Development of Automatic Trash Bin by Using Microcontroller

***Sahazati Md Rozali[1], Eliyana Ruslan[2], Rosnaini Ramli[1], Muhammad Nizam Kamarudin[1]**

[1]Development of Automatic Trash Bin by Using Microcontroller

[2]Department of Engineering Technology, Universiti Teknikal Malaysia Melaka

DOI: https://doi.org/10.47772/IJRISS.2026.100601397

Received: 19 July 2026; Accepted: 24 July 2026; Published: 21 July 2026

ABSTRACT

The increasing volume of municipal waste and the inefficiency of conventional waste collection systems have created significant environmental and hygiene challenges in residential areas. Existing trash bins are generally manually operated, lack systematic monitoring mechanisms, and often become unhygienic due to frequent physical contact. This study presents the development of an ESP32-based Automated Trash Bin integrated with infrared (IR) sensors and Internet of Things (IoT) technology to improve waste management efficiency and environmental sustainability. The proposed system utilizes an ESP32 microcontroller as the main controller, where IR sensors are employed for human detection and waste level monitoring. When a user is detected near the bin, the system automatically activates a servo motor to open the lid and closes it after a predefined duration. In addition, the waste level detection mechanism provides real-time monitoring through the Blynk IoT platform, enabling users to receive notifications when the bin reaches full capacity. The prototype was designed and simulated using Tinker cad and programmed using Arduino IDE. Experimental evaluations were conducted under different environmental conditions and waste categories to assess system performance. The results demonstrated that the system achieved high human detection accuracy under indoor and low-light conditions, with average accuracies of 98% and 95%, respectively. However, performance decreased under direct sunlight and high humidity due to infrared interference. Waste level detection accuracy was highest for dry waste materials and lowest for dark-coloured waste because of differences in infrared reflectivity. The integration of the Blynk platform enabled remote accessibility and real-time notification, contributing to more efficient waste monitoring and reduced waste overflow. Overall, the proposed automated trash bin demonstrates a cost-effective, hygienic, and environmentally friendly solution for smart residential waste management systems and has strong potential for future smart city applications.

Keyword: Smart waste management, ESP32, Internet of Things (IoT), infrared sensor, automated trash bin, Blynk, waste level monitoring.

INTRODUCTION

There are various types of dustbins in Malaysia such as mobile garbage bin, roll-on-roll-off (RORO) bin and recycle bin and all these types of bins have their own function. In addition to this manual dustbin, some residence used smart bin. Smart bin in Malaysia is designed to optimize waste management by using technology such as sensor to detect the level of waste in the bin and transmit this information over a network, such as Wi-Fi. This real-time data allows waste collection services to optimize their routes, reduce unnecessary trips and minimize fuel consumption [1]. The main feature of smart bin is level monitoring. Sensor is used to monitor the amount of waste level and provide real-time information to consumer. Some of smart bin incorporate IoT (internet of thing) technology for data analysis [2] [3].

The early stage of bins in Malaysia starts with metal bin with hinged lid. It is followed by bins with foot pedal mechanism which increase cleanliness and convenience in daily usage. Effectiveness of the bin is improved by using spring-loaded lid. These lids were designed to be opened by either pushing or tapping a specific part of the can, activating a mechanism that allowed the lid to open or swing back automatically. Technology is improved rapidly and one of the innovations in waste disposal is the touchless trash can which operates using

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

sensor-based technology. These modern trash cans are equipped with infrared sensors that can detect the movement of hands or nearby objects. When motion is detected, a small motor is activated and automatically lifts the lid to allow for hands-free waste disposal. The mechanism, which combines electronic sensors with a motorized hinge, eliminates the need for physical contact, making it invaluable in maintaining cleanliness. Touchless trash cans typically run on battery power or a rechargeable system, ensuring portability and convenience without being tied to a constant power source. There are several research that implement the technology of distance sensing in the design of smart dustbins [4], [5], [6], [7], [8], [9], [10], [11],[12], [13],[14] and [15]. This characteristic allows the dustbin automatically opened when it detects the movement nearby. Most of this research also equipped with waste level detection such that the user will have the information on the capacity of the bin.

Proper waste management system is important in our community with rapid population growth. Trash bins that recently used in most residential areas typically made of plastic or metal, serve as primary tools for temporary waste disposal. The problem arises when the existing waste collection systems are often inefficient, poorly maintained, and lack of systematic monitoring strategies. Additionally, conventional trash bins are manually operated and frequently unhygienic, discouraging users from direct contact. These limitations contribute to irresponsible disposal behaviours, where individuals choose to discard waste outside designated bins. This issue is largely attributed to the lack of proper waste disposal facilities and the widespread perception that disposing of waste in streets or rivers is more convenient.

Effective waste monitoring and user-friendly waste disposal systems are therefore essential to improve environmental hygiene and optimize waste management processes. The primary objective of this research is to design an effective automated trash bin by using ESP-32 to improve waste management system. The system integrates sensors and IoT technology to monitor waste levels and automate bin operations. A prototype is designed and developed using TinkerCAD, enabling real-time detection of waste levels within the bin. The proposed automated trash bin operates based on object detection principles. An IR sensor detects the presence of nearby objects, such as a user's hand, and sends a signal to the ESP32 microcontroller. This triggers a servo motor to open the bin lid automatically, which then closes after a preset duration. Beyond improving user convenience, this system minimizes physical contact, enhances hygiene, reduces waste overflow, and contributes to lowering carbon dioxide (CO_2) emissions. The development of an ESP32-based automated trash bin presents a promising solution for improving waste management efficiency and fostering a cleaner, healthier, and more sustainable residential environment.

METHODOLOGY

The block diagram of the whole system is illustrated in Figure 1. The ESP32 serves as the main microcontroller and is connected to two infrared sensors. The push button is wirelessly connected to the ESP32 via Wi-Fi. Once the system is powered on, the infrared sensors continuously send input to the microcontroller. On the output side (right side of the diagram), the ESP32 is connected to two components: a servo motor and two LEDs. Based on the input received from the sensors, the ESP32 sends signals to control both the servo motor and the LEDs (white LED and red LED).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

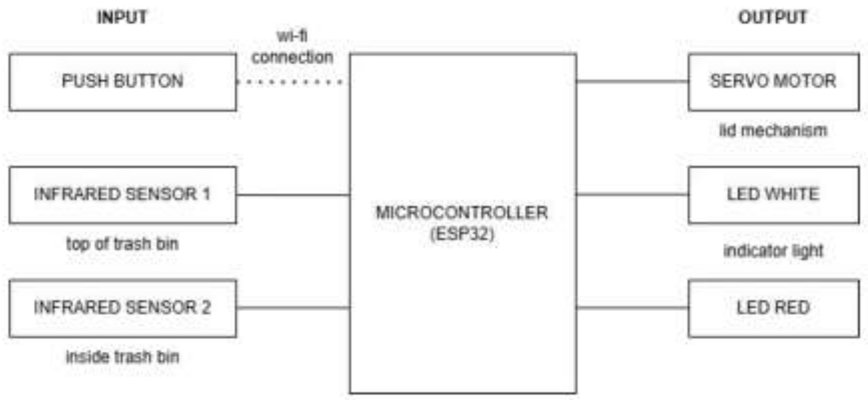

Figure 1. Block diagram of the prototype of smart bin

In this project, the ESP32 is chosen because it is a powerful and versatile microcontroller that features 520 KB of SRAM and up to 4 MB of flash memory. It comes with built-in Wi-Fi and Bluetooth capabilities, making it ideal for wireless communication applications. The board includes a rich set of GPIO pins and supports various peripherals, allowing for flexible hardware integration. Additionally, the ESP32 supports low-power modes, making it suitable for energy-efficient projects. IR sensor is chosen because Infrared (IR) sensor is a cost effective and fast solution for short-range distance measurement, typically up to around 80 cm. It offers moderate accuracy and is best suited for simple, close-range tasks such as object detection, line following, and proximity sensing.

The proposed smart trash bin system is designed based on an ESP32 microcontroller, which serves as the central processing unit for coordinating sensor inputs, actuator control, and Internet of Things (IoT) communication. During operation, an infrared (IR) proximity sensor continuously monitors the surrounding environment for user presence. When an object is detected within the predefined sensing range, the ESP32 processes the sensor input and actuates the servo motor to automatically open the trash bin lid, thereby enabling a touchless waste disposal process.

The lid remains open for a predetermined duration of 10 s before being automatically closed by the ESP32 to minimize odour emission, reduce contamination, and improve system hygiene. To monitor the waste level, a second infrared sensor is installed inside the trash bin to detect the fill level. The ESP32 continuously evaluates the sensor readings and provides visual feedback through two light-emitting diodes (LEDs). A white LED indicates that the bin is operating under normal conditions and has not reached its maximum capacity, whereas a red LED indicates that the waste level has exceeded the predefined threshold, signifying that the bin is full and requires emptying.

The system firmware is developed using the Arduino Integrated Development Environment (IDE) and uploaded to the ESP32 Dev Module, which executes the control algorithm for real-time system operation. To facilitate remote monitoring and control, the system is integrated with the Blynk IoT platform via a Wi-Fi connection. The ESP32 periodically transmits the bin status to the Blynk cloud server, enabling users to monitor the fill level through the Blynk mobile application in real time.

When the bin reaches its full capacity, the system automatically generates and delivers a push notification to the user's mobile device, allowing timely waste collection and reducing the likelihood of overflow. In addition, the Blynk application provides a remote interface that enables users to activate or deactivate the smart trash bin system as required. The integration of automated lid operation, real-time waste level monitoring, wireless IoT communication, and remote system management enhances the functionality, operational efficiency, and user convenience of the proposed smart trash bin. Furthermore, the implementation of real-time notifications and contactless operation contributes to improved sanitation, optimized waste collection schedules, and more effective smart waste management in residential and public environments.

RESULTS AND DISCUSSION

An online survey involving 70 respondents was first conducted to assess public awareness and acceptance of smart waste management systems. The survey revealed that most respondents dispose of household waste more than once daily, highlighting the importance of efficient and hygienic waste disposal facilities. However, less than 10% of respondents had experience using smart trash bins, indicating that the adoption of intelligent waste management technologies in residential areas remains limited.

Furthermore, many respondents identified unhygienic bin lids, overflowing waste, unpleasant odours, and disturbance by stray animals as the major shortcomings of conventional waste bins. More than half of the respondents expressed willingness to adopt an automated trash bin, demonstrating the potential acceptance of IoT-enabled waste management systems. The circuit diagram of the designed system is shown in Figure 2.

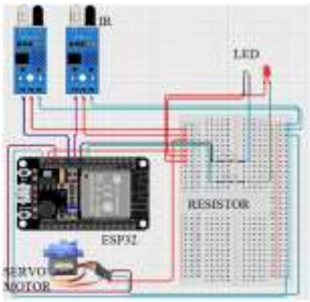

Figure 2. Circuit Diagram of Design System

The developed prototype integrated the ESP32 microcontroller, infrared (IR) sensors, servo motor, LEDs, and the Blynk IoT platform into a fully functional automated waste management system successfully. The ESP32 continuously processed the inputs from the proximity and waste level sensors to control the lid operation and transmit real-time information to the Blynk cloud platform. The system successfully performed touchless lid operation, waste level monitoring, and mobile notification, demonstrating the feasibility of implementing a low-cost IoT-based smart waste bin for residential applications. Figure 3 illustrates the prototype of the Automatic Trash Bin.

Figure 3. Prototype of Automatic Trash Bin

The designed circuit is attached at the back side of the bin. IR sensor for user detection is installed at the bottom of the bin while IR sensor for level detection is installed inside the bin.

Human Detection Performance

The human detection capability was evaluated under four environmental conditions, namely indoor lighting, low-light environments, direct sunlight, and high humidity. Twenty experimental trials were conducted under each condition at sensing distances ranging from 10 cm to 50 cm. The proposed system achieved an average detection accuracy of approximately 98% under normal indoor lighting and 95% under low-light conditions, indicating that the infrared sensor provides reliable performance in controlled environments where ambient infrared interference is minimal.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

However, the detection accuracy decreased to approximately 78% under direct sunlight and 85% under high humidity conditions. Direct sunlight emits strong infrared radiation that interferes with the sensing signal, while moisture in humid environments scatters and attenuates the reflected infrared beam. These findings indicate that environmental conditions significantly influence the reliability of infrared-based sensing systems. The accuracy is calculated using:

$$\text{Accuracy (\%)} = \frac{\text{Number of Successful Detections}}{\text{Total Number of Trials}} \times 100$$

This performance is illustrated in Figure 4.

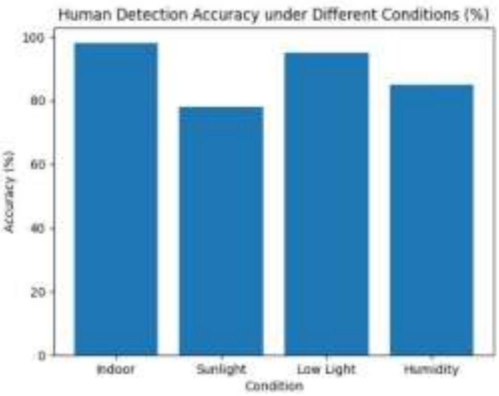

Figure 4. Human detection accuracy of the designed bin

Although the obtained accuracy remains acceptable for indoor residential applications, the results demonstrate that the current sensing approach has limitations when deployed in outdoor or semi-outdoor environments. To improve robustness, future systems should integrate multiple sensing technologies such as ultrasonic sensors, load cells, or Time-of-Flight (ToF) sensors. Sensor fusion techniques could provide complementary measurements, allowing the system to maintain reliable operation despite varying environmental conditions and reducing false detections caused by sunlight or humidity.

Waste Level Detection Performance

The waste level monitoring system was evaluated using four waste categories consisting of dry waste, wet waste, mixed waste, and dark-coloured waste. Experimental results showed that dry waste achieved the highest detection accuracy of approximately 95% because paper and plastic surfaces effectively reflected infrared signals. Mixed waste produced an average accuracy of approximately 85%, while wet waste recorded approximately 80% due to irregular surfaces and infrared absorption. The lowest performance was observed for dark-coloured waste, with an average accuracy of approximately 75%, since dark surfaces absorb rather than reflect infrared radiation. Graph on the waste detection accuracy is shown in Figure 5.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

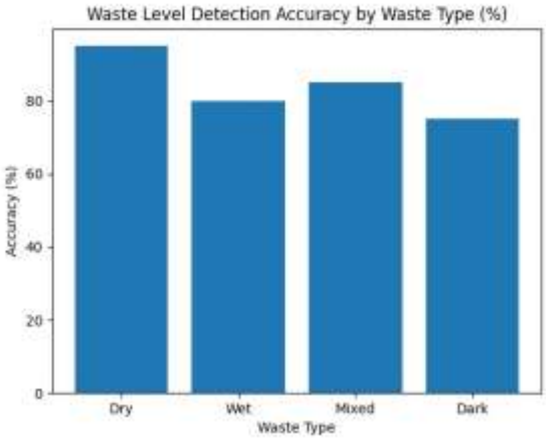

Figure 5. Waste level detection accuracy of the designed bin

These results demonstrate that the optical properties of waste materials significantly affect infrared sensor performance. Consequently, relying solely on infrared sensing limits the applicability of the system when different waste compositions are present in practical environments. Future developments should incorporate ultrasonic sensors for distance measurement and load sensors for weight estimation, enabling multiple sensing parameters to be combined for more accurate waste level estimation regardless of waste colour, texture, or moisture content. Such multi-sensor integration would substantially improve measurement reliability and system robustness in real-world applications.

IoT Integration, Energy Efficiency and Practical Considerations

The integration of the Blynk IoT platform enabled continuous remote monitoring of the waste level and automatic notification when the bin reached full capacity. This functionality reduces the need for manual inspection and enables more efficient waste collection scheduling, thereby minimizing waste overflow and improving user convenience. The remote ON/OFF capability further enhances operational flexibility by allowing users to control the system through a mobile application.

The ESP32 microcontroller demonstrated reliable wireless communication while maintaining relatively low power consumption due to its built-in Wi-Fi module and support for low-power operating modes. The overall prototype consumed only a small amount of electrical power because the servo motor operates only during lid movement, while the LEDs and sensors require minimal current during normal operation. Nevertheless, continuous Wi-Fi communication contributes to the overall energy consumption. Future work should therefore investigate the implementation of deep-sleep modes, event-driven communication, and renewable energy sources such as photovoltaic panels coupled with rechargeable batteries to further improve energy efficiency and sustainability, particularly for outdoor installations.

From a maintenance perspective, the electronic components were positioned behind the trash bin to minimize direct exposure to waste and physical damage. However, long-term deployment would require periodic cleaning of the infrared sensors to remove dust and debris that may affect sensing accuracy. Environmental sealing of the electronic enclosure would also be necessary to protect the circuitry from moisture and rain in outdoor installations.

A preliminary cost analysis indicates that the proposed prototype is economically attractive because it utilizes low-cost and commercially available components, including the ESP32, infrared sensors, servo motor, and LEDs. Compared with commercially available smart waste management systems employing LiDAR, machine vision, or industrial-grade sensing technologies, the proposed design offers a significantly lower implementation cost while providing essential smart functions such as touchless operation, waste level monitoring, IoT connectivity, and mobile notification. Although advanced sensing systems provide higher measurement accuracy and robustness, they require substantially higher hardware and installation costs. Therefore, the proposed system represents a practical and cost-effective solution for residential smart waste management where affordability is a primary consideration.

Overall Discussion and Future Improvements

Overall, the experimental results demonstrate that the proposed ESP32-based automatic trash bin provides an effective proof-of-concept for integrating sensor technology with IoT communication to improve residential waste management. The prototype successfully achieved touchless waste disposal, real-time waste monitoring, and remote notification while maintaining a relatively simple and inexpensive hardware architecture.

Nevertheless, several limitations should be acknowledged. The system performance is influenced by environmental conditions and variations in waste characteristics because waste detection relies solely on infrared sensing. Furthermore, the evaluation was performed on a laboratory-scale prototype over a limited testing period and therefore does not fully represent long-term operation under real environmental conditions.

Future research should focus on large-scale field deployment in outdoor residential environments over extended periods to evaluate long-term reliability, durability, maintenance requirements, and operational costs. The integration of multiple sensing technologies, artificial intelligence-based waste recognition, renewable energy sources, and predictive maintenance algorithms would significantly enhance system robustness and support the implementation of more sustainable smart waste management systems suitable for future smart city applications.

CONCLUSION

This study successfully developed and evaluated an ESP32-based Automated Trash Bin integrated with infrared (IR) sensors and Internet of Things (IoT) technology for smart waste management applications in residential areas. The proposed system effectively addressed several limitations associated with conventional trash bins, including unhygienic manual operation, inefficient waste monitoring, and waste overflow problems. By utilizing the ESP32 microcontroller, IR sensors, servo motor, LEDs, and the Blynk platform, the system was capable of automatically opening and closing the trash bin lid, monitoring waste levels in real time, and providing remote notifications to users when the bin reached full capacity. Experimental results demonstrated that the system achieved high human detection accuracy under indoor and low-light conditions, indicating the reliability of the IR sensor for touchless waste disposal applications. The waste level monitoring system also performed effectively, particularly for dry waste materials. However, the study identified several limitations related to environmental interference and the optical properties of certain waste materials. Detection performance decreased under direct sunlight, high humidity conditions, and for dark-colored or wet waste due to infrared signal absorption and interference. Despite these limitations, the overall performance of the system remained satisfactory for residential waste management applications.

The integration of IoT technology through the Blynk platform significantly enhanced the efficiency and usability of the system by enabling real-time monitoring and remote accessibility. The implementation of automated monitoring and notification features can help reduce unnecessary waste collection activities, minimize waste overflow, improve environmental hygiene, and contribute toward reducing fuel consumption and carbon dioxide (CO_2) emissions. Overall, the developed automated trash bin presents a practical, cost-effective, and environmentally friendly solution for modern waste management systems. The findings of this research demonstrate the potential of combining sensor technology and IoT communication in supporting smart home and smart city initiatives. Future improvements may include the integration of advanced sensing technologies such as ultrasonic or LiDAR sensors, artificial intelligence-based waste analysis, and renewable energy sources to further enhance system accuracy, efficiency, and sustainability.

REFERENCES

1. Novi Azman, Muhammad Aghil Wibowo and R. A. Suwodjo Kusumoputro, Touchless Recycle Bin Internet of Things to Preventing Germs Spread and Real-Time Integrated Waste Management, International Journal of Scientific & Technology Research, Vol 10(3), 2021, pp 69-74

2. Loo Chee Hin, Vazeerudeen Abdul Hameed and Hemalata Vasudavan, An Intelligent Smart Bin for Waste Management, IEEE Mysore Sub Section International Conference, 2021, pp:227-231
3. Sunday A. Afolalu et.al, Development of Smart Waste Bin for Solid Waste Management, International Journal of Sustainable Development and Planning, Vol. 16(8), 2021, pp. 1449-1454
4. Chen, Z., Human-Computer Interactive Intelligent Trash Can, 2023 IEEE 3rd International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA), 26 May 2023 - 28 May 2023, Chongqing, China, Vol 2(174)
5. Rahul V, Balakrishnan et.al, Arduino Based Smart Trash Can- A Solution for efficient Waste Management, 2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS), 17-19 October 2024, India, pp.1–6.
6. Chen, L.-B et.al, Design and Implementation of an Artificial Intelligence of Things-based Autonomous Mobile Robot System for Cleaning Garbage. IEEE Sensors Journal, 2023. pp.1–11.
7. Zhai, J. and Peng, Q. Design of Intelligent Voice Dustbin Based on Single Chip Microcomputer, 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 15-17 October 2021, China
8. Anand K, B, A.S. and K, A.B. Hygiene Guardian: Proximity – Activated Sanitizing Dustbin with AI Vision, 2025 International Conference on Intelligent Control, Computing and Communications (IC3), 2025
9. Meena, M., Sharma, M., Singh, M. and Saha, R. Modeling of Web-Based Solar Powered and Battery Operated Automatic Trash Compactor, 2022 IEEE Delhi Section Conference (DELCON), 11-13 February 2022, India.
10. J. Rejina Parvin, Divya Priya C, V Divya and G, A.S., Automatic Segregation of Household Waste using Machine Learning Approaches. 2022 International Conference on Edge Computing and Applications (ICECAA), 13-15 October 2022, India
11. Asep Najmurrokhman et.al, Development of Automatic Trash Bin for Sorting Metal and Non-Metallic Wastes Using Proximity Sensors and Notifications via Telegram, 2023 9th International Conference on Wireless and Telematics (ICWT), 06-07 July 2023, Indonesia
12. Shaik, S., Kumar, B.N., Anusha, M., Suhani, J., Kalyan, B. and Begum, H. An Efficient IoT based Real Time Smart Trash Separation Bin Model for Urban Areas using LabVIEW. 2023 9th International Conference on Smart Computing and Communications (ICSCC), 17-19 August 2023, India, pp.610–615.
13. Bai, H., Zhang, G., Zhu, M., Li, D., Wang, Y. and Qing, Z. (2024). Design of Smart Bin Control System, 2024 IEEE 4th International Conference on Information Technology, Big Data and Artificial Intelligence (ICIBA), 06-08 December 2024, China, pp.607–612
14. Meenakshi B, Logeswari N, Sivaprasad R, Brindha J, Janani N and Gokula Subashree N, Automated Sensing Cleaner, 2023 Intelligent Computing and Control for Engineering and Business Systems (ICCEBS), 14-15 December 2023, India, pp.1–4.
15. Kalpana Devi P, Mukesh Narayana Gadde, Oli, P. and Meghana Somineni. Automatic Trash Monitoring System, 2023 8th International Conference on Communication and Electronics Systems (ICCES), 01-03 June 2023, India