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# Waste Management Tracking System

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***ABSTRACT***

*Urbanization and population growth have intensified the challenges of managing solid waste in cities. Traditional waste collection systems, which operate on fixed schedules without monitoring the actual status of bins, often lead to overflowing bins, unhygienic conditions, and unnecessary operational costs. To address these issues, this project proposes a* ***Waste Management Tracking and Segregation System*** *that leverages* ***IoT technologies*** *for smart monitoring and automated waste handling. The system is built around an* ***ESP8266 microcontroller with inbuilt Wi-Fi****, enabling wireless data transmission and integration with online platforms. An* ***ultrasonic sensor*** *measures the fill level of the bin and displays this data on the serial monitor, while a* ***rain sensor*** *and* ***IR sensor*** *work together to identify and classify waste as wet or dry. A* ***servo motor*** *then flips or directs the waste into the appropriate compartment based on this classification, supporting automated segregation at the source. The system communicates bin status in real-time through a* ***web page interface*** *and the* ***Blynk IoT platform****, allowing users to monitor bin levels and receive notifications on their mobile devices when bins are full. Additionally, a* ***GSM module*** *is included to send SMS alerts to waste collection teams. This solution eliminates the need for expensive components like GPS modules and RFID tags, offering a* ***cost-effective, scalable, and sustainable*** *option for smart cities and urban areas. The proposed system enhances operational efficiency, reduces fuel consumption, prevents bin overflow, and contributes to cleaner and healthier urban environments.*

## 1-INTRODUCTION

Urbanization and the rapid growth of population in modern cities have significantly increased the amount of waste generated daily by households, businesses, and industries. Managing this growing volume of waste has become a major challenge for municipal authorities and waste management agencies. Traditional waste collection systems rely on fixed schedules without considering the actual status of waste bins. This often results in either overflowing bins that cause health hazards and environmental pollution or unnecessary collection trips that waste time, fuel, and manpower.

To overcome these limitations, smart waste management solutions are being developed, leveraging the power of **IoT** technologies. These systems aim to monitor bin status in real-time, automate waste segregation, and optimize collection schedules. Such intelligent solutions not only reduce operational costs but also improve urban sanitation, minimize environmental impact, and support the vision of smart cities.

This project presents a **Waste Management Tracking and Segregation System** that provides a cost-effective, automated, and efficient way of handling urban waste. The system uses an **ESP8266 microcontroller with inbuilt Wi-Fi** to connect various sensors and modules. An **ultrasonic sensor** is used to detect the fill level of the bin and display it on the serial monitor. A **rain sensor** assists in classifying detected waste as wet or dry, while an **IR sensor** identifies the presence of waste at the input. A **servo motor** is employed to flip or direct the waste into the appropriate dry or wet compartment based on this classification.

## 2-LITERATURE SURVEY

The increasing pace of urbanization and rapid growth in population density have posed significant challenges for municipalities, particularly in the domain of waste management. Conventional waste collection systems operate on predefined schedules and routes without accounting for the actual fill levels of individual bins. This outdated approach results in several issues: waste bins often overflow before collection, contributing to unsanitary conditions and environmental pollution; at other times, partially filled bins are emptied, leading to unnecessary fuel consumption, increased carbon emissions, and inflated operational costs. Furthermore, conventional systems rarely address waste segregation at the source, which is essential for improving recycling efficiency and promoting environmental sustainability.

To tackle these challenges, various researchers have developed smart waste management systems leveraging **Internet of Things (IoT)** technologies. These systems aim to enable real-time monitoring of bin status, optimize collection processes, and sometimes enhance environmental safety. However, a critical review of existing literature reveals that most solutions focus on partial aspects of waste management—such as monitoring or routing—

without delivering a complete, affordable, and easily deployable system that integrates real-time detection, segregation, and reliable communication.

***Review of Existing Works***

[1] **Vasagade et al. (2017) — *Dynamic Solid Waste Collection and Management System***
This work proposed a smart bin equipped with **ultrasonic sensors** to measure the fill level of the bin. When the bin reached a certain threshold, a **GSM module** sent SMS alerts to the relevant municipal authorities. The key advantage of this system was its ability to prevent overflow by ensuring timely notification. However, the design lacked modern IoT features such as integration with cloud platforms or mobile dashboards. The system provided no means for centralized monitoring or real-time data access via apps. Most importantly, there was no provision for **waste segregation**, limiting its usefulness in modern recycling-driven waste management practices.

[2] **Misra et al. (2018) — *IoT-Based Waste Management System Monitored by Cloud***
Misra and colleagues introduced a system where bins were outfitted with **ultrasonic sensors** for fill level detection and **gas sensors** for monitoring hazardous gases. The system sent bin data to a **cloud server** via GSM modules and provided SMS notifications to staff for immediate action. This system contributed to **environmental safety** through gas monitoring and achieved basic cloud integration. However, it lacked focus on **cost-effectiveness** and did not support **segregation of waste** at the source. The absence of dual communication channels (such as combining Wi-Fi and GSM) reduced reliability in the case of network failures.

[3] **Patel et al. (2019) — *Smart Waste Management System Using IR and Ultrasonic Sensors*** This system used **ultrasonic sensors** to measure bin fill levels and **IR sensors** to detect obstacles or obstructions in waste input areas. The solution provided basic bin monitoring and ensured that bins were not blocked. However, the system did not provide an **IoT dashboard** for real-time status visualization. It also lacked **automated segregation**, multi-channel notification, or any smart feature beyond simple level and obstruction detection. The design stayed limited to basic alerting without focusing on intelligent processing or sustainability features.

[4] **Kumar et al. (2020) — *Low-Cost IoT-Based Smart Bin***
Kumar et al. focused on **cost-effectiveness** by employing **ESP8266 microcontrollers** and ultrasonic sensors to monitor fill levels. Bin data was published to a simple **web server**, allowing real-time monitoring. The system's strength was in its affordability and simplicity, making it suitable for small-scale deployments or academic purposes. However, this design omitted important features like **GSM fallback communication** for locations with poor Wi-Fi connectivity, **servo automation** for waste segregation, and lacked multi-function sensors for additional environmental data. Thus, it addressed only part of the waste management challenge.

[5] **Ghahramani et al. (2022) — *IoT-Based Route Recommendation for Waste Management***
In this advanced work, **IoT sensors** were combined with **AI algorithms** to gather data from multiple smart bins and recommend optimized routes for garbage collection vehicles. The system successfully reduced **fuel consumption** and minimized operational inefficiencies by dynamically adjusting routes based on real-time bin fill levels. Despite its innovation in **route optimization**, this system came with high costs due to reliance on **GPS, RFID modules**, and complex AI processing. Moreover, it did not address **source-level segregation** or cost barriers that would hinder its deployment in smaller cities or towns.

## 3-HARDWARE & SOFTWARE REQUIREMENTS

The successful implementation of the **Waste Management Tracking System** depends on the seamless integration of carefully chosen **hardware and software components**, each playing a vital role in realizing the project's objectives. This chapter provides a comprehensive overview of these elements, explaining how their combined functionalities enable real-time monitoring, reliable data communication, and intelligent automation. The system is designed not only to meet current needs but also to offer **cost-effectiveness, scalability, and ease of deployment**, making it suitable for both smart cities and semi-urban areas. The hardware setup comprises essential components such as **microcontrollers (ESP8266)**, **ultrasonic sensors for bin level detection**, **infrared (IR) sensors for object detection**, **rain or moisture sensors for wet waste identification**, **servo motors for automatic segregation**, and **GSM modules for SMS-based alerting**.

On the software side, the project leverages **IoT platforms (Blynk)** for real-time visualization of bin status, fill levels, and segregation data. The **Blynk mobile application and web dashboard** provide user-friendly interfaces for tracking system performance and receiving notifications. The software also includes embedded firmware written in **Arduino IDE**, which facilitates the integration of various hardware components, manages data acquisition, and handles logic for decision-making (such as when to trigger SMS alerts or servo motor actions.

**Hardware Components**

***ESP8266 (Node MCU) Microcontroller***

The ESP8266 Node MCU serves as the primary control unit of the waste management system. It is a low- cost microcontroller equipped with an integrated Wi-Fi module, making it ideal for IoT applications that require wireless connectivity. The microcontroller is based on a 32-bit Tensilica L106 processor that runs at 80 MHz (with the option to overclock to 160 MHz), providing adequate processing power for sensor data handling and communication tasks. The ESP8266 operates on a 3.3V supply and offers multiple GPIO pins for interfacing with sensors and actuators. One of its standout features is the ability to connect directly to the internet via Wi-Fi, enabling seamless integration with platforms like Blynk for real-time monitoring and notification services.

***Ultrasonic Sensor (HC-SR04)***

The ultrasonic sensor is utilized for measuring the level of waste within the bin. This sensor works by emitting ultrasonic waves at a frequency of 40 kHz and calculating the time it takes for the echo to return after bouncing off the waste material. The distance is then determined using the speed of sound. The HC-SR04 can accurately measure distances ranging from 2 cm to 400 cm, with a typical accuracy of ±3 mm. The sensor operates on a 5V DC power supply and consumes minimal current, making it energy-efficient. Its non-contact measurement capability ensures that the sensor remains clean and maintenance-free, even in harsh or contaminated environments.

***Infrared (IR) Sensor***

The IR sensor is used for object detection in the waste segregation process. It helps identify when waste is present in the input section of the bin. The sensor works by emitting infrared light and detecting its reflection from nearby objects. When waste material is detected, the sensor triggers the servo motor to guide the waste towards either the dry or wet compartment. The IR sensor offers fast response time, low power consumption, and stable performance under indoor lighting conditions, making it ideal for use in this application.

**Software Requirements**

The Waste Management Tracking System relies on a combination of software tools to program, monitor, and manage the hardware components effectively. These software platforms enable the development, deployment, and real-time monitoring of the smart bin system:

***Arduino IDE***

The Arduino Integrated Development Environment (IDE) is used to write, compile, and upload code to the ESP8266 microcontroller. It provides a simple interface to manage the sensors, motors, GSM module, and Wi-Fi communication. The IDE supports the required libraries for handling ultrasonic sensors, IR sensors, servo motors, and GSM functionalities. The serial monitor tool within the Arduino IDE is used during development and testing to debug the system and verify real- time sensor readings, motor actions, and communication status.

***Blynk IoT Platform***

Blynk allows real-time monitoring, control, and notification through a mobile app or web dashboard. It displays waste bin levels, rain detection, and status updates, while also sending push notifications to alert users when bins are full.

***Web Page (HTML/JavaScript/CSS)***

A basic web page is created to display bin level status locally over Wi-Fi. The ESP8266 hosts this page, providing direct access to sensor data within the same network, offering another way to monitor the system without depending solely on external apps.

## 4-WASTE MANAGEMENT TRACKING SYSTEM

The **proposed Waste Management Tracking System** presents a smart, cost-effective, and scalable solution aimed at addressing the inefficiencies and limitations of traditional waste collection methods. Designed to suit both **urban** and **semi-urban environments**, the system leverages a harmonious integration of **sensors**, a **microcontroller with built-in Wi-Fi capability (ESP8266)**, and **IoT platforms** to enable automated, intelligent monitoring and management of municipal and community waste bins. By utilizing these technologies, the system not only enhances the efficiency of waste collection but also contributes toward sustainability goals by reducing unnecessary resource consumption and minimizing environmental impact.

The primary goal of this system is to ensure **timely waste collection**, **prevent overflow of waste bins**, and **optimize operational resources** such as fuel, manpower, and collection time. To achieve this, the system continuously tracks the **fill levels** of dustbins using **ultrasonic sensors**, providing accurate distance measurements that help determine the percentage of bin fullness. Simultaneously, it classifies waste as **dry** or **wet** using a combination of **infrared (IR) sensors** for object detection and **rain/moisture sensors** for identifying wet waste. A

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**servo motor** is employed to automatically direct waste into designated sections of the bin based on this classification, ensuring source-level segregation that aids in downstream processing and recycling.

At the heart of the system is the **ESP8266 microcontroller**, which serves as the central processing and communication unit. It collects sensor data, processes it in real-time, and transmits it via **Wi-Fi** to a dedicated **web page** and the **Blynk IoT platform**, enabling remote monitoring through both desktop and mobile interfaces. This provides municipal staff or waste management operators with instant visibility into bin status across multiple locations.

Additionally, the inclusion of a **GSM module** ensures an added layer of communication by sending **SMS alerts** when bins reach critical fill levels, making sure collection teams are informed without relying solely on internet connectivity. This dual communication mode (Wi-Fi + GSM) enhances reliability, especially in regions where network conditions may vary.

Overall, the proposed system represents a **practical and forward-thinking solution** that bridges gaps in existing waste management practices by combining **real-time data acquisition**, **automated segregation**, and **multi-channel notifications**. It offers an affordable and easy-to- deploy framework that can significantly improve the efficiency of municipal waste operations, reduce fuel costs, and promote cleaner urban environments.

**BlockDiagram & Explanation**

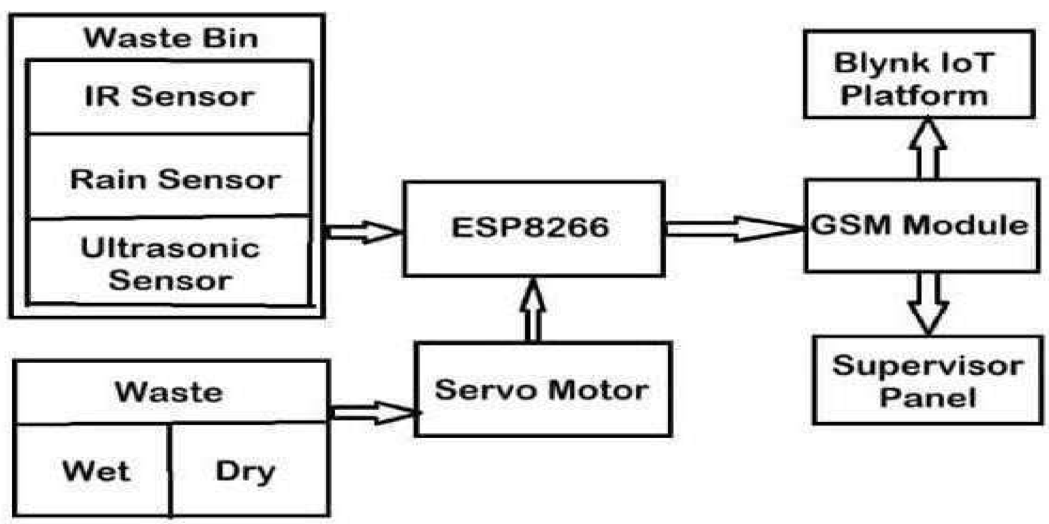


Figure 4.1 Block Diagram

The block diagram illustrates the architecture of the proposed **Waste Management Tracking System**, highlighting the interaction between various hardware components and communication modules used for smart waste monitoring and segregation.

## 5-RESULTS & DISCUSSION

The designed and implemented smart waste management tracking system was thoroughly tested to validate its functionality and efficiency. The system successfully integrates hardware components—such as ultrasonic sensors, IR sensors, rain sensors, and a servo motor—with software platforms like the Blynk IoT app, a custom web interface, and GSM-based SMS notifications.

When powered on, the system continuously monitors the waste bin using ultrasonic sensors. The sensor accurately measures the waste level and displays the distance on the serial monitor of the Arduino IDE. Whenever the bin reaches a predefined threshold, a corresponding message is shown on the serial monitor, indicating that the bin is full. This is supported byan automated SMS sent to the registered mobile number, alerting the waste collection team for prompt action. Additionally, the IR sensor and rain sensor collaboratively detect the type of waste. When dryor wet waste is detected, the servo motor activates to flip or direct the waste into the appropriate section of the bin. This real-time segregation process is displayed on the serial monitor (e.g., messages such as “Dry waste detected” or “Wet waste detected”) and is also reflected on the connected IoT platform.

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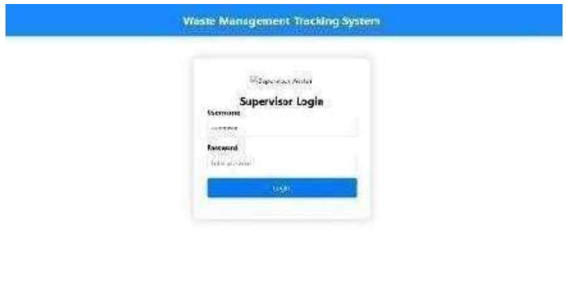


Figure 5.1 Login Page


Figure 5.2 Dashboard

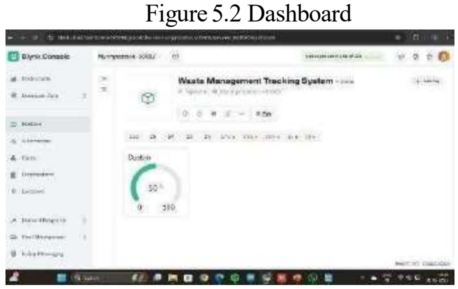


Figure 5.3 Real-Time Bin Status (Blynk)

The web page login screen allows users to access the monitoring dashboard securely by entering the correct ID and password. Upon successful login, the dashboard displays various options such as viewing current bin levels, status logs, and notifications. The dashboard dynamically updates as the bin level changes, and the Blynk IoT mobile app mirrors this data, offering flexibility in monitoring whether from a desktop or a mobile device.

Figure 5.4 Hardware Setup

Figure 5.5 Servo Motor- Flipping for Dry/Wet Segregation

The hardware setup was successfully connected to the system's web interface. A laptop screen running the web page alongside the live hardware setup (including the ESP8266, sensors, servo, and power supply) demonstrated smooth real-time communication. The mobile device showed both the Blynk app interface and the SMS alert messages when conditions were triggered. The system flipped waste as per detected type without manual intervention.


Figure 5.6 SMS Notification for Bin Full Alert

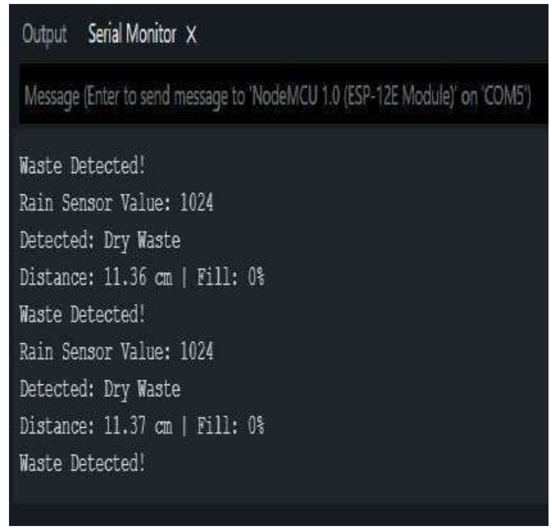


Figure 5.7 Arduino Serial Monitor

## 6-CONCLUSION

In this project, we successfully designed and implemented a cost-effective Smart Waste Management Tracking System using the ESP8266 microcontroller, ultrasonic sensors, IR sensors, rain sensors, GSM module, servo motors, and the Blynk IoT platform. The system efficiently addresses key challenges in urban and semi-urban waste management, such as overflowing bins, inefficient collection schedules, and the absence of source-level segregation.

The system provides real-time monitoring of bin fill levels through ultrasonic sensors and sends timely alerts via GSM-based SMS and the Blynk app. A unique feature of our design is the integration of IR sensors, rain sensors, and servo motors, enabling automated dry and wet waste segregation at the bin level—an advancement rarely addressed in prior work. The bin data can be accessed remotely through both a web dashboard and mobile app, facilitating quick response from collection teams and minimizing the likelihood of overflow or unsanitary conditions.

By avoiding expensive components like GPS and RFID modules, the system ensures affordability and scalability, making it ideal for deployment in resource-constrained regions. The hardware setup is simple and modular, while the software components, including Blynk and supportive libraries, ensure easy customizability. Overall, the solution provides a reliable, low-cost, and scalable method for municipalities and urban planners to modernize waste collection practices, optimize operational efficiency, and promote environmental sustainability.

In conclusion, the current system lays the groundwork for a smart, scalable, and efficient waste management solution. With future enhancements, it can evolve into a comprehensive platform that not only manages waste but also contributes actively toward the vision of sustainable and smart cities.

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