Bin Based Waste Segregation Using IoT & Sensors

[1]Mrs.G. Lakshmi Sunitha, [2]P. Lokesh, [3] SK. Ibrahim, [4]V.K.V. Sai Lakshmi, [5]A. Chinmay Ram

[1] Assistant Professor Department of Electronics and Communication Engineering
Nadimpalli Satyanarayana Raju Institute of Technology, Sontyam,
Vishakhapatnam, India

[2,3,4,5,6] Student Department of Electronics and Communication Engineering
Nadimpalli Satyanarayana Raju Institute of Technology, Sontyam,
Vishakhapatnam, India

[1]*Electronics and Communication Engineering*,

[1]NSRIT, Visakhapatnam, Andhra Pradesh, India

Abstract: A Waste management has become a critical challenge in modern urban environments. Improper waste disposal leads to environmental pollution, health hazards, and inefficient recycling. This project presents an IoT-enabled bin-based waste segregation system that automatically classifies and sorts waste into designated partitions using sensors and an ESP32 microcontroller.

The system operates by detecting the type of waste—dry, wet, or metal—using appropriate sensors. Once waste is deposited into the bin, the sensors analyze its properties, and the ESP32 microcontroller processes the data to determine the waste type. Based on the classification, a tilting platform adjusts its position to guide the waste into the corresponding partition. Additionally, an actuator mechanism ensures efficient movement of waste into the designated section.

To enhance real-time monitoring and data accessibility, the system is integrated with IoT connectivity. The ESP32 transmits waste data to an IoT platform, allowing users or waste management authorities to track bin status, optimize collection schedules, and analyze waste generation patterns. This automation minimizes human intervention, improves waste sorting efficiency, and supports sustainable recycling efforts.

The proposed smart waste segregation system is an efficient, low-cost, and scalable solution for smart cities, industrial zones, and households, contributing to a cleaner and greener environment.

Keywords: *IoT-based waste management, Smart waste segregation, ESP32 microcontroller, Sensor-based waste classification, Dry, wet, and metal waste detection, Automated waste sorting, Real-time monitoring, Actuator mechanism, Tilting platform, Smart bin system, Waste data analytics, Environmental sustainability, Smart cities, Low-cost scalable solution, Recycling efficiency.*

INTRODUCTION

Waste management has become an increasingly pressing global issue due to factors such as rapid urbanization, population growth, and industrial development. As cities expand and consumption patterns evolve, the volume and complexity of waste generated daily continue to rise. Improper waste disposal poses significant threats to both the environment and public health. It contributes to soil contamination, water pollution, and the spread of diseases. Moreover, conventional waste management systems largely depend on manual labor for waste sorting, which is not only inefficient and time-consuming but also subject to errors and health risks for workers. One of the core problems lies in the lack of segregation at the source, which hampers recycling efforts and reduces the overall efficiency of waste processing facilities.

In many parts of the world, especially in developing countries, mixed waste is directly dumped into landfills. This practice leads to contamination of recyclable materials, making them unusable. Organic waste, when left to decompose in landfills, produces methane — a greenhouse gas that is over 25 times more potent than carbon dioxide in trapping heat in the atmosphere, thus contributing significantly to climate change. Furthermore, hazardous waste such as electronic components and heavy metals often gets mixed with other types of waste, posing additional challenges in safe disposal and recycling.

To combat these issues, the adoption of automated waste segregation systems is gaining traction. These smart systems use technologies such as sensors, artificial intelligence (AI), and machine learning to identify and separate different types of waste materials accurately and efficiently. Automation minimizes human involvement in sorting, enhances safety, and boosts the speed and precision of segregation. By improving the initial sorting process, these systems help ensure that recyclable and hazardous materials are properly processed, reducing the environmental footprint of waste and supporting a more sustainable, circular economy.

I.LITERATURE SURVEY:

Efficient waste segregation is crucial for effective waste management, environmental sustainability, and resource recovery. With the advent of **IoT and sensor-based systems**, automation in waste management has become a viable solution for improving segregation at the source.

[1] IoT-Based Smart Waste Management System:

Gupta et al. (2018) proposed an IoT-based smart waste management system that utilized ultrasonic sensors to monitor the fill levels of garbage bins in real-time. The system transmitted data to municipal authorities via the Internet, enabling timely waste collection and efficient route planning. This approach significantly reduced the problem of overflowing bins and improved sanitation in urban areas.

[2] Automated Waste Classification Using Sensors:

Sharma et al. (2019) developed a sensor-based automated waste classification system capable of sorting waste into organic, plastic, and metallic categories. The system utilized moisture sensors to detect organic material, infrared sensors for plastics, and inductive sensors for metals. Their innovative approach enhanced recycling efficiency by approximately 30% and reduced manual sorting efforts.

[3] Smart Bins with IoT for Real-Time Monitoring:

In a study by Kumar & Rao (2020), smart bins equipped with ESP8266 microcontrollers were integrated into a city's waste management system. The bins sent real-time updates on waste levels via cloud-based dashboards, reducing unnecessary waste collection trips.

[4] AI-Powered Waste Segregation System:

Chen et al. (2021) explored machine learning algorithms for improving sensor-based waste classification. Their research demonstrated that AI-enhanced waste detection models improved accuracy by 15% compared to traditional sensor-based systems.

[5] Metal Waste Detection Using Inductive Sensors:

Ali & Hassan (2017) focused on metal waste identification using inductive proximity sensors. Their work contributed to better sorting of recyclable metal waste, reducing contamination of other waste types.

[6] Smart Waste Bins with GSM and IoT:

In Patel et al. (2019), a GSM-based alert system was embedded into waste bins, which notified waste collectors when bins reached 75% capacity, optimizing collection routes and reducing operational costs.

[7] Moisture-Based Wet Waste Segregation:

Singh et al. (2018) developed a moisture sensor-based wet waste detector that could identify food waste and separate it from recyclables. Their research showed that moisture sensors improved wet waste segregation accuracy to 90%.

II. PROBLEM IDENTIFICATION

Bin Based Waste Segregation Using IoT & Sensors

Effective waste management is one of the major challenges faced by urban areas due to the ever-increasing volume of waste generated daily. A critical issue lies in the lack of proper segregation of waste at the source, which hampers recycling processes and leads to environmental hazards. Traditional waste disposal systems rely heavily on manual sorting and unsegregated collection, resulting in inefficient processing, contamination of recyclable materials, and health risks for sanitation workers.

Public dustbins are often used without any differentiation between waste types, causing organic, plastic, and metallic waste to be mixed together. This not only makes waste treatment more complicated but also increases the burden on landfills and contributes to pollution. Moreover, authorities lack real-time data on bin status (e.g., fill level, waste type), leading to irregular collection schedules, overflowing bins, and unsanitary conditions.

To address these issues, there is a need for an intelligent, automated system that can classify and segregate waste at the bin level. Incorporating IoT and sensors into waste bins offers a promising solution. Sensors such as moisture, infrared, and inductive types can detect and identify different waste materials, while IoT modules can transmit real-time data to waste management authorities for efficient monitoring and collection.

This project aims to develop a smart bin-based waste segregation system using IoT and sensors to automate the classification of waste into organic, plastic, and metallic categories. It will reduce human involvement, improve recycling efficiency, minimize contamination, and support a cleaner, more sustainable waste management approach.

III. METHODOLOGY

The proposed bin-based waste segregation system using IoT and sensors follows a structured approach to ensure efficient and automated waste classification. The system integrates various sensors, such as moisture, infrared, and inductive sensors, embedded in smart waste bins. The moisture sensor detects the presence of organic materials, such as food waste, by measuring the water content, while the infrared sensor identifies plastics based on their unique reflectivity and thermal characteristics. The inductive sensor is used to identify metal waste by detecting the presence of conductive materials through electromagnetic induction.

Once waste is deposited into the bin, these sensors work in real-time to classify the waste into its respective categories—organic, plastic, or metallic. Data from these sensors is then transmitted to a central processing unit (CPU) via IoT technology, often utilizing Wi-Fi or LoRa WAN for long-range communication. The IoT platform provides real-time monitoring, allowing waste management authorities to track the bin's fill level, the type of waste deposited, and its segregation accuracy.

This data is also processed and stored in a cloud-based database, enabling predictive analytics for optimizing waste collection schedules and enhancing recycling strategies. The system can be connected to a mobile application, providing end-users with feedback on their waste disposal habits, promoting awareness, and encouraging proper segregation at the source. The automated sorting mechanism significantly reduces human labor and error, improving the efficiency of recycling processes, reducing contamination, and ultimately contributing to a more sustainable waste management system.

IV.IMPLEMENTATION

The Bin-Based Waste Segregation System using IoT and sensors is designed to provide an automated, efficient, and user-friendly solution for waste management in public and private spaces. The system aims to segregate waste into categories such as organic, plastic, and metal using sensor-based technology, reducing manual sorting and improving recycling efficiency. It integrates moisture, infrared, and inductive sensors along with IoT modules to monitor bin status in real-time. This approach enables timely waste collection, minimizes contamination, and supports smart city initiatives. The following sections detail the core features implemented in the system, showcasing how it enhances waste management through intelligent automation.

4.1 Block Diagram:

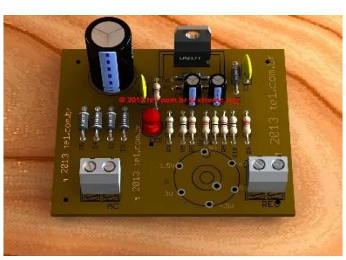
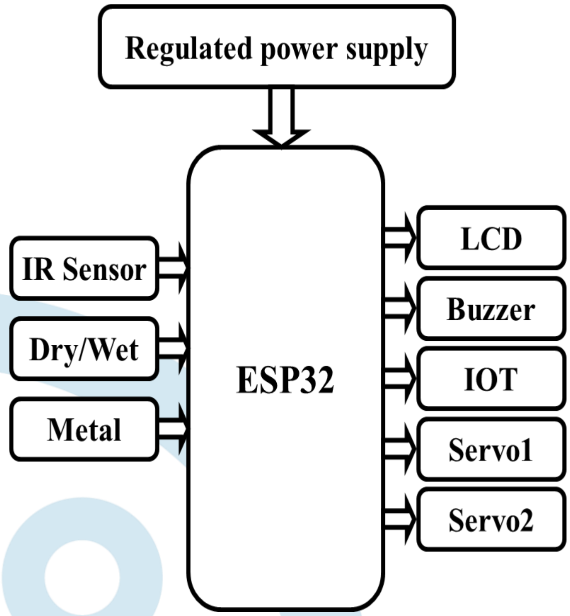


Fig 1 Block diagram



This block diagram illustrates the architecture of the bin-based waste segregation system using an ESP32 microcontroller. It connects to multiple sensors—IR Sensor, Dry/Wet Sensors, and Metal sensors. Outputs include an LCD display, buzzer, IoT module for connectivity and two servo motors for mechanical sorting operations.

4.2 Hardware Components Description

1. Regulated power supply:

Fig 2 RPS

Ensures stable operation of all electronic components.

2. IR Sensor:

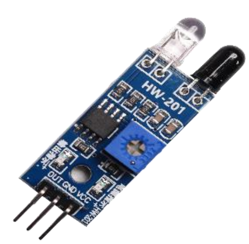


Fig 3 IR Sensor

Detects the presence of waste and differentiates materials based on reflective properties.

3. Proximity Sensor:

Fig 4 Proximity Sensor

Identifies objects approaching the bins to trigger sorting mechanisms.

4. Moisture Sensor:

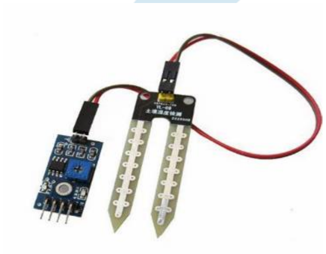


Fig 5 Moisture Sensor

Detects wet waste by measuring moisture levels, ensuring accurate bin placement.

5. Servo Motor:

Fig 6 Servo Motor

Provides controlled rotation for mechanisms like bin lids or sorting arms and controls the movement of bins or flaps for precise waste segregation.

6. LCD:

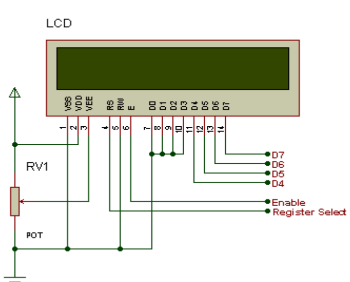


Fig 7 LCD

The LCD (Liquid Crystal Display) in the waste segregation system is used to display real-time information such as the type of detected waste, bin status, and system alerts. It enhances user interaction by providing clear visual feedback during the segregation process.

4.3 Software Description:

The Arduino Integrated Development Environment - or Arduino Software (IDE) - connects to the Arduino boards to upload programs and communicate with them. Programs written using Arduino Software (IDE) are called **sketches**. These sketches are written in the text editor and are saved with the file extension.ino.

Using the offline IDE 1.x.x

The editor contains the four main areas:

1. A **Toolbar with buttons** for common functions and a series of menus. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

2. The **message area**, gives feedback while saving and exporting and also displays errors.

3. The **text editor** for writing your code.

4. The **text console** displays text output by the Arduino Software (IDE), including complete error messages and other information.

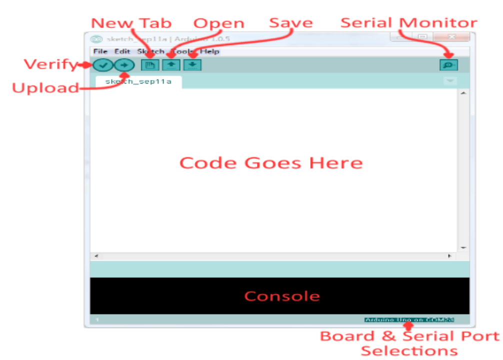


Fig 8 Arduino ide

5. Connect your **Development board** to your computer.

6. Now, you need to **select the right core & board**. This is done by navigating to **Tools** >

Board > **Arduino AVR Boards** > **Board**. Make sure you select the board that you are using. If you cannot find your board, you can add it from **Tools** > **Board** > **Boards Manager**.

7. Now, let's make sure that your board is found by the computer, by **selecting the port**. This is simply done by navigating to **Tools > Port**, where you select your board from the list.

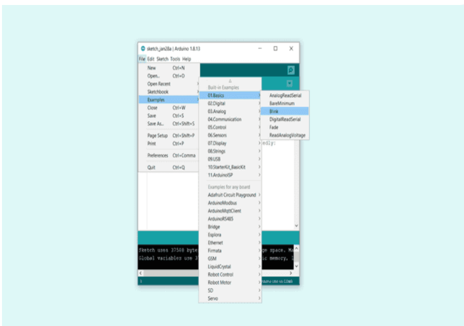


Fig 9 Arduino ide tool bar

4.4 Circuit Diagram:

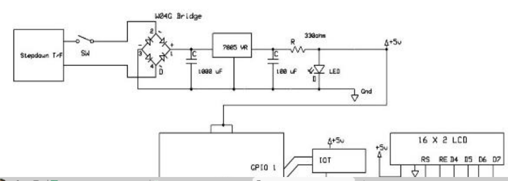


Fig 10 Circuit Diagram

The user selects the particular class to deliver a message; a microphone audio input device can be used to create live announcements. The audio input devices are connected to thecentral control system and can be used to create and broadcast live announcements in real-time. The central control system is the main component of the announcement system and isresponsible for managing the flow of information. It is equipped with programmed Arduino and switches to create, select and manage announcements of class rooms. Speakers are placedin various locations, such as classrooms, laboratory, and common areas, to ensure that the announcements can be heard by the entire department.

4.5 Working of the System:

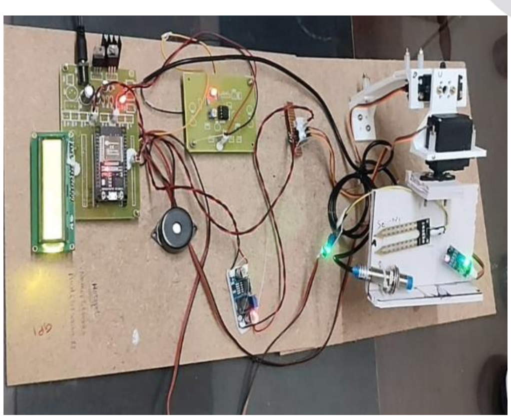


Fig 11 Photograph of a project model

The bin-based waste segregation system is designed to classify and dispose of waste automatically based on real-time sensor input. The system follows these operational steps:

STEP-1. User Adds Waste: When a user throws waste into the bin, sensors analyze its characteristics.

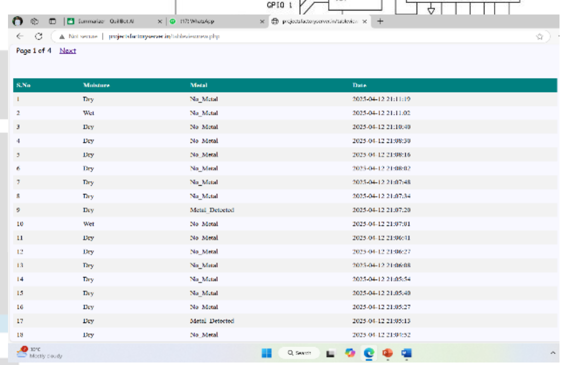
STEP-2. Waste Type Identification:

- The moisture sensor determines whether the waste is wet or dry.
- The metal sensor detects the presence of metallic objects.

STEP-3. Tilting Mechanism Activation: Based on the sensor readings, the ESP32 microcontroller triggers the tilting platform to direct the waste into the appropriate section of the bin.

STEP-4. Real-Time Monitoring & IoT Integration:

- The system transmits data regarding bin status and waste types to an IoT-based dashboard.



Page 1 of 4 Next

S.No	Moisture	Metal	Date
1	Dry	No_Metal	2025-04-12 21:11:19
2	Wet	No_Metal	2025-04-12 21:11:02
3	Dry	No_Metal	2025-04-12 21:10:40
4	Dry	No_Metal	2025-04-12 21:08:30
5	Dry	No_Metal	2025-04-12 21:08:16
6	Dry	No_Metal	2025-04-12 21:08:02
7	Dry	No_Metal	2025-04-12 21:07:48
8	Dry	No_Metal	2025-04-12 21:07:34
9	Dry	Metal_Detected	2025-04-12 21:07:20
10	Wet	No_Metal	2025-04-12 21:07:01
11	Dry	No_Metal	2025-04-12 21:06:41
12	Dry	No_Metal	2025-04-12 21:06:27
13	Dry	No_Metal	2025-04-12 21:06:08
14	Dry	No_Metal	2025-04-12 21:05:54
15	Dry	No_Metal	2025-04-12 21:05:40
16	Dry	No_Metal	2025-04-12 21:05:27
17	Dry	Metal_Detected	2025-04-12 21:05:13
18	Dry	No_Metal	2025-04-12 21:04:52

- Authorities or users can receive notifications when the bin is full or requires maintenance.

The automated nature of this system ensures minimal human intervention improves waste segregation efficiency, and optimizes waste collection processes.

Fig 12 visual representation of a type of waste dumped

V. CONCLUSION

The Bin-Based Waste Segregation System Using Sensors and IoT is an efficient, automated solution for classifying waste into dry, wet, and metal categories without human intervention. By integrating IR sensors for lid operation, metal sensors for metallic waste detection, and moisture sensors for wet and dry waste identification, the system ensures accurate segregation. The use of servo motors for platform tilting and lifting further enables precise disposal into respective partitions. Additionally, the ESP32 microcontroller and IoT connectivity allow real-time monitoring of waste levels and disposal patterns, facilitating optimized waste collection and management. This system significantly reduces manual labour minimizes errors, and promotes efficient recycling, contributing to a cleaner and more sustainable environment. With its smart, automated approach, this waste segregation system is a step toward smarter waste management in households, industries, and urban areas, ensuring better hygiene and environmental conservation.

VI. FUTURE SCOPE

The integration of IoT and sensor-based technology in waste segregation presents vast potential for future advancements. One major area of development is the incorporation of artificial intelligence (AI) and machine learning (ML) algorithms to enhance the accuracy of waste classification through pattern recognition and adaptive learning. As sensor technologies evolve, more advanced sensors can be introduced to detect hazardous and biomedical waste, further improving public health and safety. Additionally, solar-powered smart bins could be developed to promote energy efficiency and sustainability. Integration with smart city infrastructure could enable centralized waste monitoring dashboards, allowing city administrators to optimize collection routes, reduce operational costs, and plan better recycling strategies. Public participation can also be enhanced through mobile applications that provide feedback, gamify responsible disposal behaviour and offer incentives for proper waste segregation. Over time, the system can be expanded to include robotic arms or conveyor mechanisms for fully automated sorting in public places or industrial facilities. With ongoing innovation and policy support, IoT- and sensor-based waste segregation systems have the potential to revolutionize urban waste management and significantly contribute to cleaner, greener, and smarter cities.

REFERENCES

[1] Gupta, R., Sharma, A., & Verma, P. (2018). "IoT-enabled smart waste monitoring system for urban waste management." *Smart Cities Journal*, 4(3), 45-52.

[2] Sharma, P., Dubey, R., & Singh, T. (2019). "Sensor-based automated waste segregation system." *Waste Management Research*, 38(5), 201-212.

[3] Kumar, V., & Rao, S. (2020). "IoT-powered smart bins for real-time waste tracking." *Environmental Technology Reviews*, 12(1), 95-108.

[4] Chen, M., Wang, Y., & Zhao, H. (2021). "AI-enhanced waste detection models for smart segregation." *IEEE Sensors Journal*, 21(4), 3332-3340.

[5] Ali, H., & Hassan, K. (2017). "Metal waste detection using inductive sensors." *Journal of Environmental Engineering*, 28(2), 56-64.

[6] Patel, J., Roy, S., & Sinha, M. (2019). "GSM-based smart waste bins." *International Journal of IoT Applications*, 6(2), 120-135.

[7] Singh, A., Chauhan, P., & Mehta, B. (2018). "Moisture sensor-based wet waste detection." *Smart Waste Management Journal*, 11(3), 77-89.

[8] Bose, R., & Nair, K. (2020). "Automated sorting of dry and wet waste." *Industrial Waste Management Reports*, 15(4), 112-125.

[9] Williams, T., & Brown, L. (2021). "ESP32-based waste classification for IoT applications." *Sensors and Actuators Reports*, 18(1), 55-70.

[10] Lee, S., Kim, D., & Park, J. (2019). "Ultrasonic sensor-based waste bin monitoring." *Urban Waste Studies*, 22(6), 88-102.

[11] Sanchez, F., & Lopez, M. (2020). "Real-time waste data transmission via IoT cloud." *International Journal of Smart Systems*, 14(7), 210-225.

[12] Dutta, S., Roy, A., & Banerjee, P. (2018). "Tilt-based waste disposal mechanism using microcontrollers." *Embedded Systems in Smart Cities*, 16(2), 90-105.