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# IoT Based Smart Bin Waste segregation

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Abstract: Problem of waste management in urban areas. Effective waste management is essential for maintaining a clean environment and reducing pollution. Traditional waste segregation methods are inefficient and require significant human intervention. This project presents an automated system for segregating dry and wet garbage using ESP32, along with real-time monitoring of bin levels through a GSM module. The system utilizes a rain sensor to detect moisture in the waste, classifying it as either wet or dry. An ultrasonic sensor monitors the garbage bin's fill level, and when the bin is nearly full, the system triggers a buzzer and sends an SMS alert via a GSM module to notify the user. The primary goal of this project is to automate waste segregation and improve waste disposal efficiency by minimizing human involvement. This IoT-based solution is low-cost, scalable, and can be integrated into smart city initiatives to enhance urban waste management. The system is designed to be simple and adaptable, providing real-time updates, ensuring timely bin emptying, and reducing environmental impact through efficient waste recycling. Overall, this system offers an innovative approach to tackling the growing

**Keywords:** Smart Bin, Garbage Management, Scalable System, Adaptable

## I. INTRODUCTION

Waste management has become a pressing challenge in contemporary society, driven by rapid urbanization and population growth. The increasing volume of waste generated by households, industries, and commercial sectors places significant strain on waste management infrastructure. Inefficient waste handling contributes to environmental pollution and poses serious health hazards. To address this, it is essential to implement effective waste segregation practices at the source, distinguishing between dry and wet waste. However, traditional waste segregation methods, which rely heavily on manual labor, are often inefficient, error-prone, and time consuming. This has led to the adoption of automated solutions to enhance waste management efficiency. In urban settings, public and residential garbage bins serve as primary waste collection points. However, the lack of proper segregation and irregular collection schedules often results in overflowing bins, creating unsanitary conditions and promoting the spread of diseases. Moreover, the improper classification of waste disrupts the recycling process, increases landfill overflow, and contributes to soil and water contamination. Therefore, an automated system capable of segregating waste and monitoring bin levels can significantly streamline waste management operations and promote environmental sustainability. This project aims to develop an automated dry and wet waste segregation and monitoring system using the ESP32 microcontroller and a GSM module. The system uses a rain sensor to differentiate between dry and wet waste based on moisture content. Dry waste typically consists of materials such as paper, plastic, and metals, whereas wet waste includes biodegradable items like food scraps and organic matter. When waste is placed into the bin, the rain sensor detects the moisture level and classifies it accordingly. A servo motor then directs the waste to the appropriate compartment, ensuring efficient segregation. To further enhance the system, an ultrasonic sensor is employed to monitor the bin's fill level. By measuring the distance between the waste surface and the bin's top, the system can determine when the bin is nearing capacity. Upon reaching a predefined threshold, the GSM module sends an SMS alert to a designated phone number, notifying the user or waste management authority that the bin needs to be emptied. This real-time monitoring reduces the need for manual checks, prevents bin overflow, and ensures timely waste collection, making the system an effective and practical solution for improving urban waste management. The Aim of this project is to design and develop an automated waste segregation and monitoring system utilizing the ESP32 microcontroller and GSM technology.

## 1.2 AIM

The aim of our project is to develop an automated smart dustbin system that can separate dry and wet waste using sensors and send a message when the bin is full.

## 1.3 PROBLEM STATEMENT

In cities, the amount of garbage is increasing every day due to population growth and more waste being created. The current method of collecting and separating waste is mostly done by people, which is slow, not always correct, and sometimes risky to health.

Also, there is no proper system to know when the dustbin is full. This leads to garbage overflowing in public places, which causes bad smells, attracts insects, and spreads diseases. The waste collection trucks often follow fixed routes, so sometimes they visit half-empty bins, and other times they are too late to empty full bins.

## 1.4 OBJECTIVES

The primary objective of this project is to develop an intelligent system for automated waste segregation and monitoring, utilizing the ESP32 microcontroller. The system is designed to categorize waste into dry and wet types based on the moisture content detected using a rain sensor. Wet waste, such as food and organic material, contains high moisture, whereas dry waste like plastic or paper does not. The system detects this using sensor readings and then uses a servo motor to direct the waste into the correct bin compartment.

In addition to segregation, the system incorporates real-time bin level monitoring using an ultrasonic sensor. This sensor measures the distance between the top of the bin and the waste surface to determine how full the bin is. When the bin reaches a preset threshold, the system triggers an alert using a GSM module, which sends an SMS notification to the waste collection authority. This ensures timely collection of garbage and prevents overflow.

Another key objective is to reduce human involvement in waste segregation, which is often time-consuming, unhygienic, and prone to error. Automating the process improves accuracy, hygiene, and operational efficiency. The system also supports environmental sustainability by ensuring proper waste sorting at the source, which increases the efficiency of recycling and reduces the burden on landfills. Overall, the project promotes smart waste management suitable for modern urban environments and supports the development of smart cities.

The Real-Time Waste Monitoring System is a vital component of the automated waste management project, designed to continuously track the fill level of garbage bins. This system utilizes an ultrasonic sensor to measure the distance between the bin's lid and the surface of the waste. As waste accumulates, the sensor detects the decreasing distance and provides real-time data on the bin's fill level. When the bin reaches a preset threshold, indicating it is nearly full, the system triggers an alert or notification, ensuring timely waste disposal. By preventing overflowing garbage bins, the system helps maintain cleaner and more hygienic surroundings.

## II. PROPOSED METHODOLOGY

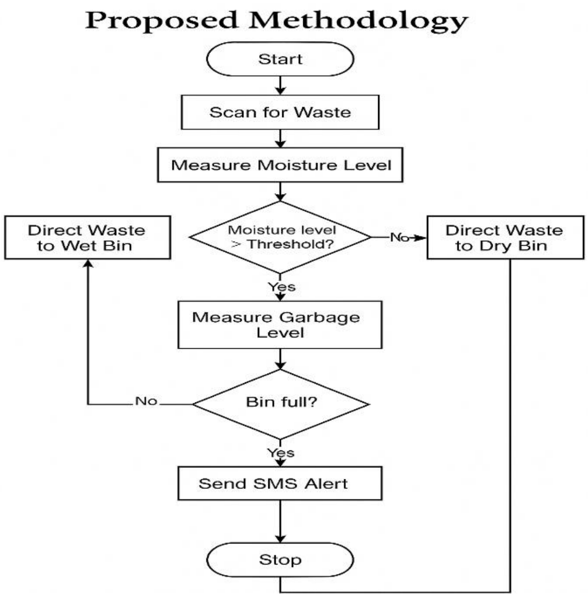


**Figure: Research Methodology Flow**

## III. RESEARCH WORK

1. Studied the current challenges in waste management, especially in urban areas where garbage collection is inefficient and waste segregation is mostly manual.
2. Explored sensor technologies and found that a **rain sensor** is effective for detecting moisture to separate dry and wet waste.
3. Researched **ultrasonic sensors** for monitoring bin fill levels and found them suitable due to accurate, non-contact measurement.
4. Reviewed the use of **GSM modules** in smart systems to send SMS alerts when the bin is full, ensuring timely garbage collection.

## IV. PRE-PROCESSING

Effective waste segregation requires accurate classification of materials at the point of disposal. In the proposed system, the preprocessing stage is critical in ensuring reliable identification of waste as either dry or wet before it is sorted into separate compartments. The input data, in this case, consists of physical waste items deposited into a smart bin equipped with various sensors. Due to the variability in waste types, shapes, sizes, and moisture levels, raw input from the environment is subject to noise, inconsistency, and uncertainty. The primary objective of the preprocessing phase is to normalize these inputs and prepare them for accurate classification and automated handling. The core component responsible for initial classification is a moisture-detecting sensor, commonly a rain or capacitive moisture sensor. When a waste item is dropped into the bin, this sensor detects its surface moisture level, which serves as the principal feature for distinguishing between wet and dry waste. Wet waste, typically consisting of organic materials such as food scraps, vegetable peels, and leftovers, retains high moisture content, whereas dry waste, including paper, plastic, and metals, is characterized by low or negligible moisture levels. The raw analog signal from the moisture sensor is read by the ESP32 microcontroller and then converted into a digital value using its inbuilt Analog-to-Digital Converter (ADC). This data is then compared against a pre-defined threshold to determine the waste type. In addition to moisture detection, pre-processing also involves bin level monitoring using an ultrasonic distance sensor. This sensor measures the vertical distance between the bin lid and the surface of accumulated waste. The signal is translated into fill-level percentages to determine when the bin is nearing full capacity. If the threshold is reached, the GSM module is triggered to send a real-time SMS notification to the waste management authority or user. The microcontroller continuously monitors sensor readings and processes data with minimal latency, enabling near-instant response to each waste disposal event. To enhance accuracy and reduce false classification, the preprocessing logic filters out sensor noise using software-based debounce mechanisms and signal averaging. Moisture readings are collected in multiple short intervals and averaged to mitigate the impact of transient fluctuations, especially those caused by wet surfaces on dry waste or condensation. Similarly, ultrasonic sensor readings are taken repeatedly and averaged to improve bin level detection accuracy, accounting for irregular shapes or protrusions in waste material. This pre-processing stage ensures the reliability of both the classification and monitoring subsystems. After classification, a servo motor is activated to physically segregate the waste into dry and wet compartments using a flap or divider mechanism. Meanwhile, bin fill data is continuously updated and transmitted only when necessary to avoid redundancy. All operations are synchronized and controlled by the ESP32 microcontroller, which acts as the central unit for real-time decision-making. Through this multi-sensor, pre-processed data handling, the system ensures accurate, efficient, and timely segregation and monitoring, thereby supporting cleaner waste management practices and reducing human intervention.

## V. METHODOLOGY

1. **Waste Detection**: Waste is inserted into the system through an input section where the process starts.
2. **Moisture Sensing**: A **rain sensor** checks the moisture level of the waste to determine if it is wet (biodegradable) or dry (non-biodegradable).
3. **Servo Motor Action**: The **ESP32 microcontroller** activates a **servo motor**, which rotates to direct the waste into the correct bin (wet or dry).
4. **Bin Level Monitoring**: An **ultrasonic sensor** checks how full the bin is by measuring the distance from the waste to the bin lid.
5. **SMS Alert**: When the bin is almost full, the **GSM module** sends an **SMS notification** to the waste collection authority.
6. **Automation & Monitoring**: The system runs continuously, automating both waste segregation and bin monitoring with minimal human involvement.

## VI. NON-FUNCTIONAL REQUIREMENT

1. **Reliability**
   The system should operate consistently without failure. It must correctly classify waste and send alerts reliably over long durations.
2. **Scalability**
   The system design should support expansion—more bins or locations can be added with minimal hardware and software modifications.
3. **Maintainability**
   The system should be easy to maintain, with components that can be easily replaced or reprogrammed if needed.
4. **Performance**
   The waste classification and SMS alert system should respond quickly and process each waste input without noticeable delay.
5. **Efficiency**
   The system should consume low power and optionally support solar energy for long-term use in outdoor or remote areas
6. **Security**
   Data (like SMS alerts) should be sent securely and only to authorized recipients to prevent misuse of system notifications.
7. **Usability**
   The system should be user-friendly with minimal human interaction needed, making it easy for non-technical users.

## VII. SYSTEM DESIGNAND DEVELOPMENT

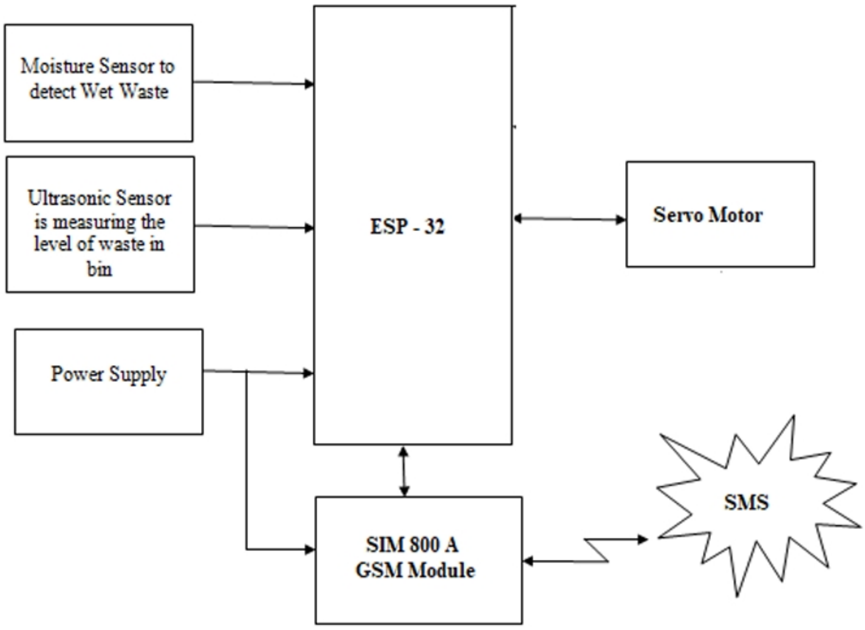


**Figure: Block Diagram**

## VIII. COMPONENTS DESCRIPTION

### 8.1 ESP32 MICROCONTROLLER

**Figure: ESP32 Microcontroller**

The ESP32 microcontroller, developed by Espressif Systems, is a highly versatile, cost-effective, and powerful chip designed for Internet of Things (IoT) applications. It features built-in Wi-Fi and Bluetooth capabilities, making it an ideal choice for wireless communication projects that require seamless connectivity. Known for its low power consumption, high processing capability, and dual-core architecture, the ESP32 is widely used in applications ranging from smart home automation and industrial control to embedded systems and security solutions. Its robust features, including multiple GPIO pins, ADC, DAC, PWM, SPI, I2C, and UART interfaces, allow it to efficiently interact with various sensors, actuators, and peripheral devices, making it a popular choice among developers and engineers for creating intelligent, connected systems. In the context of a triple authentication-based door lock system, the ESP32 serves as the central processing unit (CPU), orchestrating the entire authentication process, controlling the locking mechanism, and managing communication between various components. This system employs three layers of authentication—RFID, password input, and biometric verification—to ensure enhanced security. The ESP32 first reads the RFID tag using an RFID module; if the tag matches an authorized entry, it proceeds to the next authentication stage. The second layer involves a keypad or touchscreen interface, where the user must enter a predefined password. If the password is verified successfully, the system advances to the third authentication stage, which typically involves biometric verification, such as fingerprint scanning using a fingerprint sensor. Only upon successful completion of all three authentication steps does the ESP32 trigger the servo or solenoid lock to grant access.

### 8.2 SIM800A Functional Diagram & Features

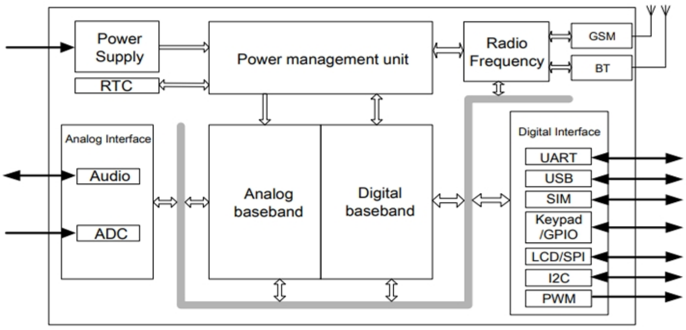


**Figure: SIM800A Functional Diagram**

Following are the Features of SIM 800A:
• SIM800A Quad Band GSM Module
• Bands: GSM 850MHz, EGSM 900MHz, DCS 1800MHz, PCS 1900MHz
• Coding schemes: CS-1, CS-2, CS-3, CS-4 Tx power: Class 4 (2W), Class 1 (1W)
• GPRS class 2/10 • Control via AT commands (3GPP TS 27.007, 27.005 and SIMCOM enhanced AT command set)
• Voltage Supply Required- 9VDC to 12VDC with at least 2A Peak Current Capability
• 5V interface for direct communication with MCU kit • TTL Rx and TTL Tx and DB9 Connector Based RS232 Outputs • Configurable baud rate • Built-in Network Status LED • Inbuilt Powerful TCP/IP protocol stack for internet data transfer over GPRS • Low power • Operating temperature: -40C to +85C • External Finger type antenna

The SIM800A module operates within a voltage range of 9V to 12V, with 9V being the recommended input. During high-power transmission, the module requires a current supply of up to 2A. For stable and efficient operation, it is essential to use a power source capable of delivering sufficient current without voltage drops. When using a 9V DC input, if power efficiency is not a major concern, a high-current low-dropout (LDO) regulator is recommended. However, for improved power efficiency, especially with higher input voltages, a switching mode DC-DC converter is preferable. This converter minimizes power loss and ensures stable voltage regulation.

Power-Saving Mode: The SIM800A module incorporates a power-saving technique that significantly reduces current consumption, going as low as 0.55mA during sleep mode. This feature makes it ideal for battery powered applications, extending the operational time.

### 8.3 Servo Motor:


**Figure: Servo Motor**

A servo motor is a specialized actuator designed for precise control of angular or linear position, velocity, and acceleration. This makes them essential in applications where accuracy and repeatability are crucial, such as robotics, CNC machines, and automated systems. Key Characteristics: • Precise Positioning: Servo motors achieve accurate positioning by incorporating a feedback mechanism that continuously monitors the motor's shaft position. • Closed-Loop Control: They operate within a closed-loop system, meaning they constantly compare the desired position with the actual position and adjust minimize errors. • Variety of Types: Servo motors can be categorized based on their power source (DC or AC) and other characteristics like gear arrangements and operating features. • Torque Rating: Servo motor strength is typically rated in kg-cm (kilograms per centimeter). This rating signifies the torque the motor can exert. For instance, a 6 kg-cm servo can lift 6 kg when the load is 1 cm from the motor's shaft. The lifting capacity decreases as the distance from the shaft increases.

**Components of a Servo Motor**: A typical servo motor consists of:

1. Motor: The core component that provides the rotational force. This can be a DC or AC motor.
2. Gear Train: A series of gears that reduce the motor's speed while increasing its torque. This allows for precise control and higher output force.
3. Position Sensor (Potentiometer or Encoder): A sensor that measures the motor's shaft position and provides feedback to the control circuitry.
4. Control Circuitry: An electronic circuit that receives control signals, compares them to the feedback from the position sensor, and adjusts the motor's operation accordingly.

### 8.4 Ultrasonic Sensor:


**Figure: Ultrasonic Sensor**

The fundamental principle behind ultrasonic distance measurement is based on the echo phenomenon. When the sensor emits sound waves, they travel through the air until they strike an obstacle. The waves then reflect back to the sensor as an echo. By calculating the time it takes for the waves to travel to the obstacle and return, the distance can be determined, as the speed of sound in air is a known constant. Ultrasonic sensors determine distance and detect objects by emitting sound waves and measuring the time it takes for the echoes to return. This non-contact method relies on the echo principle:

- Sound Wave Emission: The sensor transmits ultrasonic sound waves, which travel through the air.
- Object Interaction: These waves continue until they encounter an object, causing them to reflect.
- Echo Reception: The sensor detects the reflected waves, known as echoes.
- Distance Calculation: By measuring the time elapsed between the emission and reception of the sound waves, and knowing the speed of sound in air, the sensor calculates the distance to the object. This process enables the sensor to accurately determine This technology is implemented in a wide range of applications, including determining fluid levels, detecting the presence of objects, and assisting in automotive functions like parking assistance and collision avoidance. And return, the distance can be determined, as the speed of sound in air is a known constant.

**Distance Calculation:** The distance between the sensor and the obstacle is calculated using the formula: Distance=Time×Speed of Sound2\text {Distance} = \frac{{\text {Time} \times \text{Speed of Sound}}}{2}Distance=2Time×Speed of Sound • Time: The total time for the waves to travel to the obstacle and return. • Speed of Sound: Approximately 343 m/s in air at room temperature. The division by 2 accounts for the round-trip travel time, providing the one-way distance to the obstacle.

### 8.4 Rain Sensor:

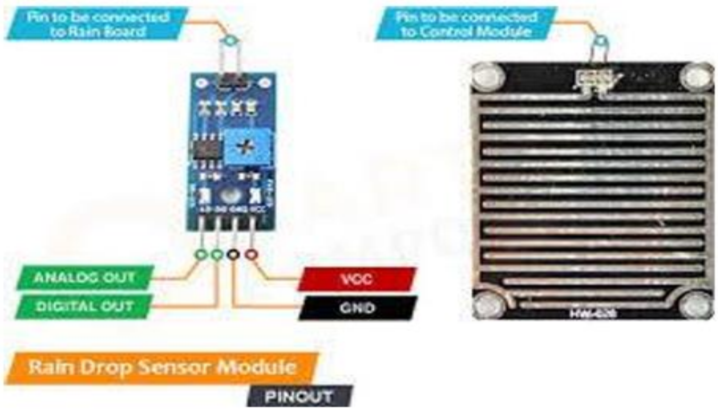


**Figure: Rain Sensor**

A rain sensor, an electronic component designed to detect water presence or measure moisture levels, finds diverse applications in fields like weather tracking, automated irrigation, and vehicle windshield wipers. In an Automated Dry and Wet Garbage Segregation and Monitoring System, this sensor is vital for determining waste moisture content, thereby aiding in the classification of waste as either biodegradable (wet) or non-biodegradable

Core Attributes: Operational Voltage: Functions within a 3.3V to 5V DC power range.
Output Modalities: Provides both analog and digital output signals.
Enhanced Sensitivity: Exhibits the capability to precisely detect moisture on its sensing surface.

Operational Mechanism: The sensor incorporates a sensing grid composed of exposed conductive pathways. Upon contact with water or moisture, a conductive bridge forms between these pathways, modifying the electrical resistance and generating a correlated output signal.

Analog Output Functionality: The sensor generates a continuous voltage output that directly corresponds to the detected moisture quantity. Elevated moisture levels lead to reduced resistance, resulting in a higher analog voltage output. This feature facilitates the measurement of varying degrees of wetness.

Digital Output Functionality: The sensor delivers a binary output signal (HIGH or LOW) based on a predetermined moisture threshold. When the moisture level surpasses the threshold, the output transitions to LOW, signifying the presence of water. Conversely, if the moisture level remains below the threshold, the output remains HIGH, indicating dry conditions.

Working Process:
1. Exposure: The sensor's detection surface is positioned within the waste container, directly exposed to the accumulating refuse.
2. Moisture Interaction: When biodegradable, moist waste makes contact with the sensor's conductive grid, the moisture acts as a conductor, creating a pathway between the sensor's conductive lines, and subsequently decreasing the electrical resistance.
3. Signal Conversion: The integrated control circuitry translates the detected resistance variation into either an analog voltage level, reflecting the degree of moisture, or a binary digital signal, indicating the presence or absence of moisture above a defined threshold.
4. Microcontroller Analysis: The ESP32 microcontroller receives the generated signal (analog or digital) and executes programmed algorithms to interpret the data. Based on the signal's value, the microcontroller determines whether the waste material is categorized as wet or dry.

# IX. MODELING AND ANALYSIS

## 9.1 Design of Hardware

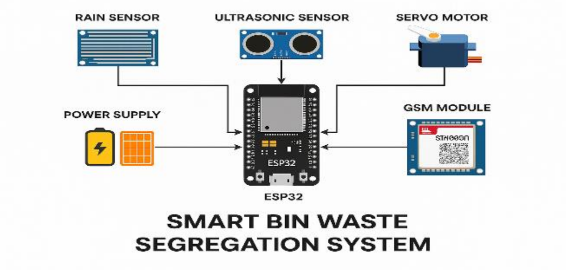


**Figure: Design of Hardware**

## 9.2 Working Model Photos


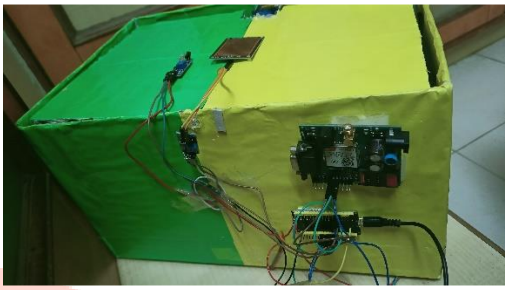

**Figure: Working Model Photos**

# X. CONCLUSION

The Dry and Wet Garbage Segregation and Monitoring System is a comprehensive and innovative solution designed to enhance waste management efficiency through automation and real-time monitoring. By integrating moisture-based waste classification, ultrasonic fill-level detection, and GSM-based notifications, the system significantly reduces manual effort, minimizes sorting errors, and ensures timely waste disposal The automated segregation mechanism efficiently classifies waste into dry and wet categories, ensuring accurate sorting and reducing contamination. The real-time monitoring feature prevents bin overflow, maintaining cleanliness and hygiene in public and residential areas. Additionally, the GSM-based alert system optimizes waste collection schedules, reducing unnecessary trips and lowering operational costs. This project not only streamlines waste management processes but also contributes to environmental sustainability by promoting efficient recycling and composting. Its scalability and IoT integration make it an ideal solution for smart cities, allowing authorities to remotely monitor and manage waste collection. With potential enhancements such as solar-powered operation and mobile app integration, the system can further improve efficiency and sustainability.

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