

# SMART WASTE MANAGEMENT SYSTEM USING IOT AND KNN

Ashwini Pawale<sup>1</sup>, Anuradha Dadasaheb Thombare<sup>2</sup>, Prajakta Prabhakar Landge<sup>3</sup>, Gauri Babaji Gadge<sup>4</sup>, and Dipti Sopana Dake<sup>5</sup>

<sup>1</sup> Assistant Professor, Department of Information Technology, JSPM's Bhivrabai Sawant Institute of Technology & Research, Pune

<sup>2-5</sup> Bachelor Students, Department of information technology, JSPM's Bhivrabai Sawant Institute of Technology & Research, Pune  
Email: ashvinijspm@gmail.com; anuradhathombare1512@gmail.com; prajaktalandge2005@gmail.com; gaurigadge17@gmail.com; diptidake777@gmail.com

**Abstract**—A Brilliant Cities are being planned and worked for agreeable human residence. Among administrations that Smart Urban areas will provide is the naturally well-disposed waste/junk accumulation and preparing. In this paper, we inspire and propose an Internet of Things (IoT) - empowered framework engineering to accomplish dynamic waste accumulation and conveyance to handling plants or exceptional junk tips. Previously, squander accumulation was dealt with in a static way utilizing traditional operations look into approach. As proposed in this paper, nowadays, with the increase of sensors and actuators, and solid and universal portable correspondences, the Web of Things (IoT) enables dynamic arrangements aimed at improving the waste vehicle fleet measure, accumulation courses and organized waste receive. We suggest a best question based dynamic booking model to tackle the challenges of close constant planning driven by sensor information streams. An Android application together an easy-to-use GUI is produced and introduced with a specific end purpose to verify usefulness and evaluate a waste collection scenario using trial data. Finally, the suggested models are evaluated on created and real data from St. Petersburg city district, Russia. The models show consistency and accuracy.

**Keywords**— Waste management system, Disposal, Dynamic Waste Collection, IOT

## I. INTRODUCTION

Efficient waste management has become a critical issue in modern urban environments due to the rapid growth of population and urbanization.

Traditional waste management systems, which rely on manual collection and disposal, are often inefficient, time-consuming, and costly. Additionally, improper waste management can lead to environmental degradation, public health risks, and economic losses. To address these challenges, there is a growing need for smart and sustainable waste management solutions that leverage modern technology to optimize waste collection, disposal, and recycling processes. The Smart Waste Management System aims to revolutionize the way waste is managed by integrating advanced technologies such as Internet of Things (IoT), sensors, cloud computing, and data analytics. In this system, smart bins equipped with sensors can monitor waste levels in real-time and communicate with a centralized platform to optimize the collection schedule, ensuring timely waste disposal and reducing unnecessary trips. This minimizes fuel consumption, labor costs, and environmental impact [1].

Furthermore, the system uses data analytics to provide insights into waste generation patterns, helping municipalities and organizations to better plan and manage their waste services. By automating and streamlining the waste management process, the Smart Waste Management System not only improves operational efficiency but also promotes environmental sustainability by encouraging better recycling and resource utilization practices. The amount of waste produced worldwide has expanded dramatically due to the fast urbanization and population growth, creating serious obstacles to efficient waste management. Conventional waste collection techniques are frequently ineffective, leading to overflowing trash cans, higher operating expenses, and environmental risks. One potential remedy in this regard is the use of contemporary technologies into waste management procedures. Real-time waste collection process monitoring, management, and optimization are made possible by the Internet of Things (IoT). In this research, the K-Nearest Neighbours (KNN) algorithm and the Internet of Things (IoT) are used to construct a smart waste management system. IoT sensors are used by the system to track bin status, environmental conditions, and garbage levels. The KNN algorithm is used to evaluate and analyse the data gathered from various sensors in order to forecast [3].

In summary, the Smart Waste Management System is a forward-thinking solution designed to tackle the inefficiencies of traditional waste management while contributing to cleaner, greener, and more sustainable cities.

Effective waste management is severely hampered by the sharp rise in garbage production worldwide brought on by urbanization and population development [1]. The inefficiency of traditional waste collection techniques frequently leads to overflowing bins, higher operating expenses, and environmental risks. In this regard, incorporating contemporary technologies into waste management procedures has become a viable remedy [1]. This paper describes the use of the K-Nearest Neighbours (KNN) algorithm and the Internet of Things to construct a smart waste management system. The system tracks bin status, environmental conditions, and garbage levels using Internet of Things sensors. The KNN method is used to process and analyse the sensor data in order to make predictions [2].

## II. LITERATURE REVIEW

Solid waste management is key to ensuring urban sustainability, hygiene, and enhancing the life quality in populous cities. The combination of IoT and smart technology has dramatically improved efficiency in waste collection, monitoring, and disposal. This section gives an overview of the latest IoT-based smart waste management systems and their contribution to urban sustainability. Jain et al. [1] suggested an IoT-based waste management system with smart dustbins featured with ultrasonic sensors, NodeMCU, and GPS modules. The system measures waste levels of bins and uses IFTTT and Thing Speak to provide SMS and email alerts, notifying authorities for timely disposal. The research work endeavors to resolve waste overflow problems, especially in crowded urban locations, by facilitating real-time waste monitoring and the optimization of collection routes. Pargaïen et al. [2] proposed a smart waste collection monitoring system that combines IoT with mobile technology to improve real-time waste tracking and collection in smart cities. The system consists of a scalable, modular dashboard prototype called "My City Dashboard," which allows authorities to track sensor-enabled smart bins effectively. The research emphasizes the importance of analytics processing in optimizing waste management by combining historical waste collection data to enhance operational planning. Shome et al. [3] highlighted strategic planning for intelligent waste management in cities. Their research presented a categorization framework to assess performance indicators in terms of objectivity and technological progress. The framework was implemented for Bari Municipality, Italy, and proved its efficiency in dealing with urban sustainability while minimizing costs. Their research coincides with that of Carli et al. [10], who introduced a framework for the categorization of performance indicators of smart cities aimed at the assessment of efficiency, sustainability, and service quality. Olivares et al. [4] spoke about population growth in urban areas and the necessity for smart city applications to develop innovative solutions for security, health, and waste management. The research emphasized the need for testbeds to verify urban management initiatives in order to effectively deploy and integrate smart city solutions. Sanchez Lopez et al. [7] also focused on the use of sensor-driven IoT solutions to streamline resource allocation and minimize inefficiencies in urban systems. Jara et al. [8] discussed mobile-based discovery frameworks for IoT, allowing real-time interaction between smart waste management systems and urban infrastructure. Their research recommends the incorporation of mobile IoT apps to increase civic involvement, public participation in trash disposal through sensing-enabled automated feedback and reporting capabilities. Suakanto et al. [9] also established a smart city dashboard model integrating several sensor networks, enabling agencies to make fact-based decisions toward the optimization of city services such as trash removal. The impact of smart city trash management methods also relies on monitoring key performance indicators. Priano and Guerra [11] suggested a model for measuring the smartness of cities, which can be used to evaluate waste management efficiency. Nam and Pardo [12] also talked about urban innovation in smart cities, with a focus on policy frameworks and management strategies for sustainable waste disposal. Giffinger et al. [14] carried out a comparative ranking of European medium-sized

cities on the basis of smart city indicators, supporting the importance of systematic evaluation methodologies in urban management. Their research is supported by Suganya et al. [15], who developed a blockchain-based optimization framework for consensus mechanisms, underlining the possible integration of reinforcement learning with IoT for decentralized and efficient waste management solutions. These studies cumulatively illustrate the increasing importance of IoT-based solutions to waste management, highlighting real-time monitoring, analytics-led decision-making, and economically viable urban sustainability solutions. The combination of mobile IoT platforms, blockchain optimization, and smart city dashboards offers new possibilities for enhancing the efficiency of waste collection and reducing environmental footprint in cities.

## III. EXISTING SYSTEM

In the existing waste management systems, waste collection, transportation, and disposal are typically done manually or through predefined schedules. The architecture of traditional waste management systems consists of the following key elements:

- 1. Waste Bins:** Regular waste bins placed in households, commercial areas, and public spaces. These bins are filled over time and require manual monitoring to determine when they are full.
- 2. Established Infrastructure:** Traditional waste management systems are well-established, with a clear operational structure in place.
- 3. Low Initial Investment:** The setup costs for traditional systems are relatively low compared to the advanced smart waste management systems that require high-tech sensors and infrastructure [5].
- 4. Ease of Implementation:** The methodology is simple to implement since it relies on manual labor and predefined schedules, requiring minimal technical expertise.

### Disadvantages:

- 1. Inefficient Resource Utilization:** The fixed schedules for waste collection often led to either overflow of waste bins or unnecessary collection of partially filled bins, resulting in wasted resources such as fuel and labor.
- 2. Lack of Real-Time Monitoring:** There is no real-time tracking of bin levels, leading to delayed responses to overflowing waste, which can cause health hazards and environmental pollution.
- 3. High Operational Costs:** The system requires more manpower and fuel to follow rigid collection routes, increasing operational costs without optimizing the process.

## IV. PROPOSED SYSTEM

Accept a Smart City which fuses IoT framework for accomplishing effective dynamic waste gathering. With respect to data the Smart City is separated into numerous areas which cover the whole city zone. Every part contains some of different middle of the road squander stops, which are impermanent waste capacity zones. Out of the outskirts of the city there is found some of numerous junk tips used to store the waste gathered from the stops. Additionally

preparing of the waste is performed by handling plants which are situated close the rubbish tips. The proposed framework design joins a heterogeneous armada of trucks for serving the waste gathering foundation. In particular, an armada of Low-Capacity Garbage Trucks (LCGTs) is utilized to gather squander from the canisters situated in the terraces of the divisions and store it incidentally to stops. An armada of High-Capacity Garbage Trucks (HCGTs) is utilized to gather squander from the warehouses and exchange it to the rubbish tips. In this paper we are considering the extraordinary instance of dynamic booking of waste from receptacles to stations through LCGTs which for reasons of effortlessness would be expressed as trucks. In Figure 1 it is displayed the system architecture.

The Smart Waste Management System uses IoT (Internet of Things) and KNN (K-Nearest Neighbors) machine learning algorithm to maximize waste collection, minimize operating expenses, and ensure a cleaner environment. The system monitors, analyzes, and predicts.

waste levels in real-time, guaranteeing efficient waste disposal.

Workflow:

### 1. Data Collection

Waste levels and environmental conditions are measured by sensors in bins.

Microcontrollers transmit real-time data to the cloud.

### 2. Data Processing & Analysis

KNN algorithm looks at past waste history and forecasts when a bin will get full.

Alarm is triggered instantaneously by anomalies such as leakage of gas or fire risks

### 3. Smart Waste Collection

According to KNN forecast, waste collection routes are planned accordingly.

Computer-aided scheduling eliminates redundant journeys and fuel consumption.

### 4. User & Authority Interaction

Local authorities get real-time notifications and optimized routes.

Residents can see bin status on a mobile app or report concerns.

### Benefits

1. Efficient Waste Collection – Minimizes overflow and excess pickups.
2. Cost & Fuel Savings – Route-optimized reduces operation costs.
3. Environmentally Friendly – Avoids waste overflow and pollution.
4. Real-Time Monitoring – Authorities have 24/7 monitoring capability for bins.
5. Data-Driven Decisions – KNN-based predictions enhance waste management planning.

## V. MATERIALS AND METHODS

This section describes the methods and materials utilized for designing and implementing the proposed smart waste management system. The approach integrates IoT technology to optimize waste collection and management. The system incorporates various components, modules, and communication frameworks as outlined below [9]:

## 1. Components Used

### Bin Module:

- RFID tags for unique bin identification using 6LoWPAN protocol.
- Sensors to monitor waste levels in bins.
- Automated lid-locking mechanism activated when the bin reaches its capacity.
- Wireless communication devices for data transmission.

### IoT Module:

- Facilitates interaction between bins and the central control system.
- Sends real-time bin status updates to the administration module.

### Admin Module:

- Centralized system for monitoring and managing waste collection schedules.
- Processes and visualizes real-time data received from IoT-enabled bins.
- Notifies contractors for waste collection when bins are full.

### Driver Module:

- Provides route optimization and task updates for waste collection drivers.

## 2. System Design



Fig 1: System Design

## 3. Waste Collection Workflow

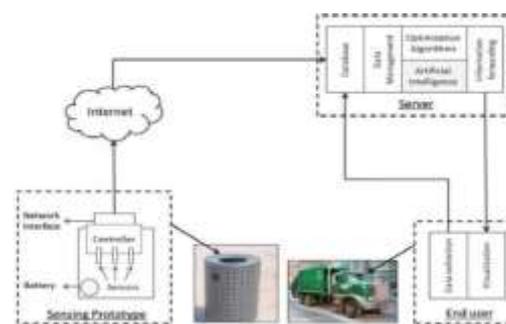


Fig 2: Waste Collection Workflow

## VII. MATHEMATICAL MODEL

Waste bins across city zones are equipped with sensors to monitor waste levels.

Bin data is transmitted in real time to a central control room. Notifications are sent to contractors for collection when bins are full.

Small garbage trucks (LCGTs) collect waste from bins and deliver it to intermediate storage locations.

Large garbage trucks (HCGTs) transport waste from these storage points to processing plants or disposal facilities.

## 4. Module Specifications and Processes

The system employs a hierarchical structure using both small and large trucks for waste transportation. Waste is processed at plants near disposal sites to enhance recycling and reduce landfill use.

This structured methodology ensures efficient monitoring, smart scheduling, and optimal resource usage, paving the way for sustainable waste management in urban areas.

## VI. KNN ALGORITHM

KNN Algorithm in the Smart Waste Management System

The K-Nearest Neighbors (KNN) algorithm is used in this system for route optimization of waste collection vehicles. The goal is to determine the most efficient path for garbage collection based on bin fill levels and location data.

## Example Scenario

Given Data from 5 Bins:

Bin	Fill Level (%)	Gas Detected(ppm)	GPS Location (x, y)
B1	90%	2.1	(5,10)
B2	75%	1.8	(8,14)
B3	45%	0.5	(12,18)
B4	85%	3.2	(6,9)
B5	30%	0.3	(15,20)

The truck's current position is (4,6).

- **Priority Classification**
- **Class 1 (High Priority Bins):** B1, B4
- **Class 2 (Medium Priority Bins):** B2
- **Class 3 (Low Priority Bins):** B3, B5
- **Distance Calculation**

Using the Euclidean distance formula:

$$d(B_n) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

- Distance to B1:  

$$d(B1) = \sqrt{(5-4)^2 + (10-6)^2} = 4.12$$
- Distance to B4:  

$$d(B4) = \sqrt{(6-4)^2 + (9-6)^2} = 3.60$$
- Distance to B2:  

$$d(B2) = \sqrt{(8-4)^2 + (14-6)^2} = 8.94$$

## COLLECTION PLAN

SINCE **K = 2**, THE TRUCK WILL FIRST COLLECT FROM THE CLOSEST HIGH-PRIORITY BIN (**B4**) AND THEN PROCEED TO **B1**.

The system S is defined as:

$$S = \{I, P, O, F\}$$

where:

**1. I (Input Parameters):** These are sensor data gathered from different sources. Sensors read parameters like fill level, gas detection, moisture percentage, and GPS position in the smart waste management system.

**2. P (Processes):** This is the inherent activities of the system, such as data processing and decision-making. The system processes sensor inputs to classify bins, measure distances, and decide optimized routes.

**3. O (Output Parameters):** The system returns optimized waste collection routes and alerts based on processed information. These outputs facilitate efficient waste collection with minimal fuel usage and time.

**4. F (Constraints):** These are restrictions that influence system performance, including sensor precision, network latency, and weather conditions. These constraints need to be addressed to guarantee correct decision-making and smooth functioning.

The input parameters (I) in the system are a set:

$$I = \{G, M, U, L, T\}$$

where:

**1. G (Gas Sensor Data):** Describes levels of gases measured in bins of waste. The data set is symbolized as {g1, g2, gn}, with each being a level of gas concentration at some point and location.

**2. M (Moisture Sensor Data):** Describes moisture levels in the waste bins. The data set is symbolized as {m1, m2, mn}, with each mi being a reading of moisture from some bin.

**3. U (Ultrasonic Sensor Data):** Records the level of fill in waste bins through ultrasonic sensors. The data set is {u1, u2, un}, where each Ui is a measurement of the fill level.

**4. L (GPS Location Data):** Records the geographical location of waste bins. The dataset is provided as {l1, l2, ln}, where each li is the GPS location of a bin.

**5. T (Time-Stamp Data):** Stores the time when sensor measurements are recorded. The data set is {t1, t2, Tn}, with each indicating the time of a recorded sensor measurement. These input parameters have real-time data required for monitoring and optimizing waste collection in the smart waste management system.

## Processing Function (P) of the System

The processing function (P) of the system contains major operations that analyse sensor data to make decisions. It involves the following calculations:

## 1. Fill Level Calculation (FL)

The fill level of a waste bin is determined using ultrasonic sensor data with the following equation:

$$FL = f(U) = \left( \frac{\text{bin height} - \text{detected level}}{\text{bin height}} \right) \times 100\%$$

- Bin Height: The overall height of the bin.
- Detected Level: The height read by the ultrasonic sensor from the rim of the bin to the waste level.
- Calculation: This equation computes the percentage of the bin filled. Larger values are for bins to be collected urgently.

## 2. Gas Detection (GD)

The system calculates the gas concentration inside the waste bins based on gas sensor readings. The equation used is:

$$\text{Gas Detection} = f(G) = \sum_{i=1}^n g_i$$

where:

- $g_i$  represents individual gas concentration readings from various sensors in the bin.
- GD refers to the total gas concentration in the bin.

If GDGDGD surpasses a predefined threshold, an alarm is triggered, warning of potential danger from poisonous gas buildup.

### Purpose of Processing Functions:

- **Fill Level Calculation** ensures that only nearly full bins are collected, optimizing waste management
- **Gas Detection** helps detect bins emitting hazardous gases, allowing early intervention to prevent environmental and health risks. These processing functions support intelligent decision-making for waste collection and monitoring, enhancing efficiency and safety.

## 3. Additional Processing Functions

### Moisture Analysis (MA)

The moisture level in waste bins is determined using moisture sensor data. The formula used is:

$$\text{MA} = f(M) = \frac{\sum_{i=1}^n m_i}{n}$$

where:

- $m_i$  represents individual moisture readings from the sensor.
- $n$  is the number of readings.
- MA is the average moisture level in the bin

**Purpose:** Helps in distinguishing between wet and dry waste, aiding in waste segregation and recycling.

### Route Optimization using KNN Algorithm

The system optimizes waste collection routes using the K-Nearest Neighbors (KNN) algorithm, based on bin locations:

$$L = \{l_1, l_2, \dots, l_n\}$$

The next bin for collection is selected based on the Euclidean distance:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

where:

- $(x_1, y_1)$  is the truck's current location.
- $(x_2, y_2)$  is the waste bin's location.
- $d$  is the distance between the truck and the bin.

Priority Criteria for Waste Collection:

1. **Highest Fill Level:** Bins that are nearly full get top priority.
2. **Shortest Distance:** Among high-priority bins, the closest ones are collected first to minimize travel time.

This method ensures efficient and cost-effective waste collection, reducing fuel consumption and optimizing route planning in real time.

## 4. Output Parameters (O)

The system generates various output parameters based on collected and processed sensor data, enabling real-time waste management.

$$O = \{W, R, N, A\}$$

Where:

(W) Optimized Waste Collection Route

- The system produces an optimized waste collection route for trucks based on bin fill levels, gas detection, and proximity.
- Helps minimize unnecessary travel and improve fuel efficiency.

(N) Notifications to Admin and Driver

- The system sends real-time updates to waste collection administrators and drivers.
- Notifications include high-priority bin alerts, suggested collection routes, and system status updates.

(A) Alerts for Toxic Gases

- If gas levels in any bin exceed a safe threshold, the system triggers an alert.

### Purpose of Output Parameters:

- **Increased Efficiency:** Waste collection is more efficient and data-driven.
- **Real-Time Decision Making:** Drivers are provided with current collection routes and bin statuses.
- **Safety Measures:** Warnings assist in avoiding hazards from toxic gas emissions.

## VIII. EASE OF USE

### A. User-Friendly Interface

The Smart Waste Management System offers a centralized platform with a clean and intuitive interface. Designed to cater to users of all technical backgrounds, the system provides easy access to real-time data, analytics, and collection schedules. Whether accessed on a desktop or mobile device, the platform ensures smooth navigation and efficient usage.

### B. Automation and Optimization

The system integrates IoT-enabled sensors to automate waste monitoring and collection scheduling. This minimizes manual effort, reduces unnecessary trips, and ensures optimal resource utilization. Users benefit from timely alerts and data-driven insights without requiring constant supervision.

### C. Easy Setup and Integration

The system is designed to seamlessly integrate with existing waste management infrastructure. Smart bins and their sensors are easy to install and configure, requiring minimal technical expertise. Comprehensive instructions and technical support are provided to facilitate a smooth setup process.

### D. Remote Accessibility

With cloud-based functionality, users can monitor and control the system remotely from any internet-enabled device. This ensures flexibility and real-time management, even for users who are not physically present at the waste management site.

**E. Customizable and Scalable**

The system can be tailored to meet specific needs, whether for a small residential area or a large metropolitan city. Its scalability makes it an ideal solution for varied waste management requirements.

**F. Training and Support**

Detailed training resources and responsive customer support are available to help users adopt the system quickly and confidently. Assistance is provided to troubleshoot any issues, ensuring an uninterrupted experience.

**IX. RESULTS AND DISCUSSIONS**

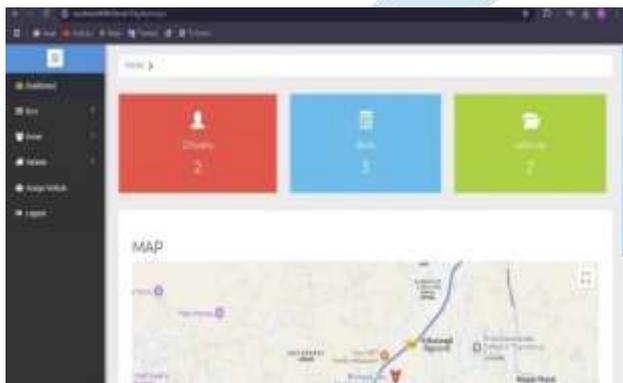
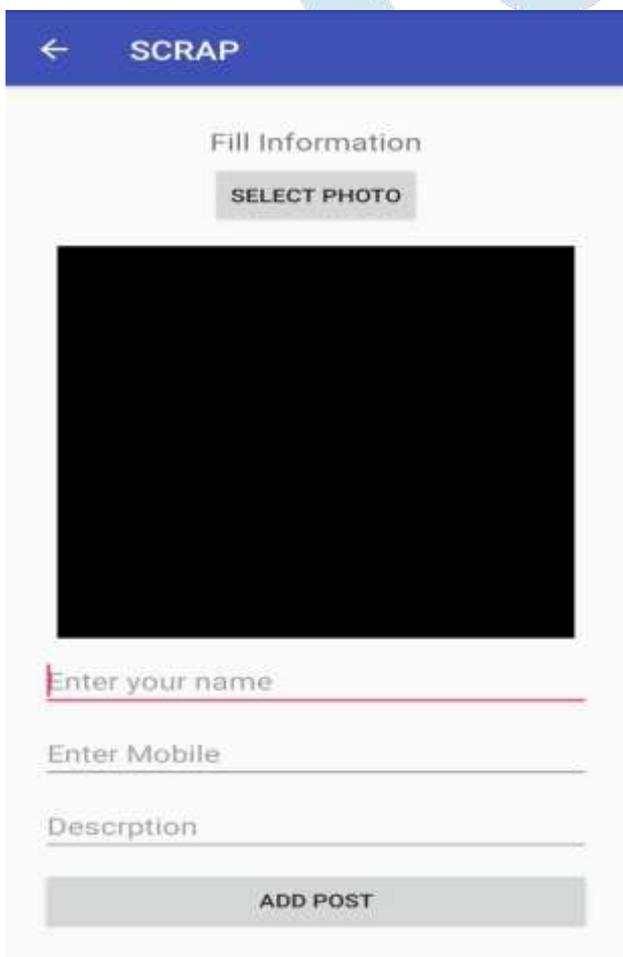


Fig 1: Desktop Application



**Fig 2: Android Application**

The dashboard interface is a real-time monitoring system for waste collection, showing critical information like the number of available drivers, bins, and vehicles. It also has a map interface that enables tracking of bin locations and status, facilitating effective waste collection operations. The mobile application allows users to be actively involved in waste management by reporting waste problems through image uploads and descriptions. This attribute promotes community participation and increases the overall effectiveness of the smart waste management system.

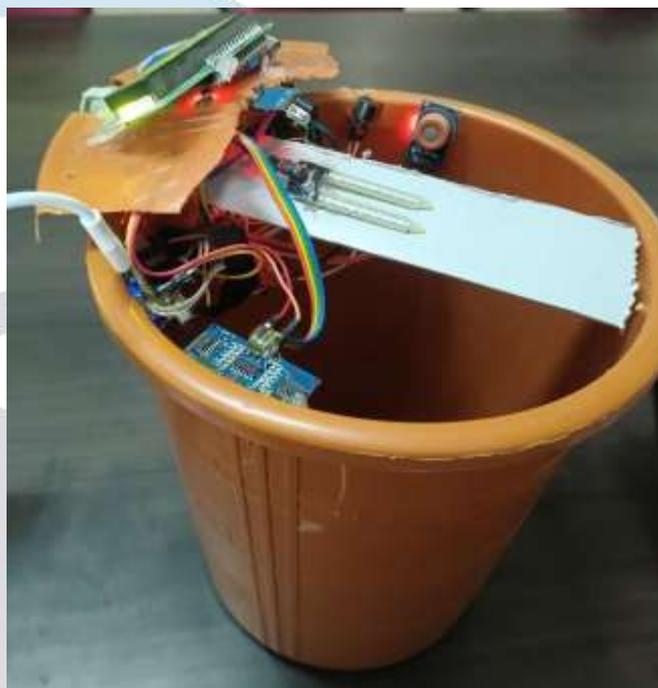


Fig 3: Smart Bin

The smart bin based on the IoT comes equipped with sophisticated sensor to measure waste fill levels, moisture content, and gas emissions in real time. It makes use of an HC-SR04 ultrasonic sensor to calculate the fill level, an FC-28 moisture sensor to determine waste moisture content, and an Embeddinator MQ-7 gas sensor to identify the harmful gas emissions. The bin incorporates a NEO-6M GPS module for position tracking and can be powered via a NodeMCU ESP8266 microcontroller while transmitting data effortlessly to a central dashboard. There is also usage of the K-Nearest Neighbors KNN algorithm whereby the system recognizes nearly full bins first to assist in collection times and prevent them from overflowing and also triggering on gas sensors the alerts on any hazardous emissions happening. This clever waste management system streamlines collection routes, lowers the consumption of fuel, and enhances the cleanliness of cities and environmental protection.

**IX CONCLUSION**

This proposed methodology can be utilized to keep our city clean. By utilizing system condition, the continuous precise information from the executed framework could be utilized for the proficient strong waste administration framework. The framework can gather precise information.

on ongoing which can be utilized further as a contribution to an administration framework. With burden cell alignment approach, it streamlines the adjustment procedure so it very well may be joined to normally utilized waste-canister without changed or alteration. The dimension sensors likewise can be connected to regular waste-canister. So, the model is appropriate for utilizing in regular waste administration foundation.

The system gives robust and comprehensive solution for waste management in urban environments using IoT technology

## X. ACKNOLOGEMENT

The authors would like to express their sincere gratitude to Mrs. Ashwini Pawale, our project guide, for her valuable guidance, support, and encouragement throughout the research and development of this project. Her expertise and insights were instrumental in the completion of this work.

We also extend our thanks to the faculty and staff of the Department of Information Technology at JSPM'S Bhivarabai Sawant Institute of Technology and Research for their assistance and cooperation. Special appreciation is given to our colleagues and friends for their contributions and support during the project.

Finally, we acknowledge the constant encouragement from our families, whose unwavering support motivated us to complete this project successfully.

## XI. REFERENCES

- [1] S. P. Jain, T. Chaudhary, and S. Gajjar, "Design and Development of Smart Waste Management System," 2023 International Conference on Communication System, Computing and IT Applications (CSCITA), Mumbai, India, 2023, pp. 199-203, doi: 10.1109/CSCITA55725.2023.10104960.
- [2] B. Shome et al., "Smart Waste Management: A Revolutionary Step Towards a Better India," in Intelligent Techniques and Applications in Science and Technology, S. Dawn, V. Balas, A. Esposito, S. Gope (Eds.), Springer, Cham, 2020, pp. 479-487, doi: 10.1007/978-3-030-42363-6\_79.
- [3] R. K. Singhvi et al., "IoT-Based Smart Waste Management System: India Prospective," 2019 4th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), Ghaziabad, India, 2019, pp. 1-6, doi: 10.1109/IoT-SIU.2019.8777698.
- [4] G. K. Shyam, S. S. Manvi, and P. Bharti, "Smart Waste Management Using Internet-of-Things (IoT)," 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), Chennai, India, 2017, pp. 199-203, doi: 10.1109/ICCCT2.2017.7972276.
- [5] M. Fazio, M. Paone, A. Puliafito, and M. Villari, "Heterogeneous Sensors Become Homogeneous Things in Smart Cities," 6th IEEE International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), Palermo, Italy, 2012, pp. 775-780.
- [6] C. Balakrishna, "Enabling Technologies for Smart City Services and Applications," 6th IEEE International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST), Paris, France, 2012, pp. 223-227.
- [7] T. Sanchez Lopez, D. C. Ranasinghe, M. Harrison, and D. McFarlane, "Adding Sense to the Internet of Things," Personal and Ubiquitous Computing, vol. 16, no. 3, pp. 291-308, 2012.
- [8] J. Jara et al., "Mobile Discovery: Discovering and Interacting with the World Through the Internet of Things," Personal and Ubiquitous Computing, vol. 18, no. 2, pp. 323-338, 2014.
- [9] S. Suakanto, S. H. Supangkat, Suhardi, and R. Saragih, "Smart City Dashboard for Integrating Various Data of Sensor Networks," IEEE International Conference on ICT for Smart Society (ICISS), Jakarta, Indonesia, 2013, pp. 1-5.
- [10] R. Carli et al., "Measuring and Managing the Smartness of Cities: A Framework for Classifying Performance Indicators," IEEE International Conference on Systems, Man, and Cybernetics (SMC), Manchester, UK, 2013, pp. 1288-1293.
- [11] F. H. Priano and C. F. Guerra, "A Framework for Measuring Smart Cities," 15th Annual International Conference on Digital Government Research (DG. O), Aguascalientes, Mexico, 2014, pp. 44-54.
- [12] T. Nam and T. A. Pardo, "Smart City as Urban Innovation: Focusing on Management, Policy, and Context," 5th International Conference on Theory and Practice of Electronic Governance (ICEGOV), Tallinn, Estonia, 2011, pp. 185-194.
- [13] T. Olivares, F. Royo, and A. M. Ortiz, "An Experimental Testbed for Smart Cities Applications," 11th ACM International Symposium on Mobility Management and Wireless Access (MobiWac), Barcelona, Spain, 2013, pp. 115-118.
- [14] R. Giffinger et al., "Smart Cities: Ranking of European Medium-Sized Cities," Centre of Regional Science (SRF), Vienna University of Technology, Austria, 2007. Online: <http://www.smart-cities.eu>.
- [15] R. Suganya, Khan Farina, Alfiya Abid Shahbad, Neelam LabhadeKumar, Mangala S Biradar, Ashvini Narayan Pawale, "Reinforcement Learning-Based Deep FEFM for Blockchain Consensus Mechanism Optimization with Non-Linear Analysis" Journal of Computational Analysis and Applications, Vol. 33 No. 05 (2024).