# Design and Implementation of Smart Waste Segregation and Monitoring System Using IOT

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## ABSTRACT

Rapid urbanization and population growth have resulted in a significant increase in solid waste generation, leading to environmental and health concerns. Conventional waste management systems are inefficient, labor-intensive, and lack real-time monitoring. This paper proposes a Smart Waste Segregation and Monitoring System using Internet of Things (IoT) technology to address these issues. The system automatically segregates waste into biodegradable and non-biodegradable categories using sensors and a microcontroller. Ultrasonic sensors monitor the fill level of waste bins, and real-time data is transmitted via Wi-Fi to a centralized monitoring platform. This enables timely waste collection, prevents overflow, improves recycling efficiency, and reduces environmental pollution. The proposed system supports sustainable waste management and contributes to the development of smart cities.

**Keywords:** Internet of Things (IoT), Smart Waste Management, Waste Segregation, Ultrasonic Sensor, Smart City, Environmental Sustainability

## INTRODUCTION

Rapid urbanization, population growth, and changing consumption patterns have led to a significant increase in municipal solid waste generation worldwide. Inefficient waste management practices pose serious environmental, economic, and public health challenges, including land pollution, greenhouse gas emissions, and the spread of diseases. One of the major limitations of conventional waste management systems is the absence of source-level waste segregation and real-time monitoring, resulting in poor recycling efficiency and increased operational costs.

Waste segregation at the source is a critical step toward sustainable waste management, as it enables effective recycling, composting, and safe disposal of waste. However, manual segregation is labor-intensive, time-consuming, and prone to human error. Additionally, traditional waste collection systems follow fixed schedules without considering the actual fill level of waste bins, leading to overflow, inefficient collection routes, and unnecessary fuel consumption.

To address these challenges, this research proposes a Smart Waste Segregation and Monitoring System using Internet of Things (IoT) technology. The proposed system integrates sensors, microcontrollers, and wireless communication modules to automatically segregate waste into biodegradable and non-biodegradable categories while continuously monitoring the fill level of waste bins. Sensors such as moisture, inductive, ultrasonic, and infrared sensors are used to identify waste type and bin status. The collected data is transmitted to a cloud-based platform, enabling real-time monitoring and decision-making by municipal authorities.

The implementation of IoT in waste management enhances operational efficiency, reduces human intervention, and supports data-driven planning. The system helps optimize waste collection schedules, minimizes overflow conditions, and promotes environmentally sustainable practices. Moreover, it aligns with smart city initiatives

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and global sustainability goals by reducing pollution, improving resource utilization, and encouraging responsible waste handling.

This research demonstrates that the proposed smart waste segregation and monitoring system provides a scalable, cost-effective, and reliable solution for modern waste management challenges, making it suitable for deployment in urban as well as semi-urban environments.

# METHODOLOGY

**Block Diagram**

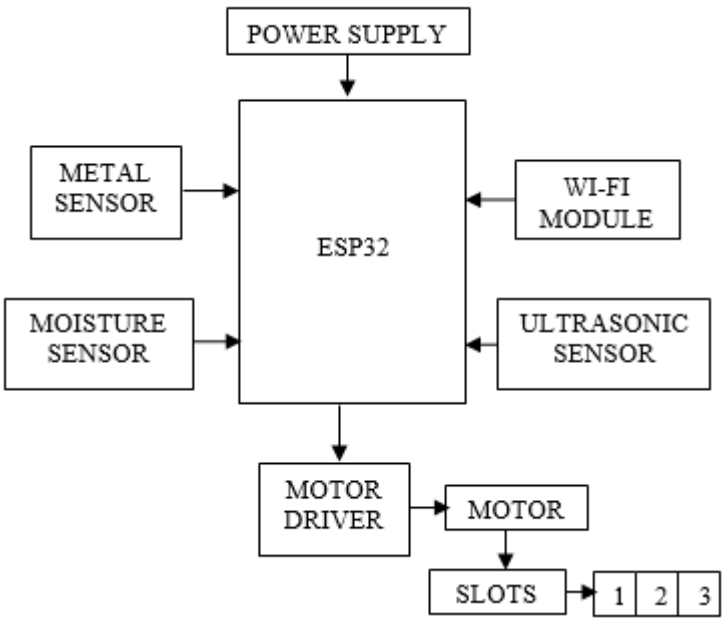


Fig.1 **Block Diagram**

**Working**

The Waste Segregation System using ESP32 works on the principle of sensor-based detection and automatic sorting of waste into three categories metallic, wet and dry using an inelegant decision process controlled by the ESP32 microcontroller. When the system is switched ON using the battery and switch, the ESP32 initializes all connected sensors ultrasonic, metal and moisture sensors and the servo motor(SG90). The system connects to the Wi-Fi network for data transmission to the ThingSpeak cloud platform The ultrasonic sensor is positioned at the top of the bin to detect when someone throws waste into the bin. When the ultrasonic sensor detects an object within a specific distance (waste presence), it triggers the waste segregation process. Once the waste is detected, the metal sensor checks if the material is metallic. If metal is detected, the waste is classified as metallic waste.

If no metal is detected the moisture sensor measures the moisture level of the waste. A high moisture value indicates wet waste, while a low moisture value indicates dry waste. Based on the type of waste detected, the ESP32 sends a command to the sensor motor to rotate the rotating disk below the main bin. The disk rotates to a specific angle that aligns the waste outlet with one of the three bins: 0→Metal bin

90→ Wet Bin

180→Dry Bin

The waste then falls into the correct bin for proper disposal. The ESP32 sends the sensor readings (metal detection status, moisture value, ultrasonic distance) to the ThingSpeak cloud. This allows real-time monitoring and analysis of waste type and activity through an online dashboard. After completing one sorting cycle, the servo motor returns to its default position. The system then waits for the next waste detection event, continuing

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the process automatically. This automated process ensures efficient, hygiene and intelligent waste segregation, minimizing human involvement and supporting smart city and sustainability initiatives.

**Hardware Details**

**Microcontroller:**

**Fig.2 Microcontroller**

Acts as a main controller of the system. Processes sensor data and control the servo motor. Sends collected data to the ThingSpeak cloud platform for monitoring. Here we use ESP32 model of microcontroller.

Operating Voltage: 3.0-3.3V

Power Input (USB):5V

GPIO Voltage: 3.3V max (SV NOT allowed)

Wi-Fi Frequency: 2.4 GHz

Flash Memory: 4MB (typical)

Operating Temperature: -20°C to 70°C

**Servo Motor:**

**Fig.3 Servo Motor**

Controls the rotation of a disk mechanism placed below the bin. Rotates to different angles to direct the waste into the appropriate bin (metal, dry and wet). Here we use SG90 type of servo motor.

Operating Voltage: 4.8-6V

Current (no load):100-250 mA

Torque: 1.8-2 kg.cm

Signal Voltage: 3.3V

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**Metal Sensor**

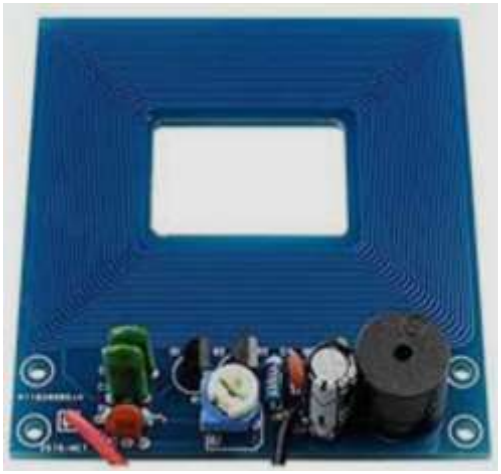

**Fig.4 Metal Sensor**

Detects metal objects (like cans, foils or bottle caps) when thrown into the dustbin. Helps the system separate metal waste from non-metal waste automatically.

Operating Voltage: 5V most metal sensors

Output Type: Digital (HIGH/LOW)

Output Voltage: OV-5V (use voltage divider for ESP32 3.3V input)

Current Consumption:10-20 mA

Detection Range: 1-3 cm

Operating Temperature 0°C to 50

**Moisture Sensor**

**Fig.5 Moisture Sensor**

Differentiate between wet waste (like food, vegetable peels) and dry waste (like paper, plastic)

Operating Voltage: 3.3-5V

Analog Output Range: 0-3.3V (safe for ESP32)

Current Consumption: 5-25 mA

Working Principle Resistance between the two electrodes Recommended Threshold<2000 = wet (as per your code)

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**Ultrasonic Sensor**


**Fig.5 Ultrasonic Sensor**

The Ultrasonic sensor detects the presence of a person's hand (or any object) near the dustbin. When something comes close, it sends a signal to the microcontroller to open the lid automatically.

Operating Voltage: 5V required

Trigger Voltage: 5V (ESP32 can output 3.3V and it still works)

Echo Voltage:65V must be reduced to 3.3V (use a divider!)

Current Draw: 15 mA

Range: 2 cm to 400 cm

Frequency: 40 kHz

**Wi-Fi Module**


**Fig.6 Wi-Fi Module**

It consists of the router which will provide the internet facilities to the user for dumping trash into the bin

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**Flowchart**

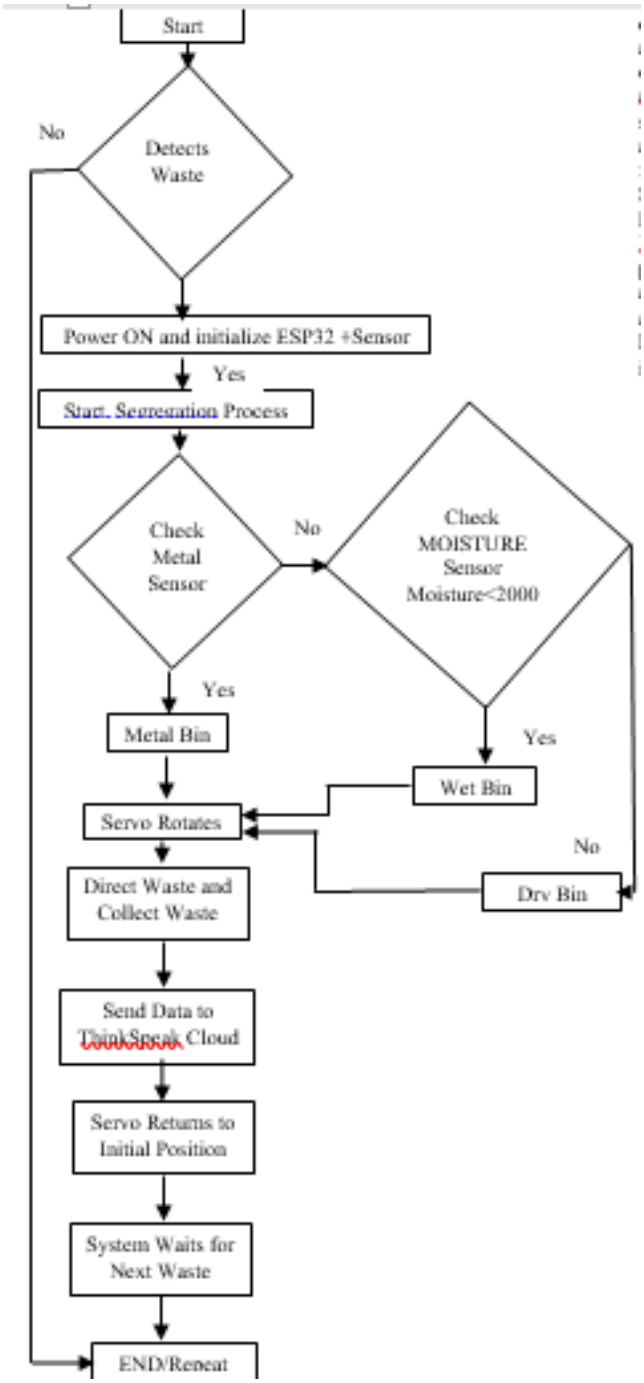


Fig.7 Flowchart

## RESULT

The smart waste segregation and monitoring system operates by integrating IoT-enabled sensors, microcontrollers, and segregation mechanisms into waste bins. When waste is deposited, sensors such as moisture sensors, gas sensors, analyse its type-whether dry, wet and metal. Based on the sensor readings, a microcontroller processes the data and activates a mechanical system (such as a conveyor belt or flap) to direct the waste into the appropriate compartment. Simultaneously, ultrasonic or weight sensors monitor the fill level of each compartment in real time. This data is sent via IoT modules (like Wi-Fi or GSM) to a central server or cloud platform, where it can be accessed by waste management authorities through a web or mobile interface. This automated, sensor-driven approach ensures efficient waste handling, real-time monitoring, and reduced human involvement.

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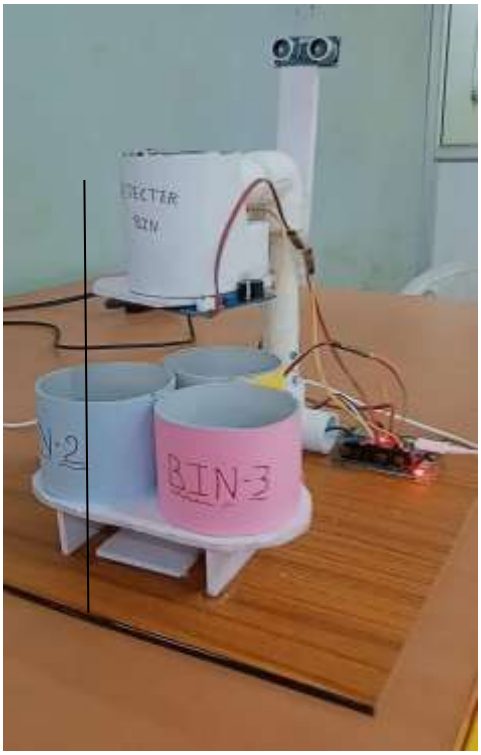


**Fig.8 Smart waste segregation system**

## CONCLUSION

Improper disposal and improper maintenance of domestic waste creates issues in public health and environment pollutions thus this paper attempts to provide practical solution towards managing the waste collaborating it with the use of IoT i.e. Providing free internet facilities for a specific time once the trash is dumped into the bin. The proposed system will be finitely help to overcome all the serious issues related to waste and keep the environment clean..

### Future Scope

The moisture sensor can be implemented hand in hand with the other sensors and the compartments for segregating the dry and wet waste can be created which will solve the issues related to waste segregation.

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