IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 2, April 2025

Impact Factor: 7.67

Smart Waste Segregation and Monitoring System using IoT

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Abstract: *The amount of waste has been increasing due to the increase in human population and urbanization. In cities, the overflowed bin creates an unhygienic environment. Thus degrades the environment, to overcome this situation "Automatic Waste Segregator" is developed to reduce to work for the ragpickers the wastes are segregated by the human beings which leads to health problems to the workers. The proposed system separates the waste into three categories namely wet, dry and metallic waste. This developed system is not only cost efficient also makes the waste management productive one. Each of the wastes are detected by the respective sensors and gets segregated inside the bins which is assigned to them the details of amount of waste disposal are updated in the server regularly.*

Keywords: Dry waste ,Wet waste , Garbage collector , Waste Management , Smart Bin , Waste Level Detection

I. INTRODUCTION

However, due to rapid increase in populations and escalating solid wastes caused by it, waste management has become a very serious issue within urban areas. Furthermore, the traditional method of waste collection lacks monitoring, leading to overflow of bins, wrong segregation, and increment in expenditure in operation due to inefficient waste segregation and possible wrong disposal.

This research introduces a Smart Waste Segregation and Monitoring System Using IoT as a possible solution to such identified problems. The automated waste classification system enables the monitoring of waste levels in collection bins as it also incorporates the Internet of Things (IoT) technology. Different types of waste are detected and sorted-as source segregation- biodegradable from non-biodegradable and recyclable-waste by incorporating machine learning algorithms and sensors. The real-time data include information on bin capacity collected through IoT-enabled sensors hence optimizing the waste collection schedule while reducing trips to collection points by waste management authorities.

This system is expected to increase efficiency in waste disposal, inculcate sustainable efforts, and minimize pollution to the environment. Waste management municipalities by IoT based monitoring can bring forth data-driven possible effective waste management care in perfect cleaner cities and a healthier environment.

In addition, this system automates the waste segregation process and thus encourages the sustainable disposal of waste with efficient recycling programs. With IoT integration, there is remote monitoring and analytics for predictive maintenance, enabling municipalities and waste management authorities to make informed decisions based on real-time insights. The research typically was conducted to build this intelligent environment, eco-friendly as well as economically efficient waste management system contributing to cleaner cities, public health, and the environment as a whole.

of waste sorting and disposal management. In a conventional waste management mechanism, waste is collected, transported, and sorted by humans at recycling centres or landfills. Such an arrangement quite frequently leads to contamination, inefficiency, and loss of recyclable materials.

Smart waste segregation systems, as opposed to the former, automated, and enhanced the segregation process for more accurate and efficient work. For instance, IoT-enabled waste bins are provided with sensors that can monitor in real-

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time the type and amount of waste being disposed of. These bins are able to monitor the changing composition of waste and provide information regarding the types of materials to assist in preventing contamination and improve sorting

1.1 Background and Importance of Waste Management

Very serious really, waste management is today one of the major problems encountered by modern urban centers as the population grows

The increasing population and industrialization in a country coupled with modern consumption patterns have become the most serious waste management problems in the cities. The way waste is managed poorly results in big disasters concerning the environment, health, and economy. It is estimated by the United Nations that over two billion people will be added to urban areas by 2050, meaning that 68% of the global population would live in urban areas. This would result in an increase in waste generation. Traditional waste management systems, reliant on manual sorting, disposal, and collection, have proved ineffectual in ensuring efficient recycling, reducing contamination, and achieving sustainability goals.

Perfect waste segregation proves to be one major step in landfill reduction, recycling improvement, and a circular economy. However, such process becomes a challenge because of human error, low public awareness, inadequate infrastructure, and contamination of recyclable waste. Currently, the requirement for an automated, accurate, and efficient waste segregation system has never been so pressing.

In this context, the integration of Internet of Things (IoT) technologies into waste management systems offers a new paradigm for transformation. IoT is a new technology that is rapidly finding its way into waste management systems to increase efficiencies while cutting operational costs, as well as promoting sustainability, through connecting physical devices to the internet and exchanging real-time data. Smart waste segregation and monitoring systems on IoT will improve the accuracy of sorting wastes, insights into the patterns of waste generation, and speed up the waste collection process.

1.2 The Concept of Smart Waste Segregation

Smart waste segregation is defined as the smart application of technologies like the Internet of Things, sensors, automated sorting, and machine learning for optimization accuracy overall.

The facility to operate right at the point of disposal is probably the greatest strength of smart waste segregation. Here users can separate waste directly into recyclables, organics, and non-recyclables. There are sensors with differentiated material detections, like plastic, paper, metal, or food waste and so.

1.3 IoT's Role in Smart Waste Monitoring and Management

IoT is key in smart waste segregation. IoT comprises sensors, devices, and connectivity networks allowing for real-time data collection and analysis. IoT can somehow help with the functioning of waste management services:

- Real-Time Monitoring of the Waste: With the IoT sensors installed in waste bins, it is possible to monitor the status, type, and level of waste bins in real-time by transmitting such data to a centralized system for larger waste monitoring authorities. This way, the authorities can monitor patterns of waste generation and optimize their schedules for collection. Thus, a bin would only get emptied when it's full, conserving fuel, incurring little operational costs, and minimally emitting carbon into the air from waste collection trucks.
- Smart Waste Bin: These smart waste bins facilitate the implementation of various sensors that detect the amount and type of waste disposal. By categorizing waste at the point of disposal, these smart bins assist in reducing contamination and ensuring that recyclables are kept separate from general waste. They can also send alerts when they become full and need collecting, thereby helping to enhance collection schedules and prevent overflowing bins.
- Optimizing through Data Analytics: The data collected by the IoT sensors can be analysed to determine trends concerning waste generation and disposal practice. This information would serve waste management authorities in determining how to optimize their collection processes, resource allocation, and in identifying

problem areas that would require public awareness or improvements in infrastructure. Furthermore, data analysis can also determine trends in waste contamination, guiding where educational or enforcement efforts may be warranted.

- Integration with Waste Treatment Facilities: The smart waste system can be integrated into the recycling facility, where IoT sensors monitor sorting and treatment. Automated sorting systems sort materials such as plastics, metals, and papers based on pre-defined criteria. Such systems will be constantly improved to enhance efficiency and accuracy in sorting, reduce human labour, and increase the volume of recyclables being processed.

1.4 Advantages of IoT-Based Smart Waste Segregation and Monitoring

The other advantages of IoT-based smart waste segregation for managing waste authorities or for the environment include:

a) Environment Benefits

- Recycling is Expected to Grow: Smart bins armed with IoT applications will enhance the recycling rate through accurate waste segregation at the disposal bin itself. More materials are prevented from being sent to landfills, which in turn must mitigate environmental pollution and conserve natural resources.
- Less Landfill Space: Proper segregation helps reduce the amount of waste sent to landfill sites, thus controlling environmental pollution and increasing landfill lifespan. Organic wastes, when separated for composting, further reduce greenhouse gas emissions from the landfills, especially methane.

Resource Recovery: Sorting and recycling valuable materials like metals, plastics and paper have facilitated a broader scope of IoT systems at the resource recovery level, thus linking them into a state-of-the-art circular economy, whereby materials are reused and repurposed instead of thrown away.

b) Economic advantages

Cost-Efficient: Thus, a better optimized waste collection route will lead the waste collection IoT-enabled system to an increased reduction in fuel used and labor costs required for waste collection.

Besides, better waste sorting lowers the cost of recycling operations since recycling streams are of higher quality with lower contamination rates.

Operational Efficiency: Real-time data on waste levels enables waste management authorities to deploy more efficient collection schedules and monitor fleet operations in real time. This ultimately results in more efficient use of resources reduced operational costs and missed pickups.

c) SOCIAL BENEFITS

Public Participation: The use of smart waste bins and instant feedback motivates them to actively participate in appropriate waste segregation. In reality, even easy and convenient processes generate a feeling of civic accountability toward waste disposal behavior in the hands of citizens' own.

Behavioral Change and Awareness: The data can be collected by IoT sensors to identify areas where education and outreach programs are needed to improve segregation styles in waste disposal practices. The current standards of waste generation can be used as the basis of tailoring public awareness campaigns to better address needs that vary across different neighborhoods.

II. LITERATURE SURVEY

Gupta, A., and Meena, A. (2018) - Suggested an IoT-based intelligent waste management system that uses sensors to measure garbage bin fill levels and sends real-time data to the municipal authorities to prevent the bins from overflowing and improve their efficiency.

Shah, K. et al. (2019) - Designed a waste segregation system that uses IoT in which sensors and microcontrollers automatically distinguish waste from biodegradable and non-biodegradable reducing manual sorting and thereby assisting recycling.

Patel, P., and Rathi, S. (2020) - Asserted a smart waste management system using the IoT sensors along with a mobile-based monitoring system, to detect the levels of bins and trigger alerts to higher authorities for the timely collection of waste, which in turn will lead to better responsiveness.

Li, H., and Zhang, Y. (2017) - Devoted their work to an energy-efficient technology for waste collection using IoT, in which optimized collection routes can save on decreased fuel consumption and operational costs in larger urban space.

Kumar, R., and Gupta, M. (2022) - Discussed the application of Artificial Intelligence in IoT-based management systems. This model uses the AI algorithm method for smart segregation and predictive analysis for waste, thereby enhancing the intelligence of the decision and operational capacity.

Patel, V., and Sharma, R. (2019) - Suggested that the waste management system, on a cloud basis, will assist smart cities in providing a centralized repository, real-time monitoring interface, extensibility and remote access that in return will improve coordination and smart governance.

Manisha Jayson and Lakshmi Hr. (2018) put forth SmartBen, an automatic system for differentiating and collecting refuse, using sensors and microcontrollers. In so doing, their model augments manual waste collection with automatic functioning, reduces the need for human intervention, and upholds hygiene in urban settings [7].

Jayshree Ghorpade et al. (2018) designed a model entitled Smart Dustbin, which gives importance to real-time garbage monitoring and automated waste collection. The object is to keep the society clean with timely disposal of waste and alerts via GSM as soon as the bin is filled [8].

Saurabh Dudhi et al. (2016) introduced an Efficient Waste Collection System with ultrasonic sensors interfacing with microcontrollers in order to measure the waste level. Their design focuses on optimizing the collection routes for waste management thereby reducing the unnecessary transportation expenses [9].

B.L. The raja and A.K. The raja (2005) provided the fundamentals with regard to electrical technologies underlying the design and implementation of automated systems such as smart bins and waste segregators. For understanding automation from an electrical perspective, their textbook is still a standard reference [10].

Subhasini Dwivedi et al. (2016) discussed an automatic waste segregator based on PLC, elucidating the merits of Programmable Logic Controllers in managing waste segregation with improved accuracy and reliability in industrial setups as well as urban scenarios [11].

Prof. B.S. Mayapur and Vani R. Puttan Hetti (2017) scrutinized an IoT-based waste management system for smart city applications. The system feeds the information from multiple bins by pushing real-time updates into a common platform, which would help in efficient waste collection and processing [12].

Sharanya A. et al. (2017) developed an Automatic Waste Segregator that utilizes IR and moisture sensors for dry and wet waste separation. Their method proves useful for the initial-level waste sorting, which stems into enabling recycling and disposal units for easy processing of the segregated waste [13].

Davide Anginal et al. (2016) presented a mathematical model for Optimal Planning of Door-to-Door Multiple Materials Separated Waste Collection. In their study, logistics and cost-efficiency on a large scale of waste collection are addressed by means of optimization algorithms [14].

K. Pardini et al. (2018) offers a new approach to Smart Waste Bin implementation based on real-time data and IoT systems for better garbage collection in large urban centers. This approach also aims to optimize collection schedules and to cut down on operational costs through smart monitoring.

R. Nikam proposed an IoT-based smart garbage system, which uses sensing of garbage levels and communicates to the authority, thereby facilitating the garbage collection process by reducing human efforts.

R. Batasi et al. (2020) worked on the Waste Separation Smart Dustbin, which uses IR and moisture sensors to automatically classify wet and dry waste types. The model advocates for sustainable waste practices by minimizing the burden of early-phase sorting.

P. Jajoo et al. developed a Smart Garbage Management System with real-time garbage level monitoring using Arduino and GSM technology and alert systems to optimize waste collection logistics.

In 2021, R. Khan et al. introduced an IoT-based Machine Learning system for predictive waste management. Their model predicts fill levels of bins and trends for intelligent route planning and waste segregation.

For differentiation between biodegradable and non-biodegradable waste, Kumar et al. (2020) worked on an Automatic Waste Segregation and Management System using simple yet effective sensor mechanisms.

A case study by J. Kehila et al. (2020) in Dar es Salaam examined the socio-economic impact of waste segregation and presented avenues for recycling and community-oriented initiatives aimed at improving urban waste systems.

A Smart Bin based on IoT was designed by A. Bano et al. (2020) for real-time solid waste monitoring. It aims to enhance urban hygiene and curb overflowing in public waste bins.

S. Kumari et al. (2018) designed a similar IoT Smart Waste Bin model focused on process optimization so that it can reduce operational delays with cloud integration feedback systems and sensor inputs.

An extensive review on waste segregation techniques contrasting sensor-based, robotic, and manual means, highlighting the impediments to the large-scale implementation of such means in practice, was put together by M. Gangwani et al. (2019).

Aksan Surya Wijaya, Zahir Zainuddin, and Muhammad Nisar (2017) presents the design of a smart waste bin using sensors and microcontrollers to enable efficient waste monitoring. It supports smart waste management by providing real-time data on bin status, aiming to optimize collection routes and reduce environmental impact.

III. METHODOLOGY

The following is a detailed methodology for developing a smart waste segregation system using components that work in unison towards an efficient and automated system:

1. Overview of the System

The smart waste segregation system would use a variety of sensors and actuators to automatically segregate different types of waste (wet, dry, recyclable, etc.) according to different environmental changes or measurements.

2. Major Components

NodeMCU (ESP8266): The system's brain, processing inputs from sensors and controlling actuators (motors, pumps, etc.).

Moisture Sensor: This will determine the level of moisture in the waste and will classify it as wet or dry. For example, wet waste such as food scraps can be composted.

3. Working Methodology

Here is a stepwise process about how the system may work:

a) Power Supply

Solar panel charging a battery for the system. This will also provide energy night consumption or during cloudy days.

b) Data Collection (Sensors)

Moisture Sensor: It senses the moisture content present in waste. If the moisture level is measured to be high, it refers to wet waste, and the respective compartment is then segregated.

Ultrasonic Sensor: Measures the height or volume of waste inside the container. Once waste reaches a certain level, it can trigger the users to empty the bin or start the appropriate mechanism for segregating the waste.

Ultrasonic Sensors: These sensors are used to measure the height or volume of waste inside the container. Once the waste level reaches the specified threshold, the system alerts the user to either empty the bin or activate the necessary mechanism to segregate the waste.

c) Data Processing (NodeMCU)

The NodeMCU receives input from all the sensors and processes data to identify the type of waste and the action that should follow.

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ISSN: 2581-9429 Volume 5, Issue 2, April 2025 Impact Factor: 7.67

For instance, the wet waste may be diverted into a separate bin or activated for composting. On the contrary, dry waste will be put into another compartment.
The information can be notified from the NodeMCU or displayed on an LCD.

d) Segregation Mechanism
The segregation of waste might include a mechanical sorting system that physically forwards waste depending on data received from the ultrasonic and moisture sensors.
Whenever the ultrasonic sensor commands the presence of waste at high levels, the system will be actuated to open that compartment.
On the presence of wetness recorded by the moisture sensor, a mechanism might be activated to push that waste into the wet waste compartment.
Otherwise, dry waste would go to the other compartment

4. System Flow
1. Waste is thrown into a smart bin.
2. A sensor (moisture, ultrasonic) reads.
3. The NodeMCU processes the data to determine whether that waste is wet or dry.
4. Depending on the moisture level, the system activates specific compartments to segregate the waste.
5. Whenever the bin gets full, the user is sent an alert, and the bin is emptied.

Flow diagram

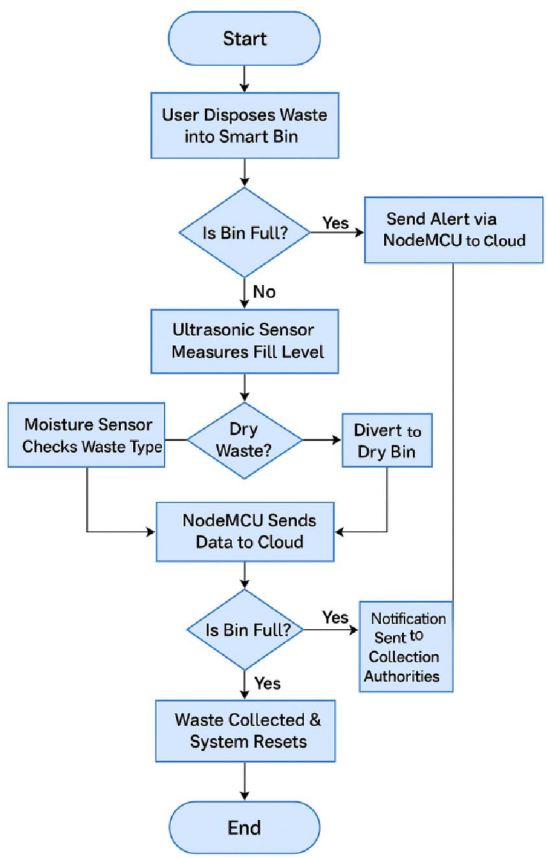

Fig 1.1. System data flow

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V. WORKING PRINCIPLE

The smart waste segregation system is an advanced automated system for sorting various categories of waste, such as wet and dry waste, recyclable, and non-recyclable materials. The working principle relies on various sensors, controllers, actuators, and communication modules that operate in unison to achieve proper classification and processing of waste.

The whole procedure begins with sensing; that is, gathering data by means of different sensors. For example, a moisture sensor measures moisture of waste to distinguish between wet and dry waste. Wet waste is usually any food scraps and organic matter, and is said to have more moisture content, usually measured by the resistance between the electrodes of the sensor.

When the moisture exceeds a certain threshold, that is a sign that the waste is organic and is to be treated in a special way, such as with the need for composting.

The ultrasonic sensor essentially measures the waste level within the bin by emitting sound waves and recording the time taken for the waves to echo from the waste. This information is relevant in determining how much waste is inside so the system knows when to empty the bin or whether it has to perform some other specified tasks.

Once the data from these sensors is collected, it is sent for further processing to the central controller, usually a NodeMCU, which accordingly processes all the data and takes action based on a predetermined logic framework. The NodeMCU compares the data output from the sensor to a pre-set threshold. For instance, in the case of wet waste, if the moisture reading is high, it can signal the system to divert the waste to a specific compartment assigned for wet waste disposal.

The working principle of a smart waste segregation system revolves around the use of sensors, a microcontroller (NodeMCU), actuators, and communication technologies that enable automatic detection, sorting, and management of waste. I will, in the sections below, explain the role and working principle of each component in the system and how they work together to segregate the waste efficiently.

1. Moisture Sensor

Goal: To know how moist the waste is.

Principles of operation: The moisture sensor has two probes that are inserted into the waste. When the probes come in touch with the waste, an electrical current passes between them. The resistance between the probes is inversely proportional to the moisture content in the waste—wet waste (such as food scraps or organic materials) offers less resistance than dry materials (such as plastic or paper). This enables the system to tell wet waste from dry waste.

Role in the system: When moisture content exceeds certain thresholds, it classifies the waste as wet waste, sending it to the specific compartment designated for wet waste typically for composting or organic disposal. On the other hand, dry waste is conveyed in another compartment-the process will help effectively segregate organic and inorganic waste categories.1

2. NodeMCU (Microcontroller)

Purpose: To process data from the sensors and controlling the actuators.

Working Principle: NodeMCU is a microcontroller with Wi-Fi that acts as firm-ware. The NodeMCU collects data from all the sensors (moisture, temperature, ultrasonic), processes it against some pre-programmed logic, and makes decisions about the type of waste and its responsible handling. For instance, based on the moisture level detected, the NodeMCU would decide if the waste was wet or dry (whether or not composting is needed) and commanding a relay to set the pump function or a sorting mechanism.

Role in the system: The principal role of the NodeMCU is to interpret the sensor data and make intelligent decisions about waste segregation. It will be sending notifications to the app on the phone or displaying the real-time data on another LCD. Moreover, it also controls the actuators (i.e., motors, pumps, or sorting doors) that physically segregate the waste.

Intelligent waste segregation systems are part of a fully automatic waste management system that utilizes various sensors, microcontroller, actuators, and a communication system to sort waste materials according to their key characteristics such as moisture, and decomposition status.

This scenario begins once the person throws waste materials into the smart bin; thus, sensors start gathering real-time data. First to action is the moisture sensor which measures the moister content in the waste. The electrical resistance between two probes present in the waste enables it to detect wet materials like food leftovers or other organic matters having a lower resistance in contrast to dry waste materials such as plastic or paper. Thus, with this piece of information, the system classifies waste into wet and dry. Wet waste is generally organic which can be composted, whereas dry waste is mostly non-organic and recyclable.

The next sensor is the temperature sensor, which keeps a watch on the internal temperature of the

The ultrasonic sensor measures the waste volume held in the bin by sending sound waves and calculating the time it takes for these waves to return after hitting the waste. This sensor helps in tracking the filling status of the bin and facilitates the detection of full status for timely alerts to the users regarding the emptying of the bin.

When the waste is classified as organic, the soil testing sensor plays a further active role. This would measure the total moisture of the organic waste, as well as other factors important for composting.

It provides optimum conditions within the composting chamber for microbiotic activity, which is important for successful composting. If the moisture level is lower, the sensor could trigger the addition of water or other adjustments to improve the best environment for composting.

All this is sent to a microcontroller, typically NodeMCU based on ESP8266, which is considered as the brain of the system and data from these sensors to it. NodeMCU processes the incoming data and has predefined logic to act accordingly to the data. For example, in case of a high moisture level NodeMCU will categorize waste as being wet then it will channel that waste to the organic waste compartment. An active decomposition phase usually denotes high temperature, and in such scenario the microcontroller might activate a cooling system or further composting action.

After processing the sensor data and making a decision, the NodeMCU controller signals the corresponding actuators to segregate the waste physically into the respective compartments. In this way, organic waste will keep separate from the rest for composting and the non-organic waste will remain for recyclables or disposal.

In short, the smart waste segregation system integrates multiple sensors and components, including moisture, an ultrasonic sensor, a microcontroller (NodeMCU to create an automated, efficient, and eco-friendly waste management solution. The system monitors waste continuously, classifying it on the basis of its characteristics, and then proceeds to physically segregate the waste into organic and non-organic compartments. It will tend to amend the composting conditions whenever necessary so as to ensure efficient processing of organic waste. Real-time updates and remote notifications make the system highly functional and user-friendly. This system promotes sustainability by giving less requirement for human intervention and effective management of waste.

VI. SYSTEM DESIGN

The Smart Waste Segregation System, as its name indicates, is a fantastic system that is used to classify and control waste by employing a high-speed set of sensors, actuators, and controllers. The waste is characterized to settle into separate compartments or sectioning into recycling, compost, or disposal for the reasons like moisture, temperature, volume, and states of decomposition.

Therefore, here is the design of the system in detail:

1. System Overview Architecture: The waste processing system can thus be constituted of a variety of components that together achieve waste using monitoring, classification, segregation, and processing capabilities. These modules include but are not limited to sensors, microcontroller (NodeMCU), actuators, display units, and power supply modules.

2. Important Components:

A. Sensors:

As the primary data collectors for validating the kind and condition of waste, waste is measured in terms of its following properties:

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1. Moisture Sensor:
Purpose: It measures the amount of moisture embedded in the waste and differentiates wet waste-the organic type (food scraps) from dry waste, which is inorganic in nature (like plastics, paper).
Location: Embedded within the waste bin, in contact with the waste.

2. Ultrasonic Sensor:
Purpose: measures the fill level of the bin. It sends sound waves and determines the time it takes for the waves to get back, i.e. height of the waste in the bin.
Location: Placed on top of the waste bin.

3. Microcontroller (NodeMCU):
Purpose: brain of the system. It is responsible for processing data obtained from sensors and makes decisions based on pre-defined rules and then actuators are controlled accordingly.
Features:
Wi-Fi enabled: Remote monitoring and notifications.
GPIO Pins: For interfacing with sensors and actuators.
Location: Attached to the side of the waste bin or fitted in some external housing.

4. Power Supply:
1. Solar Panels: o Use: Powers a whole system with sensors, microcontrollers, actuators, and several other components. This battery is indeed charged by the solar panel and is provided for the autonomous running of the system. o Location: Mounted on a waste bin or really very close to the system.
2. Rechargeable Battery: o Use: Stores the power captured by the solar panel so that the operation of the system can be nonstop. o Location: This can be found inside the bin or in an alternative outer unit.
3 System Operation:
Step 1: Waste Deposition The sensors (moisture and ultrasonic), after the waste is deposited in the bin, start measuring the properties of the collected waste. The ultrasonic sensor checks the fill level of the bin while the moisture will analyze the type of waste.
Step 2: Data Processing (NodeMCU): The NodeMCU receives the information from the sensors and processes it using its preprogrammed algorithms. The moisture level in the waste is found to be high and hence classified under wet (organic) waste. In contrast, the same moisture level is found low and classified under dry (non-organic) waste. The temperature sensor aids in determining such characteristics of the waste as high temperature are found during the period of active decay (organic waste).
4. Communication and Control: • Wi-Fi Module (NodeMCU): It would make possible monitoring and controlling the system remotely. This allows the user to check the level of waste, check its composting status, and receive notifications through a mobile application or through a cloud interface.
5 Merits of System Design: 1. Automated Waste Management: The process of sorting and monitoring waste requires minimum human intervention. 2. Energy-Efficient: Uses solar power which makes the system sustainable and reduces electricity use. 3. Real-Time Monitoring: LCD and Wi-Fi integration provides a more efficient, user-friendly system of waste management. 4. The environment: It promotes proper waste segregation for recycling and composting, thus reducing landfill waste.

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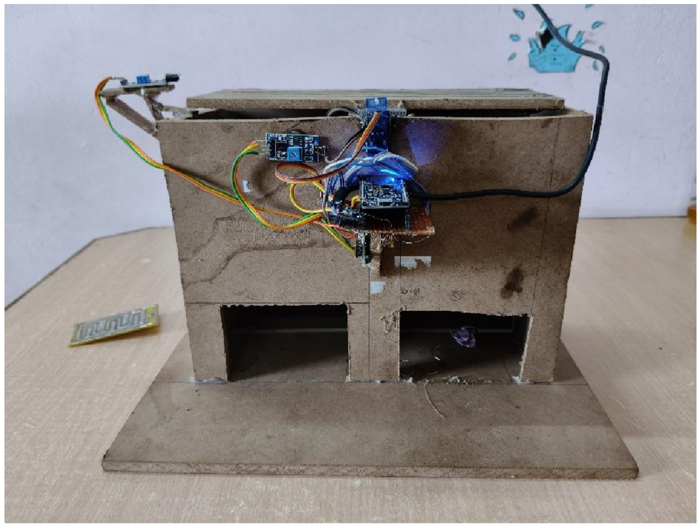
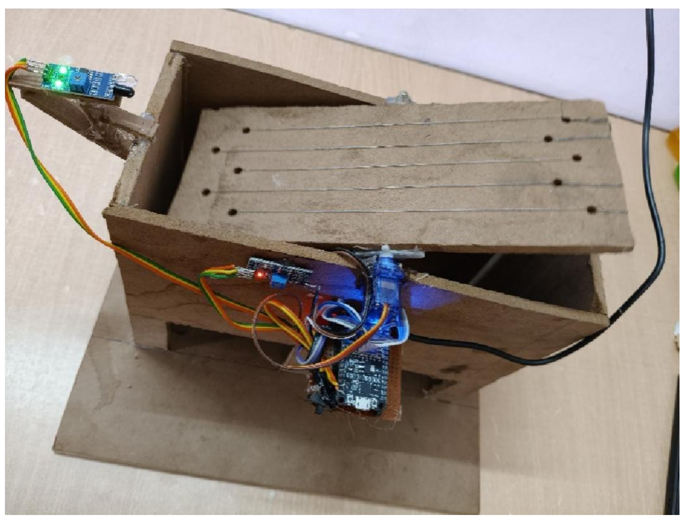
VII. RESULT AND DISCUSSION

7.1 Results





An intelligent waste segregation and monitoring system based on the Internet of Things comprises using sensors to sort waste automatically, as well as monitor the levels of the waste bins in real time. The end result is efficient waste management, reduced manual activities, enhanced recycling, and timely waste collection.

7.2 Discussion

Through smart waste segregation and monitoring system using IoT, dry and wet waste separation takes place efficiently using sensors while cloud computing to maintain healthy separation of waste. A moisture sensor smart bin will identify the nature of waste as either dry or wet. Ultrasonic and weight sensors verify the amount of waste and gas sensors can identify unwanted emissions. These data are processed via microcontroller and transmitted towards cloud platform through Wi-Fi or GSM. Cloud computing system supports real-time monitoring, paving a way in organizing the waste collection service routes according to optimized collection schedules, which will ultimately reduce operational costs. Even though the model is so expensive on initial setup, it changes the world into a much more sustainable world where recycling is highly efficient and cities a lot cleaner.

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VIII. CONCLUSION

The conclusion Automation, data monitoring, and user involvement comes together to make it a perfect tool to make better waste segregation. Assisting smart bins that will efficiently do identification, separation, and management of types of waste through ultrasonic and moisture sensors will be equipped with NodeMCU. This technology not only optimises collection processes and promotes effective recycling but also puts the community in good standing for sustainable practices. The enactment of such a NodeMCU-based washroom is expected to yield fruitful gains as cities and communities move towards improved waste management solutions. Benefits will include environmental sustainability, conservation of resources used in waste separation, and overall efficiencies in the waste segregation effort.

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IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, April 2025
Impact Factor: 7.67

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DOI: 10.48175/IJARSCT-24933