# Artificial Intelligence Smart Dustbin

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***Abstract:*** *Urban waste management remains a pressing challenge, particularly in densely populated cities, where improper disposal of garbage often leads to environmental degradation and public health risks. While conventional dustbins are widely available, their misuse or neglect exacerbates pollution, foul odors, and the spread of airborne diseases. Furthermore, inefficiencies in timely waste collection by city corporations compound these issues. This study proposes a novel solution through the integration of modern technology: an Artificial Intelligence (AI)-powered smart dustbin. The AI-powered dustbin addresses two critical problems—hygiene concerns and operational inefficiencies. By employing sensors and automated mechanisms, the dustbin opens its lid automatically when waste is brought near, eliminating the need for physical contact and encouraging proper waste disposal. Additionally, the dustbin is equipped with advanced communication technology, enabling it to notify city corporation authorities when it is full, along with its precise location. This ensures timely garbage collection and reduces environmental and logistical challenges. This paper discusses the design and functionality of the AI-powered dustbin and its potential to enhance urban cleanliness, mitigate health hazards, and optimize waste management operations. By combining technological innovation with practical application, the proposed solution demonstrates a sustainable approach to addressing urban waste management challenges, paving the way for cleaner and healthier cities.*

***Keywords:*** *Artificial Intelligence, Garbage Management, Automatic Machine, Dustbin, Waste.*

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*Nomenclature*

| Abbreviation | Expansion |
|---|---|
| AI | Artificial Intelligence |
| IR | Infrared Sensor |

## 1. Introduction

Urban cleanliness and waste management are critical components of a sustainable and healthy city environment. Despite the presence of designated dustbins in cities, maintaining cleanliness remains a persistent challenge. Pedestrians often avoid using dustbins, citing hygiene concerns, or simply discarding waste nearby. These behaviors, coupled with the inefficiency in timely waste collection by city corporations, lead to widespread environmental and health-related issues [9]. This paper explores an innovative approach to overcoming these challenges and improving urban waste management through modern technology.

Improper waste disposal contributes significantly to environmental degradation [10]. Overflowing dustbins emit foul odors, discourage people from using them, and create unsightly surroundings [11]. Furthermore, the accumulation of waste increases the risk of airborne diseases, impacting public health. These problems are further exacerbated by the inability of city corporations to collect garbage on time in larger cities. While awareness campaigns and behavioral interventions have been employed to address this issue, they often fall short due to the scale of the problem and inconsistent public participation.

To combat these persistent issues, leveraging technology can provide sustainable solutions. This study introduces the concept of an AI-powered dustbin designed to revolutionize urban waste management. The main contributions of the paper are

- The smart dustbin addresses hygiene concerns by automatically opening its lid when waste is brought near, minimizing physical contact.
- The dustbin can detect when it is full and automatically notify city corporation authorities via messages or phone calls, providing its exact location.
- AI detects the intensity of the foul smell and sends a signal based on urgency.

This paper discusses the design, functionality, and potential impact of the AI-powered dustbin in transforming urban waste management and contributing to a cleaner, healthier, and more sustainable city environment.

The rest of the paper is organized as follows: Section 2 covers the literature review, Section 3 explains the methodology, Section 4 details the testing, Section 5 demonstrates the result and discussion, Section 6 compares the proposed method with the existing method, Section 7 clearly explains the advantages and disadvantages of the proposed method and Section 8 concludes the paper.

## 2. Literature Review

In 2016, Kumar *et al.,* [1] implemented a smart intelligent garbage alert system. The system enhanced garbage management by providing timely alerts for garbage clearance, thereby maintaining public cleanliness and health. Initially, Dustbin level was measured using an ultrasonic sensor with Arduino UNO. Alerts are sent to a web server when garbage reaches a certain level then the RFID reader verifies cleaner identity, sending status updates to the server. An Android app displays alerts and dustbin status.

In 2024, Agarwal *et al.,* [2] introduced a smart dustbin using Arduino, an ultrasonic sensor, and a servo motor. The dustbin's lid opens automatically upon detecting a human hand or leg. The system addresses waste disposal issues effectively. Arduino was integrated with an ultrasonic sensor and a servo motor. The ultrasonic sensor is positioned at the top of the dustbin to measure distance. The ultrasonic sensor detects objects, calculating the distance to activate the servo motor. If the detected distance is below a predefined threshold, the lid opens for a set time.

In 2024, Sontakke *et al.,* [3] employ an ultrasonic sensor to detect the presence of a user approaching the dustbin. When a person comes within a specified distance, the sensor triggers the next action. Upon detecting proximity, the servo motor activated to automatically open the lid of the dustbin. The ultrasonic sensor continuously monitored the fill level of the dustbin. When the dustbin reaches a certain capacity, the system sends signals to a designated device, indicating that the dustbin needs servicing. The information regarding the fill level was transmitted via an RF module to a central system. This data can also be accessed through an internet connection, allowing for real-time monitoring and management of multiple dustbins across a city. The system can notify users or waste management personnel when the dustbin is full, ensuring timely collection and preventing overflow. This was crucial for maintaining cleanliness and hygiene in public spaces.

In 2024, Shaharil *et al.,* [4] designed to automate waste management efficiently. The ultrasonic sensor detects the presence of a user approaching the dustbin, triggering the system to prepare for action. Upon detecting a user, the system activated a motor to automatically open the lid, allowing for contactless disposal of waste. The IR sensor continuously monitors the level of trash inside the bin, providing real-time data on how full the dustbin is. A load cell sensor measures the weight of the waste, displaying the information on an LCD and ensuring accurate tracking of waste generation. When the trash reaches a certain level or weight, the system sends a notification to the user via the Blynk application, prompting timely waste collection.

In 2024, Poddar *et al.,* [5] used a smart waste bin system. The microcontroller (ESP-32) was connected sensors were activated to start gathering data about the waste in the bin. The system collects data from various sensors, including the DHT11 sensor for temperature and humidity, and ultrasonic sensors for measuring the fill level of the bin. If the ultrasonic sensor detects that the bin is full or if the DHT11 sensor identifies unusual temperature or humidity levels, the system prepares to send alerts. Once the bin is determined to be full (above a certain threshold), a notification is sent to the cloud server. This message includes the status of the bin and its location, allowing the municipal authorities to respond promptly. Upon receiving the alert, a garbage collection vehicle is dispatched to the location of the full bin. After the waste is collected, the system updates the status of the bin to reflect that it is now empty, and ready for the next cycle of monitoring.

In 2024, RAO *et al.,* [6] integrated a NodeMCU and an ultrasonic sensor. The NodeMCU was responsible for establishing a Wi-Fi connection and uploading the necessary code for the operation. The ultrasonic sensor continuously measures the distance to the waste level inside the bin. When the waste level reaches 70% capacity, the system triggers the NodeMCU to send a signal to the IFTTT webhook, which was configured to send an email notification to the user. This notification allows the user to take timely action to empty the bin, preventing overflow and maintaining cleanliness in the area. If the bin reaches maximum capacity, the server will send another notification to the user, ensuring that they are always updated on the status of the trash can. Throughout this process, data is collected regarding the fill levels and notification statuses, which can be useful for further analysis and improvements in waste management practices.

In 2024, RAMYA, K., *et al.,* [7] used an IoT-based smart dustbin management system. When a person approaches the smart dustbin, the IR sensor detects their presence. Upon detection of a person, the IR sensor triggers a servo motor that automatically opens the lid of the dustbin. Inside the dustbin, an ultrasonic sensor continuously monitors the fill level of the waste. It measures the distance to the waste, allowing the system to determine how full the bin is. The data collected from the IR and ultrasonic sensors is transmitted to an IoT server via a Wi-Fi module (ESP8266). When the ultrasonic sensor indicates that the bin is nearing its full capacity, the system sends alerts and notifications to the relevant authorities or waste management personnel. This ensures timely collection and prevents overflow. The status of the dustbin, including its fill level, was displayed on an LCD screen. This provides immediate feedback to users about the bin's capacity and encourages responsible waste disposal practices. The system can also send maintenance alerts if the bin requires cleaning or servicing, further promoting hygiene and efficiency in waste management.

In 2024, Paul, L., *et al.,* [8] implemented an IoT-based smart waste management system. Smart dustbins equipped with IoT-enabled sensors collect data regarding their fill levels and overall status. This data is transmitted to a central system for monitoring. City dwellers can use a mobile application to report issues or observations in their neighborhoods. The application allows users to take images and submit complaints, automatically tracking the location of the reported issue. Once a complaint is submitted, the system sends notifications or SMS alerts to the waste management team, informing them of the need for action. The smart dustbins communicate with waste collectors or control centers when they reach a certain fill level, prompting timely waste collection. The involvement of both sensors and community members creates a feedback loop, enhancing the overall efficiency of the waste management process. The system's acceptance in the community was evaluated through surveys, which have shown encouraging results, indicating community support for the model.

## 2.1 Review Table

***Table 1.*** *Review of the existing method*

| Author | Sensor | Alert Notification | Automatic opening | Waste Detection from Distance | Odor Detection | AI System/Controller | Location tracker | Other Technology | Level Monitoring |
|---|---|---|---|---|---|---|---|---|---|
| Paul *et al.,* [1] | Ultrasonic | Yes | No | No | No | Arduino | No | RFID | Yes |
| Kumar *et al.,* [2] | Ultrasonic | No | Yes | Yes | No | Arduino | No | Servo Motor | No |
| Agarwal *et al.,* [3] | Ultrasonic | Yes | Yes | Yes | No | Arduino | No | Servo motor | Yes |
| Sontakke *et al.,* [4] | load cell sensor for weighing waste and an IR sensor | Yes | Yes | Yes | Yes | Arduino | No | Blynk application | Yes |
| Shaharil *et al.,* [5] | Ultrasonic, DHT11, and Gas Sensor | Yes | No | No | Yes | ESP-32 | Yes | DHT11 for temperature and humidity monitoring | Yes |
| RAO *et al.,* [6] | Ultrasonic | Yes | No | No | No | NodeMCU | No | IFTTT for notifications | Yes |
| RAMYA, K., *et al.,* [7] | Ultrasonic | Yes | Yes | Yes | No | Not available | No | Integrated with other IoT devices | Yes |
| Paul, L., *et al.,* [8] | Ultrasonic and temperature | Yes | No | No | No | Not available | Yes | GSM modules and solar panels | Yes |

## 2.2 Research Gap

Despite extensive research in smart dustbins, certain key challenges and opportunities remain underexplored. Prior studies have primarily focused on Dustbin level monitoring and Alert systems, yielding significant insights into dustbin design. However, a thorough review of the literature reveals several gaps:

- Limited Scope in Odor Detection: Existing research predominantly addresses the level of the waste in the dustbin, often neglecting the foul smell that is released through organic and inorganic waste. Paper [5] only examines odor detection but all other papers fail to consider it.
- Underdeveloped Frameworks for Location Tracking: While several frameworks [1][2][3][4][6][7][8] have used Alert systems, these models lack comprehensive integration of the location of the dustbin for easy tracking.
- Renewable resources: The power is needed for all the processes in the dustbin, monitoring system, sensors, etc., The paper [8] only mentioned the power supply through solar panels.

Addressing these research gaps is vital for advancing the understanding of smart dustbins. The current study aims to explore Odor detection, location tracking, solar power generation and storage, and AI integration for the smart dustbin.

## 3. Methodology

The smart dustbin system designed for efficient waste management operates through a series of automated processes aimed at improving waste disposal, monitoring bin status, and addressing environmental concerns. The process begins when a user brings waste near the dustbin, triggering a sensor that detects the presence of waste. This sensor automatically opens the dustbin lid, reducing physical interaction and ensuring a hygienic disposal process. Once the waste is deposited, the lid closes automatically, minimizing further contact.

To monitor the dustbin's capacity, a fill-level sensor is employed. The sensor constantly assesses the bin's fullness, with the system entering standby mode when the bin is not full. If the bin reaches its maximum capacity, the system sends a notification to the city corporation, providing precise information about the bin's location for timely collection.

In addition to fill-level monitoring, the system integrates an odor-detection mechanism. This AI-based system continuously evaluates the intensity of odors emitted by the waste. If the odor exceeds a predefined threshold, an urgent alert is triggered, notifying the city corporation for immediate action. This ensures the prevention of unpleasant environmental conditions caused by waste overflow.

Overall, this automated system ensures an efficient, contactless waste disposal process, timely bin collection, and a proactive approach to maintaining hygiene and reducing odors. By leveraging sensors and AI, the system addresses both operational efficiency and environmental concerns, contributing to sustainable urban waste management practices. Fig 1 explains the overall flow process of the proposed method.

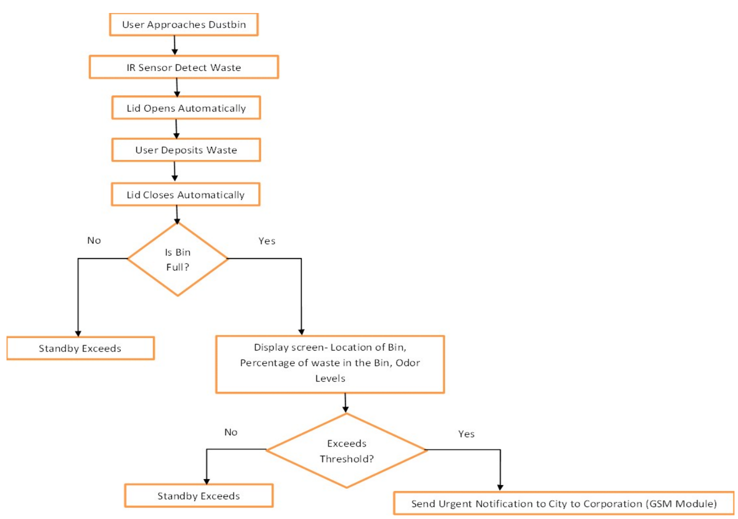


***Fig 1.*** Proposed method

The algorithm for the process covers the key steps in the process, including detecting user interaction, monitoring the fill level and odor, and sending notifications when necessary. It is mentioned below.

1. Start
2. Monitor for user proximity (using Ultrasonic Sensor)
   IF user detected THEN
   OPEN lid (automatic)
   WAIT for waste deposit

CLOSE lid (automatic)
END IF
3. Monitor bin's fill level (using Ultrasonic Sensor)
IF bin is full THEN
SEND notification to city corporation (with location)
ELSE
CONTINUE monitoring
END IF
4. Monitor odor levels (using Odor Detection Sensor)
IF odor exceeds threshold THEN
SEND urgent alert to city corporation
ELSE
CONTINUE monitoring
END IF
5. END

### 3.1 Equipment's

The smart dustbin system described requires several key equipment components to function effectively. These include:

1. **Infrared (IR) Sensor**: These sensors detect when a user approaches the dustbin, triggering the automatic opening of the lid. They ensure minimal physical contact and are typically ultrasonic or infrared sensors.
2. **Ultrasonic Sensor**: The ultrasonic sensors are used to detect the fill level and determine whether the bin is full or not.
3. **Communication Module (IoT Module)**: This equipment allows the smart dustbin to send notifications to the city corporation. It could include wireless communication technologies like GSM to transmit data regarding the bin's status or location when it is full.
4. **Odor Detection Sensors**: These sensors monitor the intensity of unpleasant smells emitted by the waste. Chemical sensors or air quality sensors (e.g., VOC or ammonia sensors) can detect the presence and concentration of odors and trigger alerts if the threshold is exceeded.
5. **AI System/Controller**: An artificial intelligence or microcontroller-based system that processes data from sensors (fill-level and odor detection), manages the bin's operational processes (like lid opening and closing), and makes decisions, such as sending alerts when thresholds are reached.
6. **Power Supply**: To run all electronic components, the dustbin will require a reliable power source, we use renewable energy to charge the battery a mini solar panel is used and the energy is stored in a Lithium Cell Battery.
7. **GPS Module**: For providing the exact location of the dustbin when full, this module can be integrated into the system, enabling the city corporation to efficiently locate the dustbin for waste collection.
8. **Arduino Uno/Nano:** The microcontroller for processing inputs and controlling outputs.
9. **Programming Language (C++ or Python):** Use C++ for Arduino programming.

## 4. Result and Discussion

The smart dustbin system proved effective in automating waste disposal and maintaining hygiene. The sensors worked accurately to detect proximity, fill levels, and odor, and the communication system efficiently relayed information to the city corporation. Fig 2 represents the smart dustbin.

***Fig 2.*** *Smart Dustbin*

The performance is assessed across several key aspects such as the Accuracy of Sensor Readings, Responsiveness of the System, Effectiveness of Notifications and Alerts, System Stability, Battery Life and Power Efficiency, User Experience, and Optimization Potential.

### 4.1 Accuracy of Sensor Readings

The IR Sensor reliably detects users approaching the dustbin, triggering the lid to open automatically. Testing results show a high accuracy rate, with minimal false triggers (e.g., opening the lid for non-users). The sensor works within a set distance range of 80 cm and reacts promptly within a few milliseconds. The ultrasonic sensor accurately measures the amount of waste in the bin. The sensor readings correspond well with the actual waste volume, ensuring that the bin's status is correctly monitored. The sensor can detect different fill levels accurately, including when the bin reaches full capacity. The threshold level of the bin is aligned in four layers.

Level 1: Distance > 30 cm (empty)
Level 2: Distance between 25 cm and 30 cm (quarter full)
Level 3: Distance between 20 cm and 25 cm (half full)
Level 4: Distance < 20 cm (full)
The distance is calculated using the formula:

$$Distance(cm) = \frac{Duration(\mu s) \times 0.0344}{2}$$

Where
Speed of sound in air= 0.0344 cm/µs
Duration= Time it takes for the sound wave to travel from the ultrasonic sensor to the object

***Table 2.*** *Comparison of IR Sensor, Ultrasonic Sensor vs Other Sensors*

| **Attribute** | **Infrared (IR) Sensor** | **Capacitive Sensor** | **Inductive Sensor** | **Ultrasonic Sensor** |
|---|---|---|---|---|
| **Detection Range** | 5 cm to 80 cm (up to 100 cm in some models) | 2 cm to 30 cm (depending on object size) | 1 cm to 10 cm (metallic objects only) | 2 cm to 4 meters (up to 400 cm) |
| **Accuracy** | High (precise detection of objects) | Moderate (good for detecting large objects) | High (only detects metals) | Moderate (can be affected by object shape) |
| **Power Consumption** | Low to moderate | Low | Low | Moderate to high |
| **Cost** | Low to moderate | Moderate to high | Moderate to high | Moderate to high |
| **Sensitivity to Object** | Sensitive to any solid object (including humans) | Sensitive to a variety of materials (not limited to metal) | Sensitive only to metals | Sensitive to object distance, shape, and surface |
| **Size** | Small and compact | Small, but requires higher sensitivity for close-range detection | Compact, but larger for high-range detection | Larger, especially for long-range detection |
| **Installation Complexity** | Simple (easy to integrate into systems) | Moderate (requires specific configuration for sensitivity) | Moderate (requires positioning near metal) | More complex (requires calibration for distance measurement) |
| **Response Speed** | Fast (instant detection and reaction) | Fast | Fast | Moderate (depends on distance) |
| **Suitability for Smart Dustbin** | Excellent for detecting human presence near the bin | Moderate (less suited for human detection) | Not applicable (only detects metals) | Good (detects distance, but less suited for detecting human proximity) |

Based on the comparison in Table 2, it is evident that the IR sensor offers higher accuracy in detecting various objects, such as humans and waste. Therefore, the IR sensor is used to trigger the lid opening mechanism when a user approaches the dustbin. On the other hand, the ultrasonic sensor is employed to monitor the fill level of the dustbin. Additionally, the cost of these sensors is reasonable, making them a cost-effective solution. Both the IR and ultrasonic sensors exhibit high sensitivity to object presence, size, and shape. Furthermore, their compact size and simplicity make them ideal for integration into the dustbin system, ensuring their suitability for the process.

The Odor detection sensor performs well in detecting foul odors. When the concentration of odors (e.g., ammonia, VOCs) exceeds the set threshold such as Ammonia ($NH_3$): > 25 ppm, Methane ($CH_4$): > 500 ppm, Carbon Dioxide

($CO_2$): > 1000 ppm, the sensor triggers the alert system. The response time to odor detection is rapid, ensuring that city authorities are promptly notified in case of high odor levels.

### 4.2 Responsiveness of the System

The system shows a quick response to detected waste and odor. The automatic lid opens and closes within a few seconds of detecting proximity and waste. Likewise, the bin status (full or not) is monitored in real-time, and notifications are sent promptly when the bin reaches its capacity. The odor detection system has a swift response time, with alerts sent almost immediately after detecting excessive odors. Fig 3 is the screenshot of the display screen.


*Fig 3. Display screen*

### 4.3 Effectiveness of Notifications and Alerts

The communication system (e.g., GSM) reliably sends notifications to the city corporation when the bin reaches full capacity, including the bin's precise location. Notifications are timely, helping to ensure that the bin is emptied on time. When the odor threshold is exceeded, the alert system effectively communicates the need for urgent attention. The alerts include detailed information, allowing city officials to take appropriate action promptly. Fig 4 is the screenshot of the alert message.


*Fig 4. Alert Notification*

### 4.4 System Stability

The system operates reliably without significant downtime. During prolonged testing, there were no instances of system failure or communication issues, and all components (sensors, lid mechanism, communication module) worked together seamlessly. The system was able to function continuously with minimal maintenance. The battery-powered setup showed good efficiency, with a long runtime per charge, ensuring that the system remains operational without frequent charging. Power usage was optimized by putting the system in standby mode when the bin was not in use. A 3300 mAh lithium-ion battery at 3.7V is required to power the system for a day. A 2.5W solar panel would be sufficient to charge the battery during the day, assuming an average of 5 hours of sunlight.

### 4.5 User Experience

The hands-free waste disposal process was seamless, with users able to deposit waste without physical contact. The automatic lid mechanism worked smoothly, and the sensors accurately detected waste, ensuring a hygienic experience.

## 5. Advantages and Disadvantages of the Proposed Method

### Advantages:

- The system automates the process of waste disposal by detecting the presence of users and managing fill levels, reducing human intervention, and improving operational efficiency.
- Using sensors for fill-level monitoring and odor detection ensures timely waste collection, preventing overflows and unpleasant odors, which contributes to a cleaner and more hygienic environment.
- The use of low-power sensors (IR, ultrasonic, and odor detection sensors) combined with a solar panel and lithium battery ensures an energy-efficient and cost-effective waste management solution, especially in areas with limited access to electricity.
- By providing real-time notifications when the dustbin is full or emits foul odors, the system helps municipal authorities plan waste collection more effectively, reducing delays and unnecessary trips to empty bins.
- The IR sensor automatically opens the dustbin lid when a person approaches, ensuring a contactless and hygienic waste disposal experience.

### Disadvantages:

- The implementation of the system requires investment in sensors, the Arduino microcontroller, a battery, and solar panels, which might be a higher upfront cost compared to traditional dustbins.
- The system relies on solar energy, which can be inconsistent due to weather conditions, geographical location, or inadequate sunlight during certain times of the year, potentially affecting its performance.
- The effectiveness of the sensors (e.g., IR, ultrasonic, and odor sensors) can be affected by environmental conditions such as temperature, humidity, and the material or shape of the waste, leading to occasional inaccuracies in detection.
- While the system is largely automated, regular maintenance (e.g., cleaning the sensors, checking battery levels, and ensuring the solar panel is functioning properly) is still necessary to ensure optimal performance.
- Ultrasonic and IR sensors have limited range and might not work effectively if waste is stacked unevenly or if large objects obstruct the sensors' line of sight. This could reduce the accuracy of the fill-level detection.

## 6. Conclusion

The proposed smart dustbin system leverages advanced technologies such as IR sensors, ultrasonic sensors, and odor detection sensors, integrated with a solar-powered battery system, to create a more efficient and sustainable waste management solution. By automating waste disposal, monitoring fill levels, and detecting odors, the system improves hygiene, reduces human intervention, and ensures timely waste collection. Additionally, its cost-effective nature, driven by the use of low-power sensors and solar energy, makes it suitable for diverse urban and rural settings. The smart dustbin offers a user-friendly, environmentally sustainable alternative to traditional waste management systems, promoting cleaner public spaces and more efficient city infrastructure. As the system proves effective in smaller or local areas, expanding the network of smart dustbins to larger cities or regions would improve overall waste management efficiency. Incorporating more robust communication technologies (like IoT connectivity) could enhance system integration across multiple locations. Educating the public about the benefits and usage of smart dustbins could increase user participation and ensure proper disposal practices, contributing to the overall success of the system.

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