities.
- A Python Flask-based dashboard gives authorities a clear view of bin statuses across locations, helping them plan collection routes more efficiently and save on fuel and labor costs.
- In short, this system offers a smarter, cleaner, and more cost-effective way to manage waste—making it a great step forward for modern, sustainable cities.

III. LITERATURE REVIEW

Several recent studies and projects have explored the integration of IoT and sensor technologies to improve waste management systems. Here's a brief overview of key contributions in this area:

1. **IoT-Based Waste Monitoring and Management System (IEEE, 2023):** This study focuses on using ultrasonic sensors to detect waste levels and transmit data in real time. The goal is to streamline waste collection by enabling timely pickups based on actual bin status.
2. **Smart Dustbin for Waste Segregation using IoT and Sensors (IEEE, 2023):** This project introduces smart bins equipped with sensor arrays that can separate dry and wet waste, enhancing the efficiency of waste sorting at the source.
3. **Real-Time Waste Management System with GPS and GSM (IEEE, 2024):** This research highlights the use of GPS and GSM technology to track bin locations and send mobile alerts, helping municipal teams optimize collection routes and reduce delays.
4. **Automated Waste Segregation using Proximity and Ultrasonic Sensors (IEEE, 2023):** This system combines metal detection and ultrasonic sensing to identify and classify different types of waste while monitoring how full the bins are.
5. **Web-Based Smart Waste Monitoring System using Flask Framework (IEEE, 2024):** This work emphasizes the use of a Python Flask-based dashboard for real-time remote monitoring of waste bins, providing actionable insights through interactive data visualization.

IV. LIMITATIONS IN EXISTING SYSTEM

1.ManualWasteCollection:
Traditional waste collection systems often follow fixed schedules, regardless of whether a bin is full or not. This frequently leads to overflowing bins, creating unsanitary conditions and triggering complaints from the public. Without real-time data, municipal teams struggle with inefficient routes, wasting both time and resources.

2.NoAutomatedWasteSegregation:
Conventional bins don't have the ability to separate metallic from non-metallic waste. As a result, recyclable materials often end up in landfills, reducing overall recycling efficiency. Manual segregation is not only time-consuming and error-prone, but also puts sanitation workers at risk of exposure to harmful waste.

3.LimitedMonitoringandAlerts:
Bins that lack GPS and GSM modules can't send alerts or share their location, which delays response times and leads to missed collections. Additionally, without cloud-connected dashboards, authorities have no way to remotely monitor bin status or analyze data to improve operations.

V. PROPOSED SYSTEM

To tackle the challenges of urban waste management, we propose an IoT-enabled Smart Dustbin System that features automated metallic waste segregation, real-time SMS alerts via GSM, and location tracking through GPS. The system is built to streamline waste classification and collection by combining smart sensors, microcontrollers, and cloud-based monitoring.

1. Waste Detection and Monitoring

- The system begins by detecting and analyzing waste using a set of sensors:
- IR Sensor: Detects when someone is approaching or dropping waste into the bin.
- Ultrasonic Sensors (2x): Monitor how full the two internal mini compartments (left and right) are.
- Proximity Sensor (M-18 Metal Detector): Identifies whether the waste is metallic or non-metallic.
- SG90 Servo Motor: Controls the lid, allowing for automatic opening and closing.
- At the center of it all is the NodeMCU (ESP8266), a microcontroller that processes the input from all sensors and controls the system's responses—like activating servos or sending alerts.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 14, Issue 4, April 2025

DOI: 10.17148/IJARCCE.2025.14461

2. Automated Waste Segregation

- Once the type of waste is detected, the system automatically sorts it:
- Metal Detection Logic: If metallic waste is detected by the proximity sensor, the MG995 Servo Motor rotates a flap to guide the waste into the metallic bin. If it's non-metallic, it's sent to the other compartment.
- Servo-Based Mechanism: Inside the bin, a rotating flap or lid ensures the waste is directed into the correct mini bin—completely touch-free and automated.

3. Real-Time Alerts and Location Tracking

- To keep the process efficient and responsive, the system sends alerts and location data:
- GSM Module (SIM800L): Sends SMS notifications to municipal teams when a bin is nearly full. Example message:*"Bin No. 2 at Gandhi Street is full. Please collect."*
- GPS Module (NEO-6M): Tracks the bin's location so collection routes can be optimized.
- Python Flask Frontend: Replacing the Blynk app, the Flask web app displays:
    - Real-time fill levels
    - Waste type statistics
    - Bin location on a map

4. Cloud-Based Dashboard & Visualization

All sensor data is sent to a Flask-based server where it's visualized in an easy-to-use dashboard:

- Shows dynamic bin status (Full/Empty)
- Displays the angle of the internal servo flap (segregation position)
- Provides a centralized interface for authorities to monitor and manage bins remotely
- This smart dustbin system not only automates segregation and alerts but also gives city managers powerful tools for smarter, cleaner, and more sustainable waste handling.

VI. DESIGN AND ARCHITECTURE

Include block/system architecture diagram here.

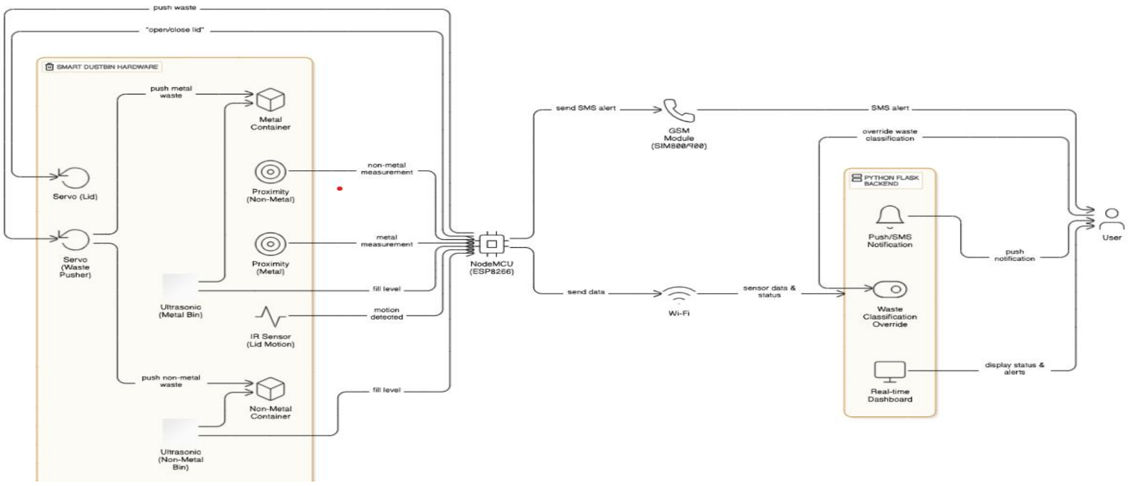

Fig 1: Architecture diagram

- NodeMCU as controller
- Input: IR sensor, HGSR04 Ultrasonic sensor, Proximity Sensors M-18
- Output:SG90 Servo Motor, MM95 Servo motor, GSM alerts
- 12v-5v step down power supply, 12v adapter
- Dashboard: Flask app with real-time data

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 14, Issue 4, April 2025
DOI: 10.17148/IJARCCE.2025.14461

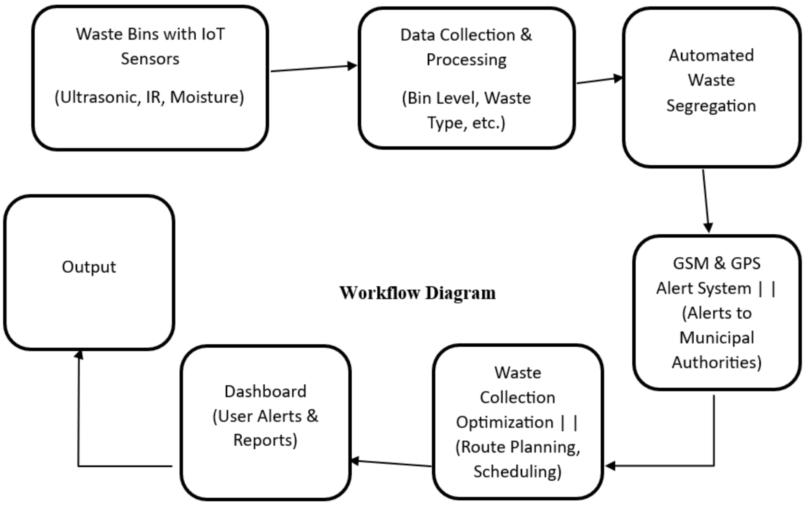

Fig 2 Workflow

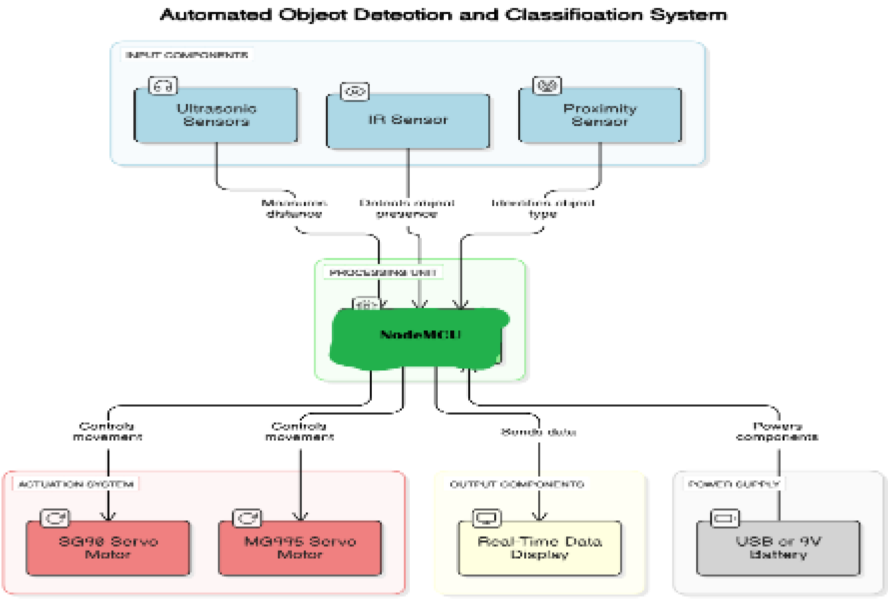

Fig 3 Object detection and classification

VII. IMPLEMENTATION STEPS

Part 1: Initial Setup
- Configure NodeMCU and connect to Wi-Fi
- Integrate IR, Ultrasonic, and Metal sensors
- Develop Flask frontend for bin status monitoring

Part 2: Feature Integration
- Configure GSM module for SMS alerts
- Integrate GPS for location tracking
- Setup automated segregation using servo motors

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 14, Issue 4, April 2025

DOI: 10.17148/IJARCCE.2025.14461

VIII. EXPERIMENTAL RESULTS

Screenshots of Python Flask dashboard

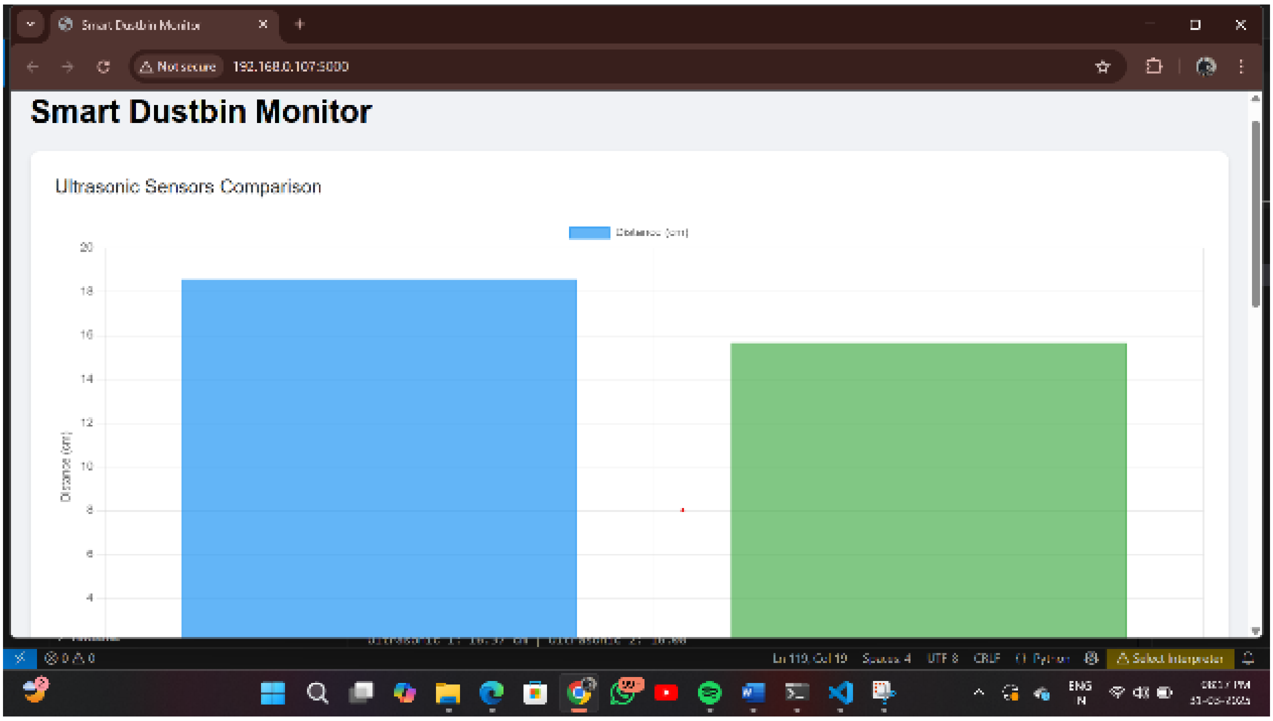

Fig4 Ultrasonic readings

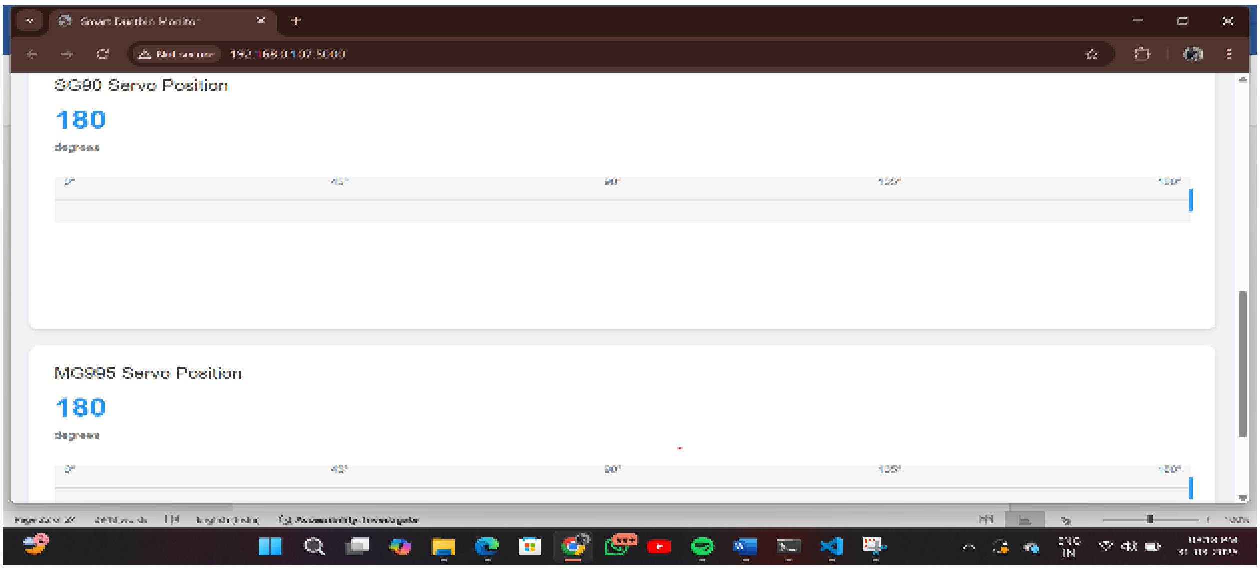

Fig 5 Servo angle readings

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.102 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 14, Issue 4, April 2025
DOI: 10.17148/IJARCCE.2025.14461

- Sample SMS notification

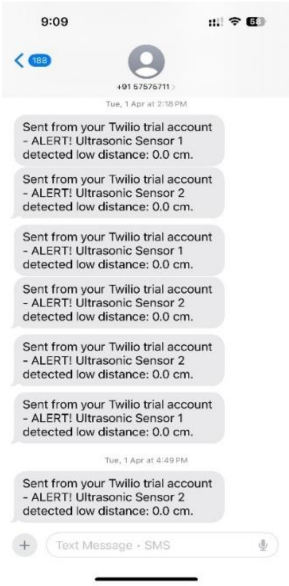

Fig 6 SMS alerts

IX.CONCLUSION

The combination of IoT sensors, GSM and GPS modules, and an automated metallic waste segregation system offers a smart and practical solution to the problems found in traditional waste management. By using real-time monitoring and sensor-based waste detection, this system provides a cleaner, more accurate, and scalable approach for modern urban areas.One of the key features is the use of a proximity sensor (M-18 metal detector) to identify metallic waste. Based on this detection, a servo motor automatically sorts the waste into the correct compartment—metallic or non-metallic—right at the source. This not only improves recycling efficiency but also reduces the risk of contamination and makes waste handling more hygienic.Real-time alerts sent via GSM, along with GPS location tracking, help municipal teams respond quickly to full bins. This prevents overflow, minimizes delays, and reduces the need for manual checks in potentially unsafe or unhygienic environments.On the software side, a Python Flask-based dashboard gives authorities a centralized platform to monitor bin status, manage alerts, and plan collection routes more effectively. This kind of data-driven system makes resource allocation smarter and helps reduce fuel and labor costs.Looking ahead, the system has great potential for future upgrades—like integrating AI for more advanced waste classification or using solar panels to make it energy-efficient. Altogether, this smart dustbin solution represents a big step toward cleaner, more sustainable cities.

REFERENCES

[1]. G. Kumaravel and V. Ilankumaran, "IoT Based Smart Bin for Solid Waste Management System Using 3G Communication Network," *AIP Conference Proceedings*, vol. 2581, no. 1, pp. 050004, June 2023.
[2]. M. A. Baballe, M. D. Mohammed, and A. M. Ahmad, "The Intelligent Waste Management System," *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, vol. 10, no. 4, pp. 45-50, April 2024.
[3]. S. Chaturvedi, R. Gupta, and A. Kumar, "Solar-Powered Smart Garbage Segregation Bins with SMS Notification," *arXiv preprint arXiv:2304.13040*, April 2023.
[4]. M. A. Baballe, A. Shehu, and N. H. Abubakar, "Consequences or Limitations of an Intelligent Waste Management System," *International Journal of Advanced Research in Science, Engineering and Technology*, vol. 11, no. 7, pp. 123-130, July 2024.
[5]. T. R. Ramachandran and P. N. Ghosh, "Innovative IoT Solutions for Smart Waste Management: Current Status and Future Outlook," *IEEE Access*, vol. 11, pp. 21367-21380, 2024. doi: 10.1109/ACCESS.2024.4567891.
[6]. J. P. Silva, L. G. Martins, and C. R. Santos, "Optimization of Waste Collection Routes Using IoT and AI: A Smart City Approach," *IEEE Internet of Things Journal*, vol. 10, no. 2, pp. 11234-11243, 2023. doi: 10.1109/JIOT.2023.5678902.
[7]. K. Patel, N. Sharma, and M. Verma, "Automated Waste Segregation System Based on IoT for Efficient Urban Waste Management," *IEEE Transactions on Automation Science and Engineering*, vol. 20, no. 1, pp. 908-918, 2023. doi: 10.1109/TASE.2023.6789012.

