IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⋇ Peer-reviewed & Refereed journal ⋇ Vol. 12, Issue 7, July 2025

DOI: 10.17148/IARJSET.2025.12713

# IOT Based Waste Management System

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**Abstract:** Solid waste management problems have gotten worse due to rapid urbanisation and population growth. Conventional approaches cannot meet the constantly changing needs of contemporary cities. An innovative chance to improve the sustainability and efficiency of waste collection and management systems is provided by the incorporation of Internet of Things (IoT) technology. An extensive literature review of current IoT-based waste management solutions is presented in this paper. It highlights research gaps, talks about different methods and technological developments, and makes recommendations for further work.

**Keywords**: Real-time monitoring, sensors, smart waste management, IoT, and route optimization

## I. INTRODUCTION

Because of the limitations of conventional systems, rising population density, and changing consumption patterns, solid waste management is becoming a bigger issue in urban settings. Rigid schedules frequently limit these systems, which results in problems like overfilled bins, ineffective vehicle routing, and higher operating expenses. Through real-time sensing, cloud-based analytics, and intelligent decision-making, the Internet of Things (IoT) offers a way to automate and optimize these systems. The components, approaches, results, and shortcomings of numerous studies and applications of IoT-based waste management systems are reviewed in this paper.

## II. LITERATURE SURVEY

By combining smart sensors, real-time communication, and data analytics, the Internet of Things (IoT) is essential to modernizing waste management. IoT systems facilitate dynamic route optimization, offer real-time waste bin status information, and support predictive analytics to anticipate waste generation trends. The literature demonstrates how system coverage, efficiency, and complexity have steadily changed over time.

Zhang et al. (2017) [1] relied on telecommunications concepts and embedded systems theory, particularly the use of GSM-based communication for remote data transmission and ultrasonic sensing for distance measurement. The main concept was to use real-time fill level data to increase operational efficiency.

Abdul Rahman et al. (2018) [2] Built upon IoT architecture and cloud computing theory. Used Firebase for real-time cloud database interaction and NodeMCU as a microcontroller supporting Wi-Fi communication. This reflects the client-server model and real-time data synchronization principles.

Narayan Sharma et al. (2019)[3] centered on low-cost automation theory that sends SMS alerts using GSM modules and Arduino microcontrollers. The idea behind the system was to provide affordable real-time surveillance in places without internet connectivity.

Abhiram et al. (2020) [4] utilized ideas from logistics and optimization theory, specifically geospatial analysis using GPS and mapping APIs and route optimization algorithms. Their work focuses on using data-driven decision-making to reduce operational inefficiencies..

Karthik et al. (2021) [5] Neural networks and machine learning theory were used to forecast waste bin fill patterns. The model, which was based on supervised learning, improved forecasting accuracy by learning from historical data.

Patil and Thorat (2022) [6] based on distributed ledger technology (DLT) and blockchain theory. By distributing authority over waste transaction records, the method guaranteed data security, transparency, and integrity.
Singh and Reddy (2023)[8] Combining weight detection and gas sensing, based on the multi-sensor fusion theory. drew on environmental monitoring and occupational safety frameworks as well, allowing for the early identification of hazardous materials in waste.

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Kumar et al.(2022)[9] installed a smartphone app that connected to IoT-enabled trash cans so that residents could monitor collection times and report overflowing bins. The system enhanced service accountability and boosted community involvement.

Tan et al.(2022)[10]Their IoT system made use of edge computing to cut down on latency and lessen dependency on cloud infrastructure. Faster processing and reaction times were made possible by this, particularly in crowded urban settings..

Mehta and Banerjee (2022)[11] created a smart trash can that uses AI-powered object detection to categorize waste before it is placed inside. Better rates of recycling and segregation were made possible by this.

Chowdhury et al.(2023)[12] based on distributed computing and the theory of the MQTT protocol. focused on scalability, real-time updates, and low-power communication, all of which are in line with the ideas of lightweight IoT network architecture.

Ali and Singh (2021)[13] applied the theory of environmental monitoring, specifically the effect of humidity and temperature on the rates of decomposition. For waste treatment optimization, this is in line with waste biology and early warning systems.

Dasagupta and Nair (2022)[14] Chemical sensor technology is used to identify dangerous contaminants in industrial waste, with its roots in toxicology monitoring theory and industrial safety regulations. The system follows alert models that are based on thresholds.

Verma et al.(2023)[15] centered on multi-tier architecture design and system integration theory, integrating IoT data, private operations, and municipal governance to enable synchronized waste scheduling. It is a reflection of urban informatics and smart city architecture frameworks.

Ramesh et al. (2021)[16] Theoretically, this study made use of LoRa (Long Range) wireless technology to enable low-power, wide-area communication between municipal servers and smart bins. The system's wireless sensor network theory enables widespread deployment in urban areas with low infrastructure costs.

Gupta and Malik (2020) Fuzzy logic control systems were used in their study to manage route prioritization and bin fill level uncertainty. Because of its foundation in fuzzy decision-making theory, the system can make more adaptable, human-like decisions in changing circumstances.

Bose et al. (2021)[18] They forecasted future collection needs by applying Big Data analytics to historical waste generation patterns. Predictive analytics theory, which processes vast amounts of data to guide operational strategies, is the foundation of this methodology.

Thomas and James (2022)[19] Their research focused on the theory of cyber-physical systems (CPS), which integrates physical and computational processes in real time. The smart waste system was created to support self-adaptive waste collection workflows by responding to sensor inputs on its own.

Qbal et al. (2023) Their model integrated smart waste management with the theory of renewable energy integration. In accordance with sustainable IoT deployment principles, solar-powered bins powered sensors and communication devices using energy harvesting techniques.

Fernandes and D’Souza (2020)[20] This system examined user adherence to waste segregation regulations using behavioral modeling. It used gamification and feedback loops to improve waste habits, drawing on environmental psychology and human-computer interaction (HCI).

## II. PROBLEM IDENTIFICATION

Static collection schedules are used in traditional waste management techniques, which leads to inefficiencies like:

1. Overflowing trash cans pose health risks and pollute the environment.
2. Unnecessary trips by waste collection trucks raise operating expenses and fuel consumption.
3. Absence of waste bin status tracking and real-time monitoring.

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4. Unable to give collection top priority in areas with high densities or waste generation.
5. Manual inspection procedures are labor-intensive, time-consuming, and frequently imprecise.

These problems highlight the need for an intelligent, automated, and scalable system that guarantees intelligent routing, effective waste monitoring, and real-time data collection.

## III. PROPOSED FRAMEWORK

The suggested framework makes use of the Internet of Things (IoT) to develop an intelligent, automated, and real-time waste collection and monitoring system. The primary goal is to eliminate inefficiencies in conventional waste collection by putting in place a sensor-based strategy that enables efficient and timely garbage disposal.

A. Overview of the System

The core modules of the framework are as follows:

1. Sensing Module: Garbage cans are equipped with ultrasonic sensors to track their fill levels. The amount of trash in the bin can be ascertained by these sensors by measuring the distance between the trash and the sensor head.

2. Communication Module

Wi-Fi or GSM modules are used to send the sensor data to a cloud platform . This eliminates the need for manual inspection and allows for remote monitoring.

3. Module for Data Processing and Decision-Making

The sensor data is retrieved from the cloud by a server or application layer. To decide whether to generate a collection task, this layer uses threshold logic (garbage level > 70%, for example).

4. Notification and Task Assignment Module

Module for Notification and Task Assignment When a bin surpasses the cutoff, the Along with routing details to get to the bin, the system creates a work order and notifies the assigned garbage collector via SMS.

5. Monitoring and Feedback Module

The system keeps track of whether the trash can has been emptied. The task is marked as finished and removed from the queue if it is emptied. If not, the garbage collector receives a reminder.

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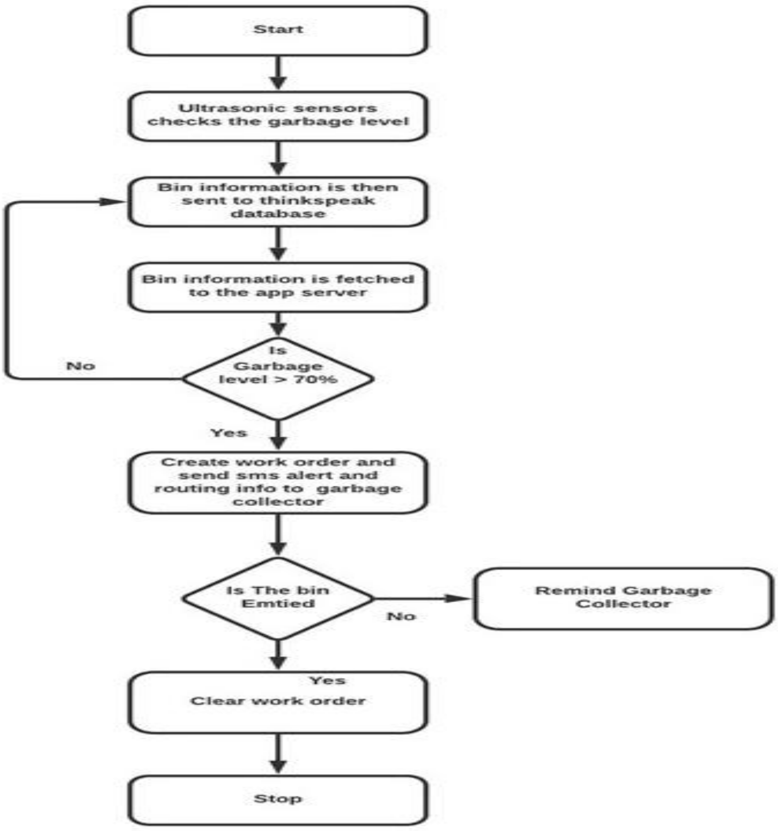


Fig. 1. Proposed data flow

## IV. CONCLUSION AND FUTURE SCOPE

The study's suggested IoT-based waste management system offers a workable and effective solution to the problems associated with urban waste collection. The system guarantees efficient and timely waste disposal by combining automated alert systems for informing garbage collectors, cloud platforms for data storage, and ultrasonic sensors for real-time garbage level detection. Bin overflow is avoided, manual monitoring efforts are greatly decreased, and environmental sustainability and public hygiene are enhanced by this automation. By facilitating data-driven routing and scheduling of collection tasks, the system also lowers fuel consumption and operating expenses.

There is a lot of room to improve the system in the future by incorporating cutting-edge technologies. Proactive waste collection is made possible by the use of machine learning algorithms to forecast bin fill levels based on historical data. To encourage greater public engagement, a user-friendly mobile application that enables citizens to report issues and view real-time bin status could be created. Solar-powered smart bins could be incorporated into future iterations of the system to encourage energy efficiency and lessen reliance on outside power sources. Furthermore, garbage collection routes can be optimized in real-time based on traffic and bin status by integrating dynamic GPS-based routing algorithms. Smart waste segregation features and the incorporation of dashboards for the entire city could be additional improvements to help local officials with resource allocation and policymaking. With these developments, the current system would become a complete, intelligent, and scalable waste management solution for smart cities.

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