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GPS-INTEGRATED SMART DUSTBIN WITH CONTACTLESS OPERATION AND WASTE LEVEL MONITORING

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Abstract:

Although Internet-of-Things (IoT)-enabled smart waste bins have widely investigated, many existing systems provide limited integration of contactless operation, real-time monitoring, geolocation and automated notification within a single low-cost platform. This study proposes an integrated IoT-based smart dustbin that combines contactless operation, real-time waste monitoring, GPS tracking, cloud-based data logging, and automated messaging within a single embedded platform. The system employs an ESP32 microcontroller integrated with a motion sensor for touch-free lid operation, an ultrasonic sensor for waste-level measurement, and a Neo-6M Global Positioning System (GPS) module for location tracking. Waste level and location data are automatically recorded in Google Sheets to enable real-time monitoring, while a Telegram bot is employed to provide instant notifications when predefined waste thresholds are reached. This automated approach addresses the limitations of manual monitoring by enabling remote supervision, timely collection, and reduced labour dependency. System functionality was validated through simulation, where results demonstrated reliable motion-activated lid control, accurate waste level measurement, and consistent alert delivery. The findings indicate that the proposed smart dustbin effectively improves hygiene in public spaces by minimising physical contact and preventing prolonged bin overflow. Results demonstrated reliable real-time monitoring through automated Telegram alerts, cloud-based data logging, and GPS-enabled location tracking. Filtered GPS measurements exhibited consistent spatial clustering with a mean positional deviation of 158.65 m (standard deviation: 55.44 m), validating the feasibility of the proposed system for practical smart waste management and location-aware waste collection. GPS clustering confirms stable location tracking after filtering. The proposed system demonstrates the potential to improve municipal waste collection efficiency and support data-driven smart city waste management.

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Keyword:

Automated Waste Level Detection, GPS Tracking, Hygiene, IoT, Real-Time Monitoring, Sustainability, Waste Management

Introduction

Rapid urbanization, accelerated industrial development, and continuous population growth have significantly increased municipal solid waste (MSW) generation worldwide, placing considerable pressure on existing waste management infrastructures (Addas et al., 2024). The World Bank (2022) notes that global waste generation is expected to increase substantially by

2050 unless comprehensive and sustainable waste management strategies are successfully implemented. Trash cans are often manually inspected, and their collection schedules are fixed, which frequently leads to overflowing before collection. Overfilled bins can cause unsanitary conditions, attract pests, generate unpleasant odours and create serious risks to public health.

In addition, the waste collection vehicles are not routed efficiently, which results in more fuel consumption, operational costs and pollution to the environment. Existing waste management systems lack the ability to monitor in real time or to track location, which limits their efficiency. Municipalities struggle to ensure cleanliness standards, especially in densely populated or industrial areas, in the absence of data-driven decision-making. Thus, there is a need for an intelligent waste management system that integrates motion-based contactless operation, real-time waste-level monitoring, weight detection, GPS tracking, and automated alert notification. Such a system can avoid overflow, improve scheduling efficiency, and improve the standards of urban sanitation.

The latest developments in the International Telecommunication Union's smart sustainable city framework are centered around the convergence of Internet of Things (IoT), sensor networks, and real-time data analytics for urban services. Smart waste management systems employ embedded technologies for automatic monitoring, better collection routing, and contactless operations to improve environmental sustainability and public hygiene (Addas et al., 2024). The use of GPS technology improves traceability and enables location-based planning for waste collection. The geospatial data for every bin will enable waste management teams to plan optimized routes, resulting in fewer unnecessary collection trips and increased operational efficiency. Moreover, contactless lid operation is enabled via a motion-sensing technique. This feature is especially valuable in high-sanitation settings such as hospitals, industrial facilities, and food-processing regions where hygiene requirements are crucial (Rahman et al., 2022).

The proposed study is a GPS-Integrated Smart Dustbin with Contactless Operation and Waste Level Monitoring, which is an IoT-enabled embedded system designed to improve the efficiency of conventional waste disposal and to minimize environmental and health dangers. The system utilizes ultrasonic and infrared sensors to monitor the waste level in real time, and a Telegram bot with GPS to determine the exact location of the dustbin. It is equipped with passive infrared (PIR) sensors that detect when a person approaches and automatically open the dustbin to eliminate the risk of contact and cross-contamination. These sensors can tell if a bin is empty or full and relay the data back to a centralized monitoring platform using a Google Sheets interface. The proposed system is in the domain of smart waste management in embedded systems engineering that includes automation, sensor fusion, wireless communication, and real-time monitoring. It can be employed in rural as well as industrial settings, such as in factories, warehouses, and healthcare institutions. The system is an IoT-based, scalable, and upgradable solution linked with smart city ambitions, integrating waste-level monitoring, GPS tracking, and lid control in an automated manner. Also, geospatial analysis is performed using data collected in Google Sheets. This analysis is important for the feasibility studies of real-world deployments.

Literature Review

The growing urbanization and population density have posed significant challenges to the management of municipal solid waste, resulting in inefficient collection schedules, frequent waste overflow, unsanitary conditions, and elevated environmental pollution (Henaien et al.,

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2024). Also, recent surveys on smart cities conducted by Jia et al. (2026) concluded that smart waste management is one of the seven components of smart cities' services. Conventional waste management systems rely on passive dustbins and static collection routines, which can lead to avoidable operational costs and delayed waste collection, thereby aggravating health and environmental issues. These limitations have motivated the development of intelligent waste management solutions with a special focus on enhanced dustbins with motion detection and waste level monitoring as a major part of smart city infrastructures (Agalyaa et al. 2025; Gawali et al. 2023; Ghorpade-Aher et al. 2018; Henaien et al. 2024; Keshava Murthy et al. 2023; Muley et al. 2025; Panara et al. 2023; Salau et al. 2024; Saxena et al. 2024; Sohag & Podder 2020; Thirumugam et al. 2023; Wen et al. 2025).

Smart dustbin systems rely on sensing technologies, Internet of Things (IoT) connectivity, and data analytics to enable real-time monitoring of waste levels and contactless user interaction (Gawali et al., 2023; Henaien et al., 2024; Panara et al., 2023; Salau et al., 2024; Sohag & Podder, 2020; Sumathi et al., 2025; Thirumugam et al., 2023; Wen et al., 2025). These systems enable continuous status updates (Mishra & Ray, 2020) and facilitate optimized waste collection routes, reduced fuel consumption, and improved operational efficiency. Moreover, smart waste management systems improve public cleanliness and reduce environmental impact, contributing to wider sustainability objectives in urban planning (Revolutionizing Waste Management, 2024). Recent studies indicate growing interest in deploying IoT-enabled smart dustbins as effective, scalable solutions for sustainable urban waste management (Ahmed et al., 2024; O et al., 2025).

Moreover, to further increase the accuracy of waste estimation, weight sensors or load cells are frequently utilized in tandem with volume-based sensing techniques. However, with the combination of ultrasonic and weight data, a more accurate estimation of waste accumulation can be achieved, especially in the case of compacted waste or irregularly shaped materials (Badhoutiya, 2025). Motion detection technologies also allow for automatic, contactless lid operation by sensing the presence of users near the dustbin. The gadget operates hands-free, which greatly reduces physical contact, thereby enhancing cleanliness and minimizing the risk of contamination, especially in public spaces and hygiene-sensitive environments such as hospitals and healthcare facilities (Anitha & Arockiam, 2020).

This paper proposes an enhanced dustbin system for IoT-enabled smart waste management, using embedded systems for automated monitoring and control (Maddileti & Kurakula, 2020). The systems are intended to be deployed in a variety of environments, such as urban public spaces, rural areas, industrial sites, and sanitation critical locations. Moreover, the application of Global Positioning System (GPS) technology allows for the accurate tracking of bin location, allowing for dynamic route planning, quicker response to overflow events, and improved operational management for municipal authorities (Agalyaa et al., 2025; Badhoutiya, 2025; Henaien et al., 2024; Saxena et al., 2024). A smart dustbin can use an ultrasonic sensor to monitor the level of waste. Ultrasonic sensors are the most preferred for waste level monitoring due to their non-contact measurement, resilience, and low cost. Ultrasonic sensors measure the distance between the sensor and the waste surface to establish the fill level, allowing systems to deliver timely notifications when bins are nearing capacity and preventing overflow (Nivisjhonson et al., 2026).

Methodology

The methodology combines system design and development, beginning with conceptual modelling through flowcharts and progressing to hardware-software integration for practical deployment as well as geospatial analysis for smart bin location accuracy. The proposed smart bin aims to develop a GPS-integrated smart dustbin with motion detection and real-time waste level monitoring with an automated alert notification system for efficient waste collection scheduling. Figure 1 illustrates a contactless dustbin system with integrated multiple components for efficient waste management. A motion sensor senses motion around and send a signal to the servo motor to open and close the dustbin lid automatically without any physical contact. The waste level and weight sensors keep a check on the trash capacity. The system communicates wirelessly using Wi-Fi and sends notification using telegram. The sensor data is processed by a microprocessor, and the information is displayed on an Organic Light-Emitting Diode (OLED) screen. Excel saves the records for analysis. There's also an LED indicator that gives visual feedback. This automated arrangement increases hygiene and reduces physical contact and also optimises the waste disposal by real-time monitoring and notifications making it more user-friendly.

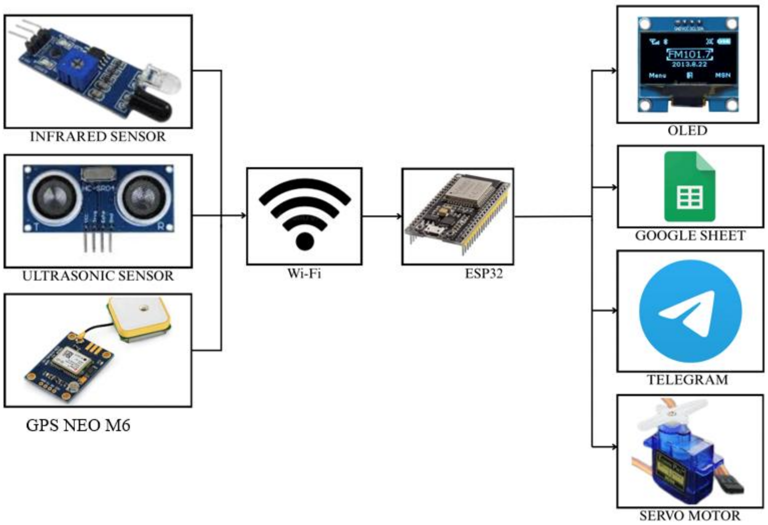

Figure 1: Block Diagram of the Proposed System

The flowchart in Figure 2 describes the operation of a contactless dustbin system. The flowchart describes the operation of a smart waste management system in a clear sequence. First, it tries to connect to Wi-Fi. If the connection is unsuccessful, the process terminates. If successful, the system starts detecting the level of waste inside the bin and its GPS location.

Then it checks whether there's a human. Then, if no one is nearby, the servo motor keeps the lid closed. If a person is detected, the lid opens automatically and waste can be disposed of. Following this, the system enters a loop for continuous monitoring, where it keeps measuring the waste level, tracks the bin's location, transmits data to Google Sheets for record-keeping, and displays the data on an OLED screen for local monitoring.

In this loop, the system checks whether the bin is full. If it is not full, the monitoring continues. Once the bin reaches full capacity, the system sends a notification via Telegram to alert the waste management team, updates the status, and confirms that the trash has been collected. At that point, the process concludes.

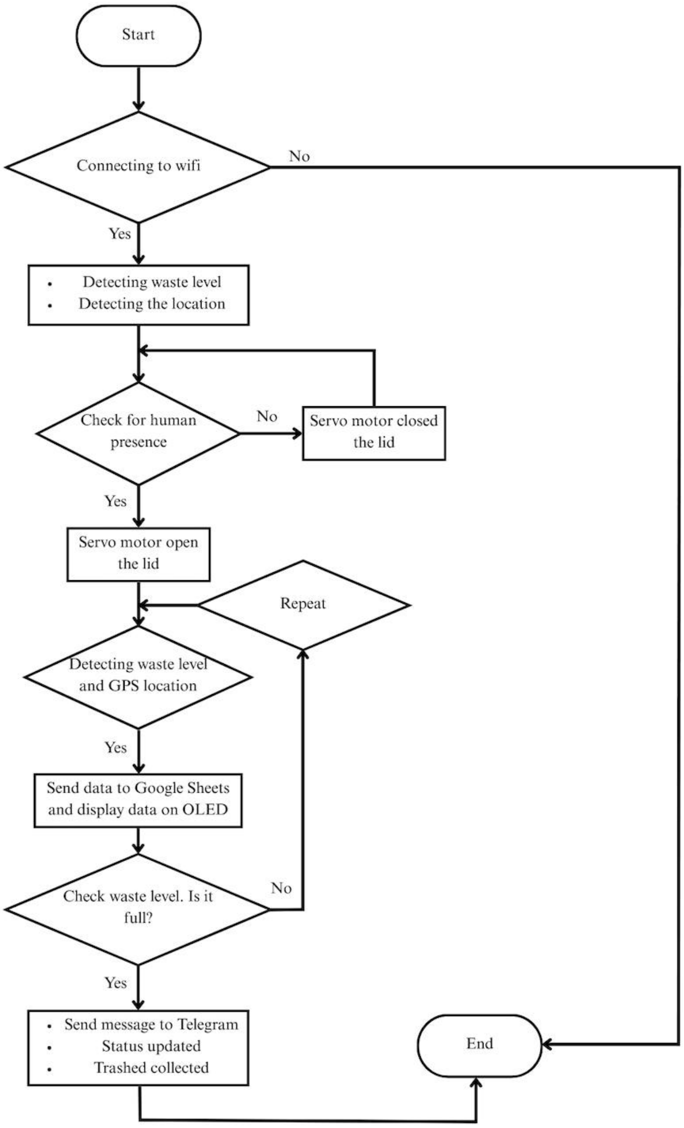

Figure 2: Flowchart of the Proposed System

Software Simulation

The proposed smart bin system is simulated based on the schematic diagram in Figure 3 using an ESP32 that is connected to sensors which are an ultrasonic sensor and an infrared sensor. The ultrasonic sensor functions as a waste level sensor since it can detect the distance range. While the infrared sensor used to identify the motion with the help of the servo motor, the lid of the dustbin will automatically open, and both are interfaced via digital General-Purpose Input/Output (GPIO) pins. An OLED display is connected to the output pin. The components communicate with the ESP32 by going through specific pins using jumper wires.

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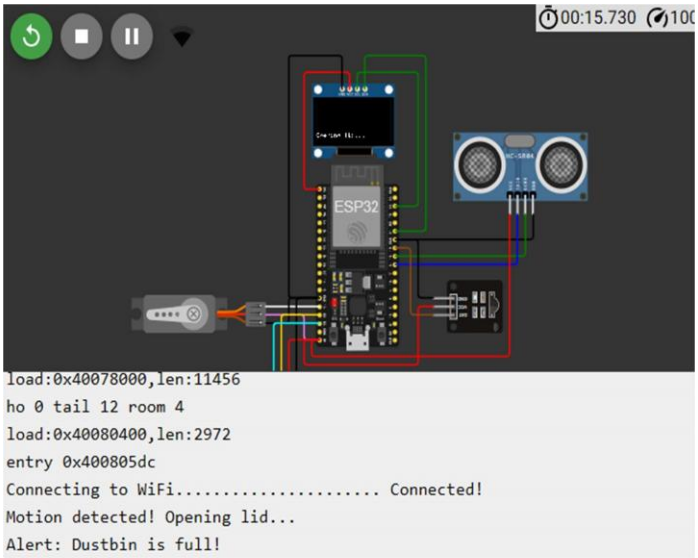

Figure 3 Simulation Result of Contactless

Hardware Implementation

The hardware implementation of the contactless waste bin system is demonstrated in Figure 4. The core of the setup is a microcontroller with several sensors and wiring attached, which is responsible for detecting motion and trash levels. The zoomed view of the hardware shows the circuit of the microcontroller along with the digital display that displays the real-time readings, e.g. waste-level measurement. This display provides users and operators with instant feedback and makes the system's operation transparent.

The physical waste bin is fitted with a mounted display that displays the current waste level and has clear printed instructions for users. Messages such as “DO NOT TOUCH. JUST WAVE YOUR HAND NEAR THE SENSOR” highlight the contactless feature of the system, encouraging hygiene and reducing the risk of contamination. This is an example of motion detection working with servo motor control. The bin has a sensor that opens the lid automatically when a hand is waved in front of it. The lid stays open for 5 seconds, then closes automatically.

The sensor and wiring arrangement are securely held within the bin and placed neatly to ensure reliable operation. The example images show how the sensor responds to human proximity, opening the lid without touch. This implementation verifies the simulation results and also demonstrates the practical usability of the system under real-world conditions. Thus, the hardware design is balanced to be functional, user-safe, and automated, which is in line with the system's purpose of improving waste disposal efficiency while meeting hygiene standards.

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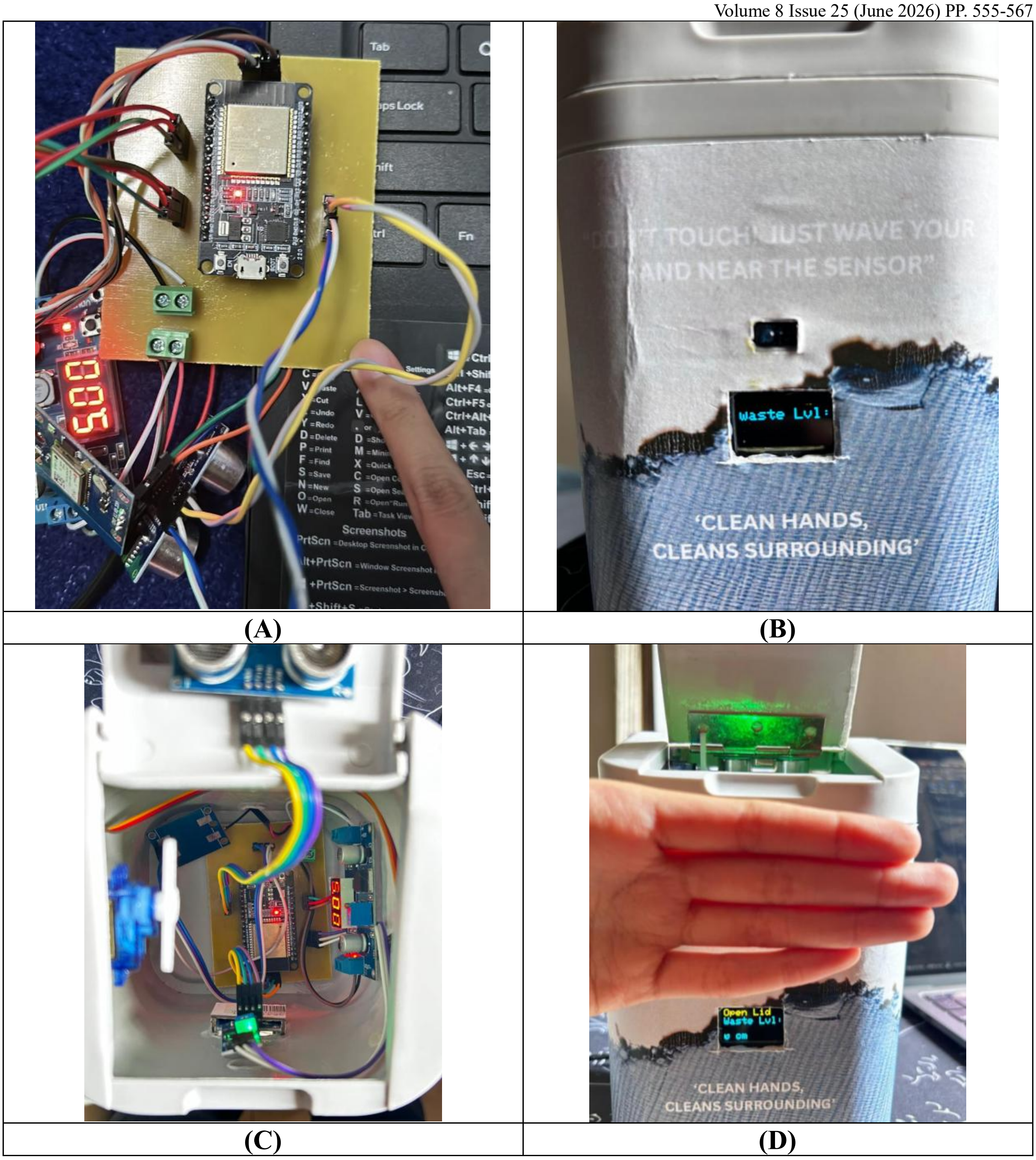

Figure 4: Hardware Implementation of the Proposed Smart Bin (A) Final Printed Circuit Board (PCB) (B) OLED Displaying Waste Level (C) Internal Assembly (D) Lid Opens Automatically with Human Presence.

Result and Discussion

The system is programmed to notify the owner when the bin reaches certain thresholds-partially full, full or in an overweight state. If the bin trash remains uncollected, the system continues to send the alerts as reminders. This feature ensures prompt attention to the bin's status and helps to maintain the cleanliness with prevention from the trash to be overflowing. This automation enables the owner to take a quick action within more effective ways based on real-time updates from the system. The alert message was successfully transmitted through the Telegram bot shown in Figure 5 after appropriate coding was integrated.

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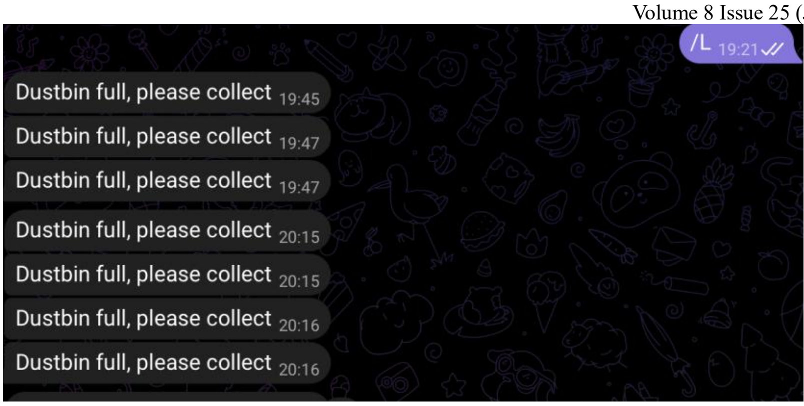

Figure 5: Notifications on Telegram Bot

Additionally, Figure 6 presents the data collected in a Google Sheet, which includes date, time, waste level, latitude, and longitude obtained via GPS integration. Both latitude and longitude data are great for geospatial analysis. Geospatial analysis was conducted to evaluate the positional stability of the stationary smart dustbin shown in Figure 7. Outlier coordinates were removed, and the GPS measurements were spatially clustered inside the deployment region. The GPS accuracy metrics are shown in Table 1. The mean positional deviation is 158.65 meters, the maximum deviation is 298.57 meters, and the standard deviation is 55.44 meters. This difference is due to environmental conditions and the inherent limitations of low-cost GPS devices. However, the accuracy is suitable for applications such as smart garbage collection routing and location-based monitoring in industrial and urban zones.

DATE	TIME	WASTE LEVEL	LATITUDE (N)	LONGITUDE(E)
17/1/2026	11:44:55	9	1.52717	103.8722
17/1/2026	11:45:57	9	1.527183	103.8722
17/1/2026	11:46:58	9	1.527163	103.872162
17/1/2026	11:47:58	9	1.527174	103.872154
17/1/2026	11:48:59	9	1.527126	103.872093
17/1/2026	11:50:00	9	1.527063	103.872032
17/1/2026	11:51:00	9	1.52707	103.87207
17/1/2026	11:52:02	9	1.527051	103.87204
17/1/2026	11:53:02	9	1.527099	103.872108
17/1/2026	11:54:03	9	1.527071	103.872078
17/1/2026	11:55:08	9	1.527154	103.872185
17/1/2026	11:56:07	9	1.527069	103.872063
17/1/2026	11:57:09	11	1.527009	103.871994
17/1/2026	11:58:17	11	1.527061	103.872055
17/1/2026	11:59:12	0	1.526997	103.872017
17/1/2026	12:00:15	0	1.526981	103.87191
17/1/2026	12:01:15	14	1.527004	103.871902
17/1/2026	12:02:16	13	1.526915	103.871872
17/1/2026	12:03:17	14	1.526917	103.87191
17/1/2026	12:04:18	14	1.526896	103.871925
17/1/2026	12:05:18	0	1.526899	103.871895
17/1/2026	12:06:20	14	1.52687	103.871887
17/1/2026	12:07:20	14	1.526928	103.87188
17/1/2026	12:08:21	14	1.527025	103.871811
17/1/2026	12:09:21	0	1.527006	103.871956
17/1/2026	12:10:22	13	1.526853	103.871964
17/1/2026	12:11:22	14	1.526995	103.871887
17/1/2026	12:12:22	14	1.526898	103.871925

Figure 6: Data Collected in Google Sheet

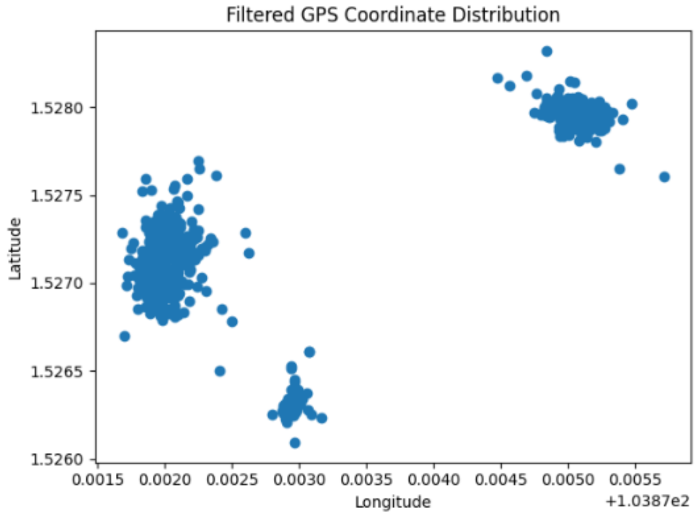

Figure 7 Filtered GPS Coordinate Distribution

Table 1: GPS Accuracy Metrics

Metric	Value (m)
Mean deviation	158.65
Maximum deviation	298.57
Standard deviation	55.44

The results demonstrate the efficiency of the smart waste management system through real-time monitoring, automatic alarms, and geographic analysis. According to messages from the Telegram bot, the system is capable of sending alerts in real-time when the bin is in critical situations, such as full, partially full, or overweight. With this feature, garbage collection workers are alerted as early as possible to minimize service delays and the risk of overflow. The multiple alerts at different timestamps also demonstrate the system's ability to respond to dynamic changes in bin status.

The Google Sheets integration provides a structured record of waste levels, timestamps and GPS coordinates. It facilitates not just the preservation of data but also the longitudinal examination of trends of waste accumulation. The recorded values are constant in the detection of the waste levels and the positional data, which is vital for the monitoring of many bins at different locations. The solution also helps improve openness and accountability in waste management operations through a centralized dataset.

The scatter plot of filtered GPS coordinates is a visual representation of the additional dimension of geospatial analysis that the system's capabilities provide. Valid coordinates clustered around a point of positional stability were deleted together with outliers to enhance accuracy. However, the average positional deviation of 158.65 meters, with a maximum of 298.57 meters, indicates that GPS accuracy remains a challenge. The standard deviation of 55.44 meters shows that most of the readings are not too far apart, and despite this constraint, the system is accurate enough for basic position tracking.

Overall, the discussion indicates that the smart bin system effectively integrates automation, data logging, and geospatial analysis to improve the waste collection process. GPS, though not perfect, gives the system the ability to provide real-time warnings and store detailed data, a big step forward in modern waste management procedures.

Conclusion

This paper describes the design and development of a GPS Integrated Smart Dustbin for contactless operation and waste level monitoring. The proposed method is a low-cost and practical way to boost the efficiency of waste collection, minimise manual monitoring and promote intelligent urban waste management.

The hardware implementation confirms the concept and demonstrates the integration of sensors, microcontrollers, and servo motors into a working prototype. The findings also illustrate the importance of handling data in real-time. The waste levels and GPS coordinates are logged in Google Sheets for transparency and to help analyze usage patterns. The Telegram alerts allow to react quickly to full bins, thus linking monitoring and immediate action. The geospatial analysis offers further insight, confirming location stability even with occasional GPS errors. The measurements are not perfect, but good enough to track reliably.

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