STM JOURNALS

Research & Reviews: Journal of
Embedded System & Applications

ISSN: 2395-6712 (Online)
ISSN: 2321-8533 (Print)
Volume 13, Issue 3, 2025
September–December
DOI (Journal): 10.37591/RRJoESA

https://journals.stmjournals.com/rrjoesa

Review RRJoESA

Smart Waste Management System Using IoT and KNN

Ashwini Pawale[1,*], Anuradha Dadasaheb Thombare[2], Prajakta Prabhakar Landge[2], Gauri Babaji Gadge[2], Dipti Sopan Dake[2]

Abstract

Smart Cities are being developed with the goal of providing a comfortable living environment for humans. One of the services these cities will offer is eco-friendly waste collection and processing. This study proposes an Internet of Things (IoT)-based system architecture designed to enable dynamic waste collection and delivery to processing plants or designated waste disposal sites. Traditionally, waste collection was managed in a relatively static manner using conventional operations research methods. However, as suggested in this study, the widespread use of sensors, actuators, and robust mobile communication networks enables IoT-driven dynamic solutions to optimize waste fleet management, collection routes, and organized waste pickup. We introduce a dynamic scheduling model based on object-oriented principles to address the challenges of near-real-time scheduling driven by sensor data streams. An Android app with a user-friendly interface is developed and implemented to demonstrate the feasibility of this system and assess a waste collection scenario using experimental data. Finally, the proposed models are evaluated using both synthetic and real data from the St. Petersburg, Russia metropolitan area, showing consistency and accuracy.

Keywords: Waste management system, disposal, collection, IoT

INTRODUCTION

Waste management has emerged as one of the most pressing challenges in contemporary society, particularly in rapidly urbanizing regions where population density continues to rise. The traditional approach to waste management, which largely relies on manual collection, transportation, and disposal, has become increasingly unsustainable [1]. These conventional systems are often characterized by inefficiencies such as irregular waste collection schedules, excessive operational costs, and inadequate recycling practices. When left unchecked, such inefficiencies lead to significant consequences including the accumulation of waste in public spaces, emission of harmful gases due to improper disposal, and contamination of soil and water resources. Collectively, these problems not only pose serious threats to public health but also contribute to environmental degradation and climate change [2].

To address these shortcomings, there is growing interest in integrating technology-driven solutions into the waste management process. Smart Waste Management Systems represent a paradigm shift, leveraging advanced technologies such as the Internet of Things (IoT), cloud computing, sensor networks, and data analyticss to optimize every stage of waste handling. By embedding sensors in waste bins, it becomes possible to monitor waste levels in real-time, track the location of bins, and communicate directly with central control systems [3]. This allows for the dynamic scheduling of waste collection, ensuring that bins are emptied only when necessary, thereby reducing redundant collection trips and minimizing fuel consumption [4]. Beyond operational efficiency, such systems hold significant environmental and economic benefits.

***Author for Correspondence**
Ashwini Pawale
E-mail: ashvinijspm@gmail.com

[1]Professor, Department of Information Technology, Savitribai Phule Pune University, Pune, India
[2]Bachelor Students, Department of Information Technology, Savitribai Phule Pune University, Pune, India

Received Date: February 18, 2025
Accepted Date: June 20, 2025
Published Date: September 20, 2025

Citation: Ashwini Pawale, Anuradha Dadasaheb Thombare, Prajakta Prabhakar Landge, Gauri Babaji Gadge, Dipti Sopan Dake. Smart Waste Management System Using IoT and KNN. Research & Reviews: Journal of Embedded System & Applications. 2025; 13(3): 42–46p.

© STM Journals 2025. All Rights Reserved

With optimized collection routes, municipalities can reduce their carbon footprint, decrease dependency on manual labor, and lower transportation expenses [5]. Additionally, the integration of analytics enables authorities to study patterns in waste generation, seasonal variations, and demographic trends. This data-driven insight supports the design of better recycling campaigns, allocation of resources, and policymaking initiatives aimed at sustainability. Furthermore, by automating much of the monitoring and reporting processes, human error and delays in communication can be minimized [6].

In essence, Smart Waste Management Systems are not just tools for optimizing collection but are holistic solutions that support environmental stewardship [7]. They encourage responsible waste disposal practices, facilitate recycling, and contribute to building smart cities that are cleaner, greener, and more sustainable. By reducing the inefficiencies of traditional systems, such technological innovations create long-term value for communities, governments, and the environment [8]. Ultimately, the adoption of smart waste management approaches is a necessary step forward in meeting the sustainability goals of urban societies.

LITERATURE REVIEW

Research on smart and sustainable waste management has expanded significantly in recent years, with scholars and practitioners exploring the potential of IoT, sensor technology, and data-driven platforms to transform traditional methods of collection and disposal [9]. Various studies have emphasized how integrating digital systems with waste handling processes can optimize operations, reduce environmental harm, and improve urban living conditions [10].

One stream of research highlights the design and development of IoT-enabled garbage bins. These systems typically employ ultrasonic sensors to detect fill levels, microcontrollers for processing, and communication modules for transmitting real-time data. The advantage of such designs is the ability to notify authorities when bins approach capacity, preventing waste overflow in densely populated areas [11]. These solutions demonstrate how sensor-based monitoring can make waste management more proactive rather than reactive.

Other studies have focused on integrating IoT platforms with mobile and web-based applications for municipal authorities and the public. Such systems often utilize cloud servers to store and process data, which can then be displayed on interactive dashboards [12]. These dashboards not only allow city administrators to monitor the current state of waste bins but also enable predictive analytics for future planning. For instance, scalable dashboards have been proposed for smart cities, where modular frameworks can be adapted to different urban needs. The addition of mobile notifications and geolocation services ensures that waste management becomes a more transparent and participatory process [13].

There is also significant discussion in the literature about the broader role of waste management within the larger framework of smart cities. Studies suggest that efficient waste management is not an isolated system but rather part of an interconnected urban ecosystem that includes transportation, energy, and public safety [14]. Research indicates that testbeds for smart city applications are essential for validating new technologies before large-scale deployment. Through controlled experimental setups, municipalities can assess performance, identify limitations, and fine-tune their solutions to local requirements.

Another important aspect raised in academic work is the strategic planning of sustainability indicators. Some frameworks classify performance metrics not just by technological efficiency but also by social and environmental impact. Such approaches highlight that smart waste management should not only focus on efficiency but also support long-term ecological balance and cost-effective governance [15]. By applying these frameworks in real-world municipalities, researchers have demonstrated the potential for significant improvements in both sustainability outcomes and urban quality of life.

© STM Journals 2025. All Rights Reserved

Collectively, the literature reveals a consistent trend: waste management is evolving from a labor-intensive, resource-heavy practice into a sophisticated, technology-driven system. The convergence of IoT, data analytics, and strategic planning is enabling cities to move closer to sustainable living, making smart waste management a cornerstone of future urban development.

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:

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.

System Design

Low-Level Architecture

- Infrared sensors installed in bins detect waste levels.
- Microcontrollers (Arduino) process sensor data and trigger the IoT module to communicate with the central system (Figure 1).
- The Admin Module oversees data visualization and displays waste levels on dashboards.

Block Diagram Overview

- *Transmitter Section:*
  - Includes sensors, Arduino, and the IoT module.
  - When a bin reaches its capacity, the infrared sensor activates the Arduino, which sends notifications via the IoT module to the control system.
- *Receiver Section:*
  - Includes the Admin Module connected to a central monitoring system.
  - Displays bin statuses and dispatches alerts to contractors for waste collection.

Waste Collection Workflow

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 (Figure 2).

© STM Journals 2025. All Rights Reserved

Figure 1. System Design.

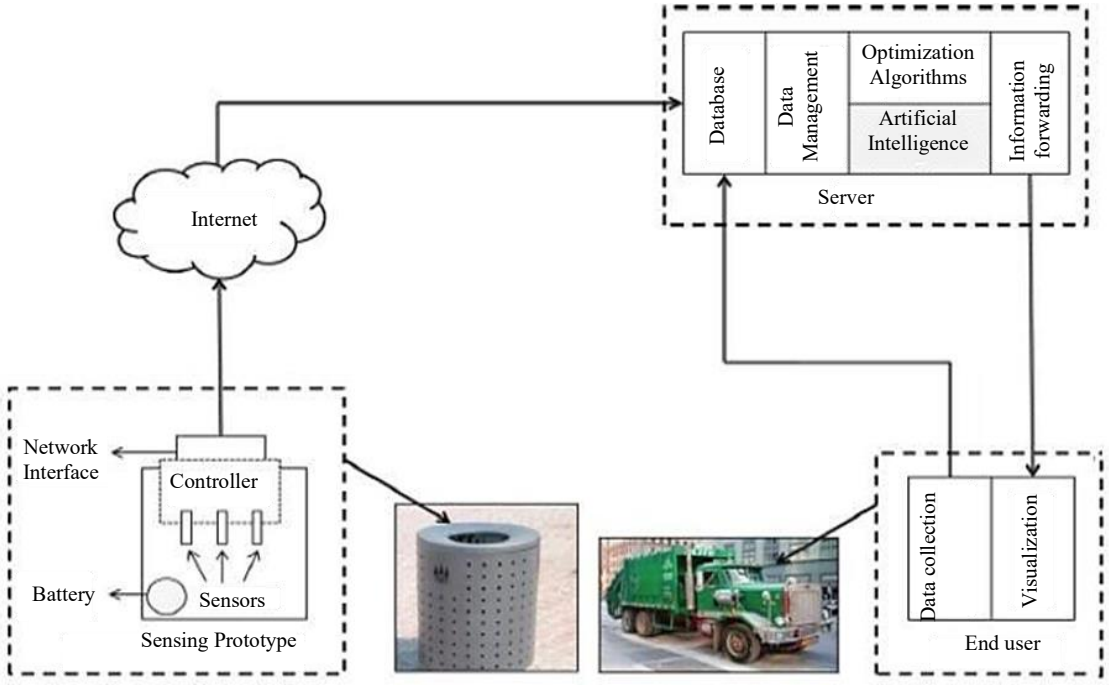

Figure 2. Waste collection workflow.

Module Specifications and Processes

The system employs a hierarchical structure using both small and large trucks for waste transportation. Waste is processed at facilities close to disposal sites to improve recycling efforts and minimize reliance on landfills. This structured methodology ensures efficient monitoring, smart scheduling, and optimal resource usage, paving the way for sustainable waste management in urban areas.

© STM Journals 2025. All Rights Reserved

CONCLUSION

The proposed approach can be applied to maintain cleanliness in our city. By leveraging system status, real-time accurate data from the implemented system can be used for an efficient solid waste management framework. The system can collect precise real-time data, which can then be utilized as input for a management system. 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.

REFERENCES

1. Jain P, Chaudhary T, Gajjar S. Design and development of smart waste management system. In 2023 IEEE international conference on communication system, computing and IT applications (CSCITA). 2023 Mar 31; 199–203.
2. Shome B, Deb A, Ghosh S, Shukla A, Prasad A, Biswas R, Nandy A. Smart Waste Management: A Revolutionary Step Towards a Better India. In International Conference on Innovation in Modern Science and Technology. Cham: Springer International Publishing; 2019 Sep 20; 678–683.
3. Singhvi RK, Lohar RL, Kumar A, Sharma R, Sharma LD, Saraswat RK. IoT Based Smart waste management system: India prospective. In 2019 IEEE 4th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU). 2019 Apr 18; 1–6.
4. Shyam GK, Manvi SS, Bharti P. Smart waste management using Internet-of-Things (IoT). In 2017 IEEE 2nd international conference on computing and communications technologies (ICCCT). 2017 Feb 23; 199–203.
5. Fazio M, Paone M, Puliafito A, Villari M. Heterogeneous sensors become homogeneous things in smart cities. In 2012 IEEE sixth international conference on innovative mobile and internet services in ubiquitous computing. 2012 Jul 4; 775–780.
6. Balakrishna C. Enabling technologies for smart city services and applications. In 2012 IEEE sixth international conference on next generation mobile applications, services and technologies. 2012 Sep 12; 223–227.
7. Sánchez López T, Ranasinghe DC, Harrison M, McFarlane D. Adding sense to the Internet of Things: An architecture framework for Smart Object systems. Pers Ubiquitous Comput. 2012 Mar; 16(3): 291–308.
8. Jara AJ, Lopez P, Fernandez D, Castillo JF, Zamora MA, Skarmeta AF. Mobile digcovery: discovering and interacting with the world through the internet of things. Pers Ubiquitous Comput. 2014 Feb; 18(2): 323–38.
9. Suakanto S, Supangkat SH, Saragih R. Smart city dashboard for integrating various data of sensor networks. In IEEE International Conference on ICT for Smart Society. 2013 Jun 13; 1–5.
10. Carli R, Dotoli M, Pellegrino R, Ranieri L. Measuring and managing the smartness of cities: A framework for classifying performance indicators. In 2013 IEEE international conference on systems, man, and cybernetics. 2013 Oct 13; 1288–1293.
11. Priano FH, Guerra CF. A framework for measuring smart cities. In Proceedings of the 15th annual international conference on digital government research. 2014 Jun 18; 44–54.
12. Nam T, Pardo TA. Smart city as urban innovation: Focusing on management, policy, and context. In Proceedings of the 5th international conference on theory and practice of electronic governance. 2011 Sep 26; 185–194.
13. Olivares T, Royo F, Ortiz AM. An experimental testbed for smart cities applications. In Proceedings of the 11th ACM international symposium on Mobility management and wireless access. 2013 Nov 3; 115–118.
14. Baltac V. Smart cities—A view of societal aspects. Smart Cities. 2019 Dec 9; 2(4): 538–48.
15. Chen B, Liang W, Yu JX. Online time interval top-k queries in wireless sensor networks. In 2010 IEEE Eleventh International Conference on Mobile Data Management. 2010 May 23; 177–182.

© STM Journals 2025. All Rights Reserved