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Smart Waste Management Using IoT: A Sustainable Model for Umarkhed, Yavatmal, Maharashtra

An IoT-Based Approach for Real-Time Waste Monitoring and Improved Municipal Collection

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Abstract
Solid waste management is an important environmental and municipal challenge in small and medium-sized towns. Conventional collection systems are useful, but they may provide limited information about the actual filling condition of individual waste bins between collection rounds. This paper proposes a practical Internet of Things (IoT)-based smart waste management model for Umarkhed, Yavatmal, Maharashtra. The study combines a local field assessment with a low-cost technology framework intended to complement the existing municipal waste collection system. A field-based assessment was carried out by direct observation in Umarkhed during July, August and September, covering approximately 30 locations across the market, bus stand, residential and college areas. Around seven to eight existing waste-bin locations were observed during the assessment. Several bins were approximately 40–50% filled, while one or two locations showed overflow conditions. Roadside and public-place disposal was also observed. Informal interactions with local shopkeepers, students and residents indicated concerns about waste being thrown outside bins, spreading of waste by stray animals, and variation in collection timing in some areas. The existing Ghantagadi collection system was observed as an important part of local waste collection, including wet and dry waste separation during collection. Based on these observations, the paper proposes a 15-bin pilot model using ultrasonic fill-level sensors, an ESP32-class microcontroller, IoT communication, cloud-based data storage and a municipal dashboard. A 90% fill-level threshold is proposed for generating a collection alert. The model does not claim measured performance or cost savings because a full hardware pilot has not yet been deployed. Instead, it provides a practical implementation and evaluation framework that can be tested by the municipal authority. The study highlights that smart waste management is not only a technology problem; it also involves collection scheduling and citizen disposal behaviour. Therefore, the proposed model combines IoT monitoring, existing waste collection services and citizen awareness for a cleaner and more sustainable Umarkhed.

***Keywords**: Internet of Things, Smart Waste Management, Umarkhed, Yavatmal, Smart Bin, Municipal Waste, ESP32, Environmental Sustainability*

1. Introduction

Municipal solid waste management requires regular collection, transportation, segregation, processing and safe disposal. In smaller towns, the challenge is often not the absence of a collection service but the difficulty of maintaining timely collection, monitoring public waste points and encouraging proper disposal behaviour. When information about a bin's condition is available only through periodic physical observation, an overflowing bin may remain unnoticed until the next collection visit.

IoT provides a practical way of connecting physical objects to a digital monitoring system. In a smart waste application, sensors can measure the fill level of a bin and transmit the information to a server or dashboard. Recent research reviews describe sensor-based monitoring, automatic notifications and data-driven collection planning as important directions in smart municipal waste management. Ahmed et al. (2024), for example, reviewed AI- and IoT-based municipal waste architectures in which sensor information is used to notify municipal staff when a bin requires attention. Esmaeilian et al. (2018) also identified intelligent infrastructure and on-time collection as important components of smart and sustainable waste management. Sharma et al. (2020) highlighted that connectivity, standardization, policy support and implementation cost can influence IoT adoption in the Indian waste-management context.

The local context is important for a practical research study. The Maharashtra Directorate of Municipal Administration lists Umarkhed Municipal Council as a B-Class municipal council, with a 2011 Census population of 47,458 and an area of 27.51 square kilometres. The official Yavatmal district website also lists Umarkhed Municipal Council as a municipal authority. The Yavatmal District Environment Plan reports that the district has 17 Urban Local Bodies and, in the data used for that plan, total solid-waste generation was 183.81 metric tonnes per day, comprising approximately 101.09 MTD wet waste and 82.71 MTD dry waste. These district-

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level figures provide a broader environmental context, but they are not treated as Umarkhed-specific measurements in this study.

The present work therefore focuses on a simple question: how can IoT monitoring complement the existing waste collection system in Umarkhed without requiring an unnecessarily complex or expensive smart-city infrastructure?

2. Literature Review

Research on smart waste management has moved from simple sensor-based bin monitoring toward integrated systems involving IoT, cloud computing, route planning, artificial intelligence and citizen participation. Esmaeilian et al. (2018) reviewed smart and sustainable waste-management research and emphasized intelligent infrastructure for proper separation, timely collection and recovery. Their work supports the idea that waste management should be connected to broader sustainability goals rather than treated only as a collection problem.

Sharma et al. (2020) examined IoT adoption barriers in the Indian smart-city waste-management context. Their findings point to issues such as Internet connectivity, lack of standardization, policy and regulatory support, technical knowledge, privacy and operational considerations. These issues are particularly relevant when a technology model is proposed for a smaller town. A technically advanced system may not be practical if it is difficult to maintain or depends on infrastructure that is not consistently available.

Ahmed et al. (2024) reviewed AI- and IoT-driven municipal waste-management architectures and described systems in which sensor data can trigger notifications to municipal offices and collection personnel. Their review also connects smart monitoring with potentially better collection efficiency and route planning. A more recent review by Engineering Reports (2025) discusses the role of AI and IoT in waste collection, sorting and recycling and stresses the importance of collaboration among government, technology providers and the public.

The literature therefore suggests three principles relevant to the present study: first, real-time sensing can improve visibility of waste-bin conditions; second, technology should be adapted to local infrastructure and implementation constraints; and third, public participation remains important. The present paper applies these principles to a Umarkhed-specific pilot model rather than claiming that a generic smart-city architecture can simply be transferred without local assessment.

3. Research Work and Field Assessment

The research uses a field-based case-study approach combined with a proposed IoT system design. The local assessment was conducted by the author through direct observation during July, August and September. Approximately 30 locations were considered across the Umarkhed market, bus stand, residential areas and college area. The assessment was intended to understand the existing waste situation and identify practical locations and requirements for a technology-assisted system.

Approximately seven to eight existing waste-bin locations were observed. Several of the observed bins were around 40–50% filled at the time of observation, while one or two locations showed overflow conditions. Waste was also observed outside bins and at public places. Informal interactions with local shopkeepers, students and residents indicated that the problem was not limited to the physical availability of bins. People reported that waste is sometimes thrown on roads or in open public spaces and that stray animals can spread waste after disposal.

The existing Ghantagadi collection service was also considered in the assessment. The local system provides door-to-door or area-based collection, and wet and dry waste separation was observed in the collection process. However, the field interactions indicated that collection does not always occur at a single predictable time in every area and that some locations may experience a gap of two or three days. These observations suggest a gap between having a collection service and having real-time information about where collection is most urgently required.

The assessment therefore supports a complementary model rather than replacement of the existing system. The proposed IoT system is designed to tell the municipal authority which monitored bins are approaching capacity. The existing collection workforce and vehicles can then respond to the alert.

4. Proposed IoT-Based Smart Waste Management Model

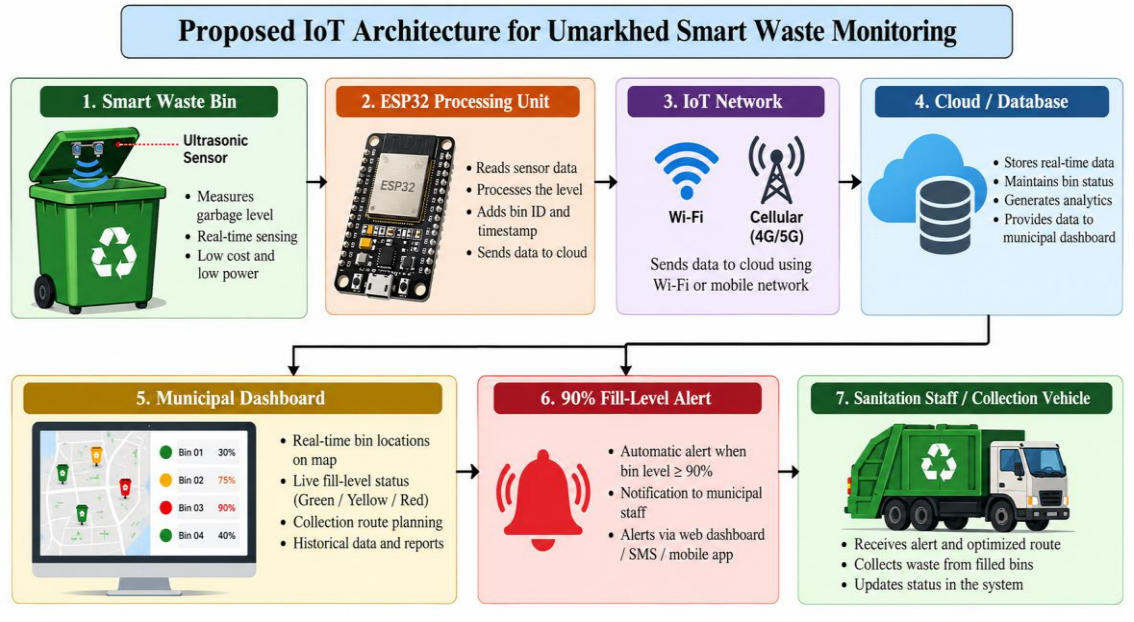


Figure 1. Proposed IoT architecture for Umarkhed smart waste monitoring.

The proposed system contains five practical components. First, a smart waste bin is fitted with an ultrasonic sensor that measures the distance between the sensor and the upper surface of the waste. Second, an ESP32-class microcontroller reads the sensor and prepares the data. Third, an available wireless connection transmits the reading. Fourth, a cloud or local server stores the bin information and presents it through a municipal dashboard. Fifth, the dashboard generates an alert when a monitored bin reaches the selected threshold.

For a simple implementation, the fill percentage can be estimated using the usable bin height (H) and the measured distance from the sensor to the waste surface (D):

Fill Level (%) = ((H − D) / H) × 100

A proposed status scheme is: 0–50% Normal, 51–75% Moderate, 76–89% High, and 90% or above Collection Required. The 90% threshold is a design choice for the proposed pilot and should be calibrated during actual field testing.

The system should record Bin ID, location, fill level, date, time, communication status and collection status. This creates a basic historical database. Over time, the data can show which locations fill quickly, when waste accumulation is highest and how frequently collection is required.

5. Umarkhed 15-Bin Pilot Implementation

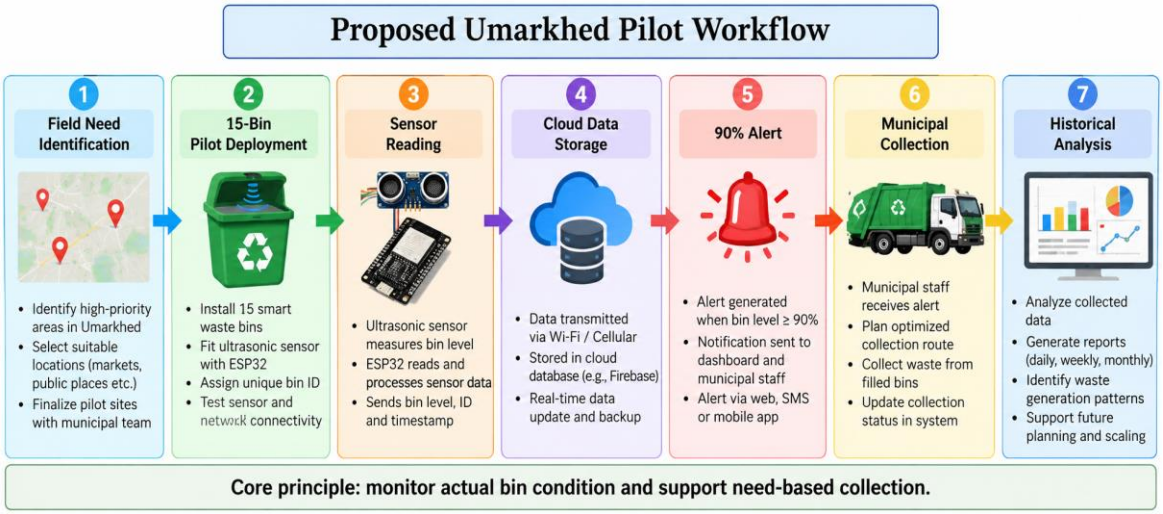


Figure 2. Proposed workflow for the Umarkhed 15-bin pilot.

A full-town deployment is not recommended as the first step. The proposed study recommends a 15-bin pilot so that the technical and operational performance can be evaluated before expansion. Priority locations can include the main market, bus stand, college area, garden/public areas and selected high-footfall residential or commercial points. Exact placement should be finalized through a joint site survey with the municipal authority.

The pilot can be implemented in four stages. Stage 1 is site selection and baseline observation. Stage 2 is installation and calibration of sensors. Stage 3 is continuous monitoring and recording of alerts, communication failures, battery condition and collection response. Stage 4 is evaluation and decision-making for wider deployment.

The proposed pilot is intentionally simple. It does not require cameras, artificial intelligence or complicated robotics in the first phase. These technologies can be considered later if the basic sensing and collection workflow proves reliable. Keeping the first phase simple can reduce maintenance and training requirements and make the system more appropriate for a smaller municipal setting.

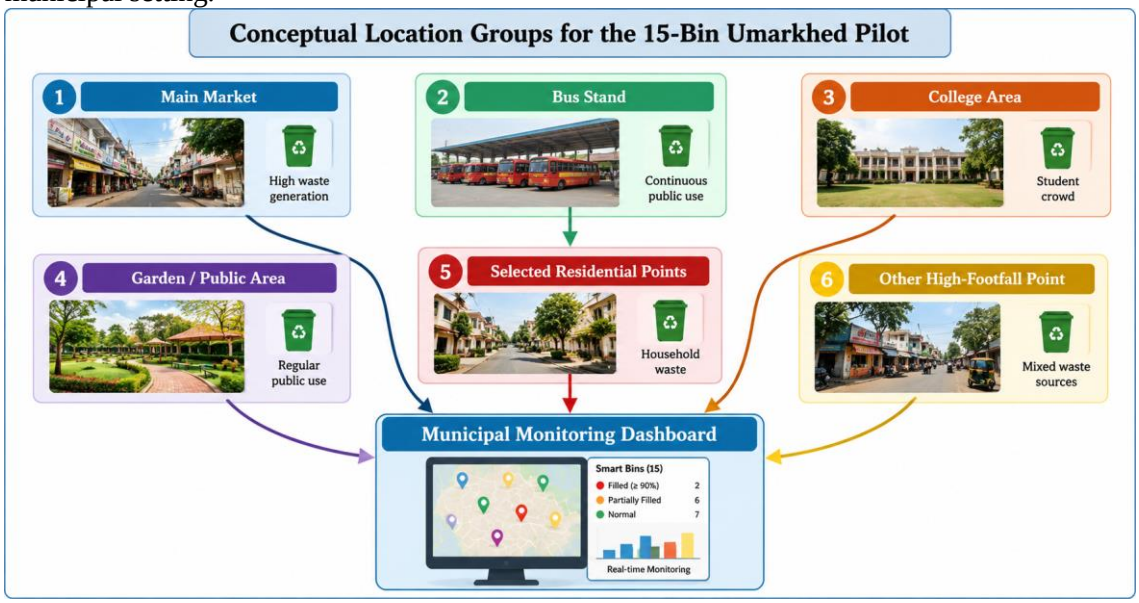


Figure 3. Conceptual location groups for the proposed 15-bin Umarkhed pilot.

6. Results and Discussion

The field assessment produced several practical findings. First, waste-management conditions were not uniform across the observed locations. Some bins were only partially filled, while one or two observed locations showed overflow. This indicates that fixed collection schedules alone may not always correspond to the actual condition of every bin.

Second, roadside and public-place disposal was observed. Local interactions also highlighted the role of citizen disposal behaviour and the spreading of waste by stray animals. This finding is important because an IoT system can monitor a bin, but it cannot by itself prevent a person from throwing waste outside the bin. Technology therefore needs to be combined with awareness, clear disposal points and regular collection.

Third, the existing Ghantagadi service is an important foundation rather than a system that needs to be replaced. The field assessment indicates that the main opportunity is to add a digital monitoring layer to the existing service. A real-time alert can help staff prioritize a bin that is near capacity while other bins remain within a normal range.

Fourth, the proposed 90% alert threshold provides a simple decision rule. For example, when Bin UB-05 reaches 90%, the municipal dashboard can display “Collection Required.” The sanitation team can then schedule the appropriate vehicle. After collection, the bin status can be updated and the next cycle can begin.

The proposed model should not yet be described as having reduced fuel use, reduced collection cost or reduced overflow incidents because those outcomes require a measured pilot. Instead, these are evaluation targets for future implementation. This distinction keeps the research evidence-based.

7. Evaluation Framework

A future pilot can evaluate the system using measurable technical and operational indicators. Sensor accuracy can be assessed by comparing sensor readings with manual measurements. Alert accuracy can be calculated from correct and incorrect alerts. Response time can be measured from the moment a bin crosses the threshold to the completion of collection. Overflow events can be recorded before and during the pilot. Communication reliability, battery life and maintenance requirements can also be documented.

A simple evaluation table is given below.

Parameter	Proposed Measurement
Sensor accuracy	Sensor reading compared with manual fill-level measurement
Alert accuracy	Correct alerts compared with total alerts
Response time	Time between 90% alert and completed collection
Overflow events	Number of observed overflow incidents
Communication reliability	Successful transmissions compared with attempted transmissions
Battery performance	Operating duration between battery maintenance events
Operational usability	Feedback from municipal/sanitation staff

8. Citizen Awareness and Responsible Use

The field assessment suggests that citizen behaviour is an important part of the local waste problem. Therefore, the proposed model includes a small awareness component. Each smart-bin location can display clear instructions such as “Please use the bin. Do not throw waste on the road.” Where appropriate, separate wet- and dry-waste instructions can be displayed.

A future version may include a QR code linking citizens to collection information, waste-segregation guidance and a complaint/reporting mechanism. Such features should be introduced only after the basic monitoring system is stable. The goal is to use technology to support municipal service delivery and public responsibility, not to create an unnecessarily complex application.

9. Limitations

- The present work is a local field assessment and proposed pilot design; it is not a full-scale hardware deployment.
- The observed bin count and fill levels are field observations and are not intended to represent every waste bin in Umarkhed.
- The study does not claim measured cost, fuel, time or environmental savings before a pilot is conducted.
- Sensor readings can be affected by irregular waste surfaces, moisture, dust and maintenance conditions.
- Internet availability, power supply, device security and municipal staff training must be considered during implementation.
- The proposed 90% threshold should be calibrated using actual local operating data.

10. Future Scope

Future work can extend the pilot in several directions. Historical fill-level data can be used for waste-generation prediction and collection-route planning. A mobile application can provide alerts to sanitation workers. GPS can be added to collection vehicles for route tracking. Computer vision can later support waste classification, while solar power can be explored for autonomous sensor operation. GIS mapping can help the municipality visualize monitored locations and recurring waste hotspots.

After technical validation, the model could be expanded from 15 bins to a larger set of locations. A comparative study could then measure overflow frequency, collection response time, vehicle movement, operating cost and citizen complaints before and after implementation. Such measured evidence would allow the proposed model to develop from a conceptual pilot into a validated municipal waste-management system.

11. Conclusion

This paper presents a practical IoT-based smart waste management model designed for Umarkhed, Yavatmal, Maharashtra. The study is grounded in a local field assessment that

identified partially filled and overflowing bins, roadside waste disposal, waste spreading by stray animals and variation in collection timing in some areas. At the same time, the existing Ghantagadi collection system and wet/dry waste separation provide a useful operational foundation.

The proposed solution does not attempt to replace the existing municipal system. Instead, it adds a real-time monitoring layer using an ultrasonic sensor, ESP32-class controller, IoT communication, cloud/database storage and a municipal dashboard. A 15-bin pilot with a proposed 90% alert threshold offers a manageable starting point for testing the concept.

The central finding of the study is that smart waste management should combine technology with municipal operations and citizen responsibility. IoT can provide information about bin conditions, but sustainable waste management also depends on timely collection, appropriate disposal behaviour and continued public awareness. The proposed Umarkhed model therefore provides a simple and scalable pathway toward cleaner public spaces and more data-informed municipal waste management.

References

1. Ahmed, K., Dubey, M. K., Kumar, A., & Dubey, S. (2024). Artificial intelligence and IoT driven system architecture for municipality waste management in smart cities: A review. Measurement: Sensors, 36, 101395. https://doi.org/10.1016/j.measen.2024.101395
2. Directorate of Municipal Administration, Government of Maharashtra. (2026). Regional offices contact information: Umarkhed Municipal Council. https://mahadma.maharashtra.gov.in/
3. Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C., & Behdad, S. (2018). The future of waste management in smart and sustainable cities: A review and concept paper. Waste Management, 81, 177–195. https://doi.org/10.1016/j.wasman.2018.09.047
4. Maharashtra Pollution Control Board. (2021). District Environment Plan: Yavatmal. Government of Maharashtra. https://mpcb.gov.in/sites/default/files/environmentactionplan/Yavatmal23062021.pdf
5. Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. Journal of Cleaner Production, 270, 122047. https://doi.org/10.1016/j.jclepro.2020.122047
6. Yavatmal District Administration. (2026). Municipal Council Umarkhed. Government of Maharashtra. https://yavatmal.gov.in/en/public-utility/municipal-council-umarkhed/
7. Engineering Reports. (2025). Revolutionizing urban solid waste management with AI and IoT: A review of smart solutions for waste collection, sorting, and recycling. Results in Engineering, 25, 104018. https://doi.org/10.1016/j.rineng.2025.104018