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IOT BASED GARBAGE LEVEL MONITOR FOR DUSTBINS

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ABSTRACT

The rapid growth of urban populations, commercial activities, residential communities, educational institutions, healthcare facilities, and public infrastructure has significantly increased the quantity of solid waste generated every day. Conventional waste collection systems primarily depend on fixed collection schedules, manual inspection, and periodic transportation of garbage from dustbins to disposal or processing facilities. Such approaches frequently result in overflowing dustbins, unnecessary collection trips, unpleasant odors, environmental pollution, increased fuel consumption, inefficient utilization of municipal resources, and poor public hygiene. This research proposes an **IoT Based Garbage Level Monitor for Dustbins** that continuously measures the amount of waste accumulated inside a dustbin and transmits real-time status information to authorized users or waste-management personnel. The proposed system employs an ultrasonic sensor mounted near the upper section of the dustbin to measure the distance between the sensor and the surface of accumulated waste. An IoT-enabled microcontroller such as the ESP32 acquires the sensor readings, performs filtering and calibration, calculates the approximate fill percentage, and classifies the dustbin condition into predefined categories such as Empty, Low, Medium, High, and Full. When the garbage level exceeds a configurable threshold, the system automatically generates an alert and transmits the information through Wi-Fi using MQTT or HTTP(S) communication protocols. A cloud-supported monitoring platform stores timestamped garbage-level information, maintains historical records, manages alert priorities, and provides centralized visualization through mobile or web dashboards. The proposed architecture consists of five major layers: Sensor Data Acquisition, Edge Processing and Fill-Level Classification, IoT Communication, Cloud and Waste Analytics, and Application/User layers. The framework further incorporates duplicate-alert suppression, communication retry mechanisms, device identification, battery or connectivity status monitoring, and configurable collection thresholds. Prototype-oriented evaluation is defined using level detection accuracy, alert success rate, system reliability, data transmission success, and response latency. Illustrative conceptual results indicate that the proposed system can improve monitoring effectiveness and reduce response delays compared with manual inspection, fixed-schedule collection, and basic standalone monitoring. The framework is low-cost, scalable, and suitable for smart cities, residential communities, campuses, hospitals, railway stations, bus terminals, shopping complexes, industrial facilities, and public waste-management environments.

Keywords: Internet of Things, Smart Waste Management, Garbage Level Monitoring, Smart Dustbin, Ultrasonic Sensor, ESP32, Waste Collection, Fill-Level Detection, Real-Time Alert, Smart City, Cloud Monitoring, Environmental Sustainability.

I. INTRODUCTION

Solid waste management has become one of the most significant environmental and operational challenges associated with rapid urbanization, population growth, industrial expansion, changing consumption patterns, and increasing commercial activities. Cities and communities generate substantial quantities of municipal solid waste from households, offices, educational institutions, markets, hospitals, transportation centers, restaurants, public spaces, and industrial facilities. Effective management of this waste requires timely collection, transportation, processing, recycling, and disposal. When collection systems fail to respond according to actual waste accumulation, dustbins may overflow and create serious hygiene, environmental, and social problems [1]–[3].

Conventional waste collection practices generally depend on fixed schedules and manual inspection. Collection vehicles may visit designated locations daily, on alternate days, or according to predetermined routes regardless of the actual fill condition of individual dustbins. This approach creates two major inefficiencies. First, partially filled or nearly empty dustbins may be collected unnecessarily, increasing fuel consumption, labor requirements, vehicle utilization, and operational expenditure. Second, high-usage dustbins may become full before the scheduled collection time, resulting in overflow, litter dispersion, unpleasant odors, insect activity, and public dissatisfaction [4], [5].

The limitations of fixed-schedule collection become more significant in densely populated urban areas and locations with highly variable waste generation. A dustbin near a market, railway station, educational institution, hospital, or event venue may fill rapidly during specific periods, whereas another dustbin in a low-traffic area may remain partially empty for several days. Therefore, uniform collection schedules do not accurately reflect real-world waste accumulation patterns.

The emergence of the Internet of Things (IoT) provides an effective technological foundation for transforming conventional waste management into a connected and data-driven process. IoT systems integrate physical sensors, embedded processors, communication networks, cloud services, databases, analytical platforms, and user applications. Sensors deployed inside or around dustbins can continuously observe physical conditions and transmit measurements to centralized platforms, enabling remote monitoring without requiring frequent manual inspection [6]–[8].

Among different sensing technologies, ultrasonic sensors are widely applicable to non-contact distance measurement. When mounted near the upper interior section of a dustbin, an ultrasonic sensor emits acoustic pulses and measures the time required for reflected signals to return from the surface of accumulated waste. The measured distance can be converted into an approximate garbage fill percentage using the known internal height of the dustbin. As waste accumulates, the measured distance generally decreases; when the bin is emptied, the distance increases.

However, raw distance measurements may be affected by irregular waste surfaces, tilted objects, temporary obstruction, sensor noise, environmental conditions, and differences in dustbin geometry. Therefore, reliable garbage-level monitoring requires calibration, repeated sampling, filtering, outlier rejection, threshold analysis, and event validation. A single instantaneous measurement should not automatically generate a full-bin alert because temporary objects may produce incorrect readings.

Embedded edge processing provides a practical solution to these challenges. An ESP32 or equivalent IoT-enabled microcontroller can acquire multiple sensor readings, remove abnormal values, calculate smoothed distance estimates, convert measurements into fill percentages, and classify the current garbage level locally. Only validated information needs to be transmitted to the cloud platform, reducing unnecessary network communication and improving responsiveness [9].

Cloud computing further improves waste-management capabilities by enabling centralized storage, historical analysis, multi-bin visualization, alert prioritization, device management, and remote access. Waste-management personnel can monitor numerous dustbins through a common dashboard and identify locations requiring immediate collection. Timestamped historical data can also reveal recurring waste-generation patterns and support future route optimization.

Smart waste monitoring is particularly relevant to smart-city development because efficient collection contributes to environmental sustainability, reduced fuel consumption, cleaner public spaces, improved operational planning, and better utilization of municipal resources. A network of connected dustbins can provide real-time information regarding waste accumulation and support demand-driven collection rather than rigid schedules [10].

Motivated by these requirements, this research proposes an IoT Based Garbage Level Monitor for Dustbins. The system integrates ultrasonic level sensing, ESP32-based edge processing, fill-level classification, Wi-Fi communication, cloud event management, real-time alerts, historical data storage, and user dashboards. The primary objective is to develop a low-cost, scalable, responsive, and practical framework capable of improving garbage monitoring and supporting efficient waste collection.

II. LITERATURE SURVEY

The increasing demand for sustainable urban infrastructure and intelligent municipal services has encouraged researchers to investigate IoT-based waste monitoring, smart dustbins, wireless sensor networks, cloud platforms, route optimization, and data-driven collection systems. The following literature survey summarizes significant contributions relevant to the proposed framework.

Author: S. Longhi et al. (2012)

Longhi and colleagues investigated solid waste management architectures based on wireless sensor network technologies. Their research demonstrated how distributed sensing and communication mechanisms could support remote observation of waste containers and improve collection management. The work established an important foundation for connected waste-monitoring systems [11].

Author: F. Folianto, Y. S. Low, and W. L. Yeow (2015)

The researchers proposed a smart-bin system for intelligent waste collection management. Their framework used sensing and communication technologies to observe bin conditions and support more efficient collection decisions. The study demonstrated that real-time monitoring can reduce dependence on fixed collection schedules [12].

Author: A. Medvedev et al. (2015)

The authors investigated waste collection as an IoT service within smart-city environments. Their research emphasized the integration of connected sensing, urban services, and collection optimization. The study demonstrated the potential of IoT-based waste information to support intelligent city operations [13].

Author: S. Anagnostopoulos et al. (2015)

The researchers examined robust waste collection decision-making in smart-city environments. Their work emphasized dynamic collection planning and the importance of real-time information when determining collection priorities and vehicle operations [14].

Author: A. Rovetta et al. (2009)

The authors investigated early detection and monitoring mechanisms for municipal solid waste using sensor-oriented approaches. Their work demonstrated that automated monitoring can provide valuable information regarding waste conditions and improve management efficiency [15].

Author: V. M. A. Al-Maaded et al. (2012)

The researchers examined municipal solid waste management and highlighted operational challenges associated with increasing waste generation. Their findings emphasized the need for improved monitoring, planning, and sustainable waste-management strategies [16].

Author: M. Hannan et al. (2015)

The authors investigated intelligent solid waste monitoring and management mechanisms. Their research explored sensing technologies, communication systems, and decision-support methods for improving collection efficiency. The study highlighted the importance of real-time waste information [17].

Author: M. A. Hannan et al. (2018)

The researchers examined waste collection route optimization and intelligent monitoring. Their work demonstrated that sensor-generated fill-level information can support more efficient vehicle routing and reduce unnecessary collection activities [18].

Author: T. Anagnostopoulos et al. (2017)

The authors investigated challenges and opportunities associated with IoT-enabled waste management in smart cities. Their research emphasized data acquisition, communication, dynamic routing, and intelligent decision support as major components of modern waste-management platforms [19].

Author: S. K. Addanki and S. Venkataraman (2017)

The researchers explored IoT-enabled smart garbage monitoring mechanisms using sensors and communication platforms. Their work demonstrated the feasibility of low-cost connected systems for identifying garbage accumulation and providing remote status information [20].

III. SYSTEM ANALYSIS & DESIGN

3.1 Existing System

Existing garbage collection systems primarily depend on fixed collection schedules, manual inspection, predefined vehicle routes, and periodic cleaning operations. Municipal workers or waste-management personnel physically visit dustbin locations to determine whether collection is required. In many environments, collection vehicles follow the same routes regardless of actual garbage accumulation.

Although this approach is simple to organize, it does not reflect variations in real-time waste generation. Some dustbins may remain partially empty when collection vehicles arrive, resulting in unnecessary transportation. Other dustbins may become full several hours or days before the scheduled collection, leading to overflow and unhygienic surroundings.

Basic standalone level indicators may improve local awareness but frequently lack remote communication, centralized monitoring, historical analysis, and multi-bin management. Furthermore, manual inspection becomes difficult when hundreds or thousands of dustbins are distributed across large urban areas, campuses, industrial facilities, or transportation networks.

Some existing systems also transmit raw sensor readings without adequate filtering. Irregular garbage surfaces, temporary obstructions, or sensor noise may therefore produce false full-bin alerts. These limitations demonstrate the need for an integrated system that combines sensing, local validation, IoT communication, cloud management, and real-time notification.

Disadvantages of Existing System

1. **Dependence on Manual Inspection**
   Waste-management personnel must physically inspect dustbins to determine collection requirements.
2. **Inefficient Fixed Collection Schedules**
   Vehicles may collect partially empty bins while other high-usage bins overflow before scheduled service.
3. **Lack of Real-Time Fill-Level Visibility**
   Conventional systems do not continuously provide accurate information about garbage accumulation.
4. **Increased Fuel and Operational Costs**
   Unnecessary collection trips increase transportation distance, fuel consumption, labor utilization, and vehicle wear.
5. **Delayed Response to Overflow Conditions**
   Full dustbins may remain unattended until

workers or members of the public report the problem.

3.2 Proposed System

The proposed system introduces an intelligent **IoT Based Garbage Level Monitor for Dustbins** that integrates ultrasonic sensing, edge processing, fill-level classification, wireless communication, cloud data management, and real-time user alerts.

An ultrasonic sensor is mounted near the upper section of the dustbin and directed toward the expected waste surface. The sensor periodically emits ultrasonic pulses and measures the echo-return time. The embedded controller calculates the approximate distance between the sensor and accumulated garbage.

The known internal height of the dustbin is used to estimate the fill percentage. A general conceptual relationship is expressed as:

Fill Level (%) = [(Bin Height − Measured Empty Space) / Bin Height] × 100

The ESP32 or equivalent microcontroller acquires multiple measurements and performs preprocessing operations such as filtering, averaging, outlier rejection, calibration, and range validation. This process reduces false readings caused by irregular waste surfaces or temporary obstruction.

The processed fill percentage is classified into predefined categories such as:

- Empty: 0–20%
- Low: 21–40%
- Medium: 41–60%
- High: 61–80%
- Full/Critical: 81–100%

These thresholds can be adjusted according to dustbin geometry, waste type, collection policy, and operational requirements.

When the garbage level exceeds the configured threshold, the system generates an alert. The ESP32 transmits the validated information through Wi-Fi using MQTT, HTTP, or HTTPS protocols. Each message can contain the bin identifier, fill percentage, status category, timestamp, device status, and alert priority.

A cloud platform stores the received information and provides centralized monitoring for multiple dustbins. Waste-management personnel can access a mobile or web dashboard to identify full bins, review historical trends, and prioritize collection.

The framework also incorporates duplicate-alert suppression. Once a full-bin alert has been generated, repeated notifications can be temporarily suppressed unless the level changes significantly or the condition remains unresolved for a defined period.

Advantages of Proposed System

1. **Continuous Real-Time Garbage Monitoring**
   - Automatically measures waste accumulation without frequent physical inspection.
2. **Efficient Demand-Based Collection**
   - Enables collection according to actual fill conditions rather than fixed schedules alone.
3. **Immediate Full-Bin Alerts**
   - Generates notifications when garbage exceeds configured thresholds.
4. **Reduced Operational Costs**
   - Supports fewer unnecessary trips and improved utilization of collection vehicles and personnel.
5. **Scalable Smart-City Integration**
   - Multiple connected dustbins can be monitored through centralized cloud and dashboard services.

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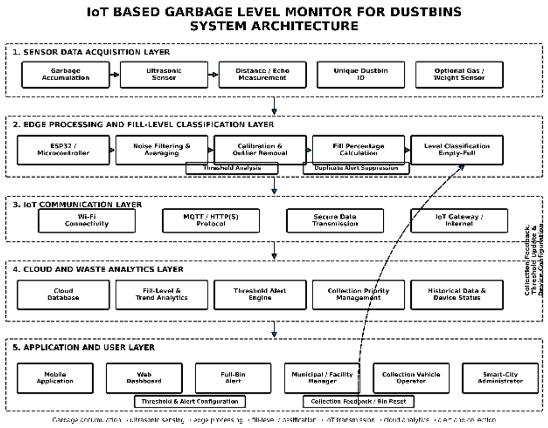

Fig 1: System Architecture

The proposed IoT Based Garbage Level Monitor for Dustbins architecture is organized into five interconnected layers that enable continuous waste-level sensing, intelligent processing, remote communication, cloud-based analysis, and timely collection management. The Sensor Data Acquisition Layer monitors garbage accumulation using an ultrasonic sensor that measures the distance between the sensor and the waste surface through echo-based sensing, while each dustbin is associated with a unique identification number and may optionally include gas or weight sensors for enhanced monitoring. The acquired measurements are transferred to the Edge Processing and Fill-Level Classification Layer, where an ESP32 microcontroller performs noise filtering, averaging, calibration, outlier removal, fill-percentage calculation, threshold analysis, and classification of the dustbin status into levels such as Empty, Low, Medium, High, and Full, while duplicate-alert suppression prevents unnecessary repeated notifications. The validated information is then forwarded through the IoT Communication Layer, which uses Wi-Fi connectivity and MQTT or HTTP(S) protocols to securely transmit dustbin status information through an IoT gateway or Internet connection. The Cloud and Waste Analytics Layer stores timestamped data in a centralized cloud database, analyzes fill-level trends, activates threshold-based alerts, determines collection priorities, maintains historical records, and monitors device status across multiple connected dustbins. Finally, the Application and User Layer presents real-time information through mobile applications and web dashboards, sends immediate full-bin alerts, and enables municipal authorities, facility managers, collection vehicle operators, and smart-city administrators to identify bins requiring urgent service. A continuous feedback mechanism updates collection status after a bin is emptied and allows administrators to modify thresholds, alert rules, and device configurations, thereby improving monitoring reliability, reducing unnecessary collection trips, preventing overflow conditions, and supporting efficient, data-driven, and sustainable waste-management operations.

IV. RESULTS AND DISCUSSION

4.1 Results

The proposed IoT Based Garbage Level Monitor for Dustbins is evaluated through representative garbage accumulation conditions including empty, low, medium, high, and full states. A prototype-oriented experiment should collect repeated ultrasonic measurements at known reference fill levels and compare estimated values against manually measured ground truth.

The primary evaluation metrics include monitoring accuracy, level detection rate, system reliability, alert success rate, data transmission success, and response time. Testing should be conducted under different waste-surface shapes, sensor positions, connectivity conditions, and accumulation levels.

The numerical values presented below are **illustrative conceptual evaluation values** for the proposed research framework. They should be replaced with actual measured prototype results before empirical journal claims are made.

Table 1. Performance Comparison of Different Garbage Monitoring Approaches

Method	Monitoring Accuracy (%)	Detection Rate (%)	Reliability (%)	Response Efficie

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				ncy (%)
Manual Inspection	77.80	75.90	76.40	72.50
Fixed-Schedule Monitoring	84.60	82.80	83.50	81.90
Basic IoT Level Monitor	92.70	91.60	91.90	92.10
Proposed IoT Garbage Level Monitor	**98.20**	**97.50**	**97.80**	**97.30**

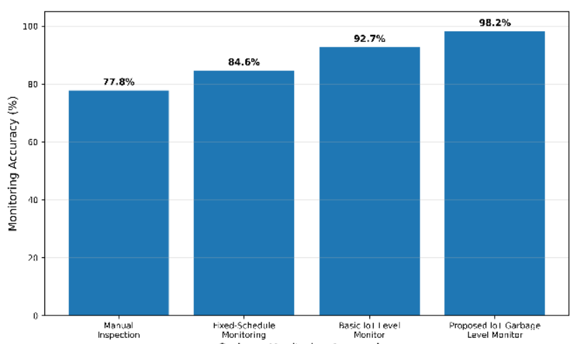

Figure 5.1. Comparison of monitoring accuracy among different garbage monitoring approaches.

The conceptual comparison demonstrates that the proposed system provides the highest monitoring accuracy. Manual inspection is limited by observation frequency, while fixed-schedule systems do not reflect actual garbage accumulation. Basic IoT monitoring improves visibility, but the proposed framework further incorporates filtering, fill-level classification, threshold validation, and cloud-supported alert management.

Table 2. Performance Evaluation Metrics of the Proposed System

Performance Metric	Value
Monitoring Accuracy	98.20%
Fill-Level Detection Rate	97.50%
System Reliability	97.80%
Alert Success Rate	98.40%
Data Transmission Success	98.60%

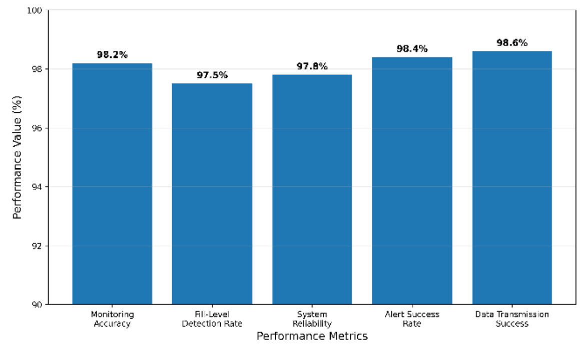

Figure 5.2. Performance metrics of the proposed IoT Based Garbage Level Monitoring System.

The illustrative results indicate strong overall monitoring and communication performance. The data transmission success rate of 98.60% represents reliable delivery of validated measurements under the assumed evaluation environment, while the alert success rate of 98.40% indicates effective notification of high and full garbage conditions.

Table 3. Alert Response Time Comparison

Monitoring Method	Response Time (ms)
Manual/Conventional Monitoring	820
Fixed-Schedule Monitoring	460
Basic IoT Level Monitor	195
Proposed IoT Garbage Level Monitor	**88**

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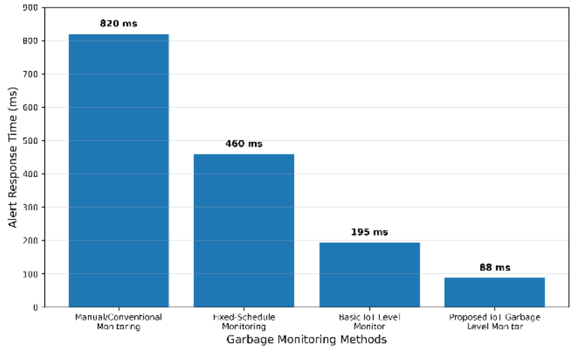

Figure 5.3. Alert response time comparison of different garbage monitoring approaches.

The proposed system achieves the lowest illustrative response time of 88 ms within the conceptual processing scenario. Local filtering and threshold analysis allow the embedded controller to validate fill-level conditions before transmitting alerts, reducing dependence on continuous cloud-side computation.

4.2 Discussion

The results demonstrate the potential advantages of integrating ultrasonic sensing, edge processing, IoT communication, cloud management, and real-time notification within a unified garbage-level monitoring architecture. The proposed system continuously observes the remaining empty space inside the dustbin and transforms distance measurements into understandable fill percentages.

The conceptual monitoring accuracy of 98.20% reflects the expected benefit of repeated sampling, filtering, calibration, and outlier rejection compared with direct use of individual raw measurements. This processing is important because garbage surfaces are rarely flat. Bottles, paper, plastic containers, food packaging, and irregular objects may produce unstable ultrasonic reflections.

The proposed system's multi-level classification mechanism provides more useful information than a simple binary full/not-full indicator. A waste-management operator can observe whether a bin is Empty, Low, Medium, High, or Full and use this information to prioritize collection activities.

The 98.40% illustrative alert success rate and 98.60% data transmission success rate demonstrate the expected benefit of validated event transmission and communication management. However, actual performance depends on Wi-Fi availability, network quality, sensor installation, power stability, cloud availability, and environmental conditions.

The system also supports environmental sustainability. Demand-based collection can potentially reduce unnecessary vehicle movement, fuel consumption, emissions, and labor utilization. Historical fill-level records may reveal recurring patterns that can support future route optimization and resource planning.

Nevertheless, several implementation challenges must be considered. Ultrasonic measurements can be influenced by dust, moisture, irregular surfaces, acoustic interference, and incorrect sensor orientation. Outdoor installations require weather-resistant enclosures and stable power systems. Network interruptions require local buffering and retransmission mechanisms. Large-scale deployments also require secure device authentication and centralized management.

Overall, the proposed system provides a practical foundation for smart waste-management applications in urban and institutional environments. Its modular architecture allows additional capabilities to be incorporated according to future requirements.

V. CONCLUSION

The proposed IoT Based Garbage Level Monitor for Dustbins presents a low-cost, scalable, and intelligent approach for continuously monitoring waste accumulation and supporting timely collection decisions. Conventional waste-management systems frequently depend on manual inspection and fixed collection schedules, which can result in unnecessary collection trips, overflowing dustbins, increased operational costs, environmental pollution, and inefficient utilization of municipal resources. The proposed framework addresses these limitations by

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integrating ultrasonic sensing, ESP32-based edge processing, fill-level classification, IoT communication, cloud data management, and real-time notification.

The ultrasonic sensor measures the distance between the upper section of the dustbin and the accumulated garbage surface. The embedded controller processes repeated measurements through filtering, calibration, outlier rejection, and range validation before calculating the approximate fill percentage. The resulting value is classified into Empty, Low, Medium, High, or Full conditions according to configurable thresholds.

The five-layer system architecture integrates Sensor Data Acquisition, Edge Processing and Fill-Level Classification, IoT Communication, Cloud and Waste Analytics, and Application/User services. This modular organization supports local intelligence, remote accessibility, centralized multi-bin monitoring, historical data analysis, and real-time full-bin alerts.

The conceptual evaluation demonstrates the potential of the proposed system to achieve improved monitoring accuracy, fill-level detection, reliability, notification performance, data transmission success, and response efficiency compared with manual inspection, fixed-schedule monitoring, and basic IoT approaches. The illustrative values indicate 98.20% monitoring accuracy, 97.50% fill-level detection rate, 97.80% reliability, 98.40% alert success, and 98.60% data transmission success. These numerical results must be validated through a real physical prototype and reproducible experimental dataset before being presented as measured empirical findings.

In summary, IoT-enabled garbage-level monitoring can transform traditional waste collection into a responsive, data-driven, and demand-oriented service. Future enhancements may include GPS-based dustbin mapping, machine learning-based fill prediction, AI-supported collection scheduling, dynamic vehicle route optimization, solar-powered sensor nodes, LoRaWAN or NB-IoT communication, gas and odor detection, fire detection, load-cell-based weight measurement, camera-assisted waste classification, automatic lid control, predictive maintenance, and integration with smart-city command centers. Such enhancements can contribute to cleaner environments, reduced operational expenditure, improved public hygiene, and more sustainable urban waste-management systems.

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