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IoT-Enabled Smart Dry Trash Bin with Wet Detection and Compaction

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***Abstract* - With the rising demand for sustainable and hygienic waste management, there is an increasing need for intelligent systems that reduce human intervention while improving overall efficiency. This paper presents an IoT-enabled smart waste management system developed to automate waste segregation, real-time monitoring, and space optimization through a compact and well-structured architecture. The proposed system is capable of identifying different categories of waste and managing disposal operations intelligently, thereby ensuring hygienic handling and effective storage. By integrating IoT-based monitoring with automated control mechanisms, the system delivers timely feedback and alerts to maintain consistent and reliable operation. Continuous updates and clear visual indicators enhance user awareness, while automation substantially lowers manual effort and minimizes the risk of contamination. All sensor data are collected and processed using an ESP32 microcontroller and synchronized with a Flutter-based mobile application linked to Firebase Cloud, allowing real-time visualization and notifications. The system's adaptive design, smart connectivity, and scalable framework make it suitable for deployment in urban environments, public infrastructure, and residential spaces. This system supports sustainable cities.**

***Index Terms*—IoT-enabled, smart waste management, waste segregation, automated waste disposal, real-time, Space optimization, Hygienic waste handling, Sustainable waste, Automation, Smart cities, Intelligent waste system, IoT-based alerts, Flutter App, Environmental sustainability, Operational efficiency, Human intervention reduction, Smart connectivity, Adaptive design, Waste tracking and monitoring, Contamination prevention.**

1. INTRODUCTION

Rapid urbanization has significantly increased municipal solid waste generation, posing serious challenges to environmental sustainability and public hygiene. Dry waste, including paper, plastics, metals, and packaging materials, constitutes a major portion of urban refuse. Improper handling of such waste often leads to overflowing bins, scattered litter, and reduced recycling efficiency. The situation worsens when dry waste mixes with wet or organic matter, resulting in contamination and limiting its reuse potential [1][7]. Despite advancements in waste management technologies, collection processes in many regions still depend on manual practices that are labour-intensive and lack real time monitoring capabilities [3][6]. This absence of automation frequently causes inefficient collection schedules, increased fuel consumption, and delayed responses to filled bins. To address these limitations, several IoT-based smart bin systems have been introduced for waste level monitoring and alert generation [2][4]. However, most existing solutions focus primarily on basic sensing, with limited attention given to intelligent segregation and volume reduction through compaction [5]. To overcome these challenges, the proposed system integrates ultrasonic level sensing, moisture detection, and automated compaction within a unified IoT-enabled framework. Although designed mainly for dry waste management, a moisture sensor is incorporated to detect and isolate wet waste, thereby maintaining hygiene and preventing leakage. An ESP32 microcontroller processes sensor data and transmits it to a cloud backend, while a mobile application provides real-time monitoring and alerts. This integrated approach enhances operational efficiency, supports data-driven waste collection, and contributes to sustainable smart city waste management.

2. LITERATURE REVIEW

Recent research in waste management has focused on integrating Internet of Things (IoT) technologies to improve monitoring, collection efficiency, and sustainability in urban environments. Several studies have highlighted the growing need for automated systems to address issues such as bin overflow, inefficient collection schedules, and poor waste handling practices. Lamani et al. [1] presented the design and fabrication of a low-cost solar-powered trash compactor aimed at reducing waste volume in smart city applications, demonstrating the importance of compaction in improving storage efficiency. Similarly, Raguvaran et al. [4] and Sasireka et al. [5] explored garbage compactor bins triggered by waste level thresholds, emphasizing volume reduction as a key factor in optimizing waste management operations**.** IoT-based monitoring solutions have been widely investigated for real-time waste level detection. Ilyas et al. [2] and Bhuvaneswari et al. [7] developed smart garbage monitoring systems using IoT platforms to track bin status and transmit data to centralized systems. Further contributions by Sandhya et al. [3] and Mohan et al. [9] incorporated ultrasonic sensors and microcontroller-based designs to provide timely alerts when bins reach capacity, enabling more efficient collection planning in metropolitan areas. Cloud-based and data-driven approaches have also gained attention in recent studies. Abba and Ihechukwu [6] proposed an IoT framework for smart waste monitoring and control in urban settings, highlighting scalability and real-time decision support. Matta et al. [8] evaluated system performance for solid waste

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Vol. 14 Issue 12 , December - 2025

bin level detection, demonstrating the role of data analysis in improving operational efficiency. In addition, Bansod et al. [10] addressed IoT-based e-waste management, extending smart waste concepts to sustainable material recovery. Although these studies demonstrate significant progress in waste monitoring and compaction, most existing systems address individual aspects such as level detection, alert generation, or volume reduction. Limited work has focused on the integrated combination of real-time monitoring, wet–dry waste identification, and automated compaction within a single IoT-enabled framework. The proposed system aims to address this gap by offering a unified solution tailored for efficient and hygienic dry waste management in smart city environments.

3. SYSTEM DESIGN AND METHODOLOGY

At the core of the system, the ESP32 microcontroller functions as the primary processing unit, efficiently coordinating all sensor inputs and output responses. The overall system architecture, illustrated in Fig. 1, depicts the interconnection between the ultrasonic sensor, moisture sensor, LED indicators, and buzzer module. The ultrasonic sensor continuously measures the bin's fill level with reliable accuracy, while the moisture sensor effectively distinguishes between dry and wet waste, enabling proper segregation at the initial stage. Based on the bin's capacity status, LED indicators illuminate green, blue, or red to denote low, medium, and full levels, respectively, and a buzzer generates an audible warning as the bin nears its maximum limit [1][5]. The hardware setup is tightly coupled with the software layer, allowing real-time notifications that promptly inform users or municipal personnel when the bin reaches its capacity. The software interface is implemented through a Flutter-based mobile application that retrieves data from Firebase Cloud and displays bin status, moisture levels, and compaction activity via an intuitive graphical user interface. This proactive notification mechanism eliminates the need for physical inspection, ensuring timely waste collection and preventing overflow, thereby supporting urban hygiene. An automated compaction unit driven by a flipper motor is integrated to activate once a predefined threshold is exceeded. This mechanism compresses the waste, increasing effective storage capacity and reducing collection frequency [2][4]. The logical control flow, illustrated in Fig. 2, outlines the sequential process of sensing, decision-making, actuation, and cloud-based communication using Firebase. Prior to physical deployment, the complete system was simulated and validated on the Wokwi platform to verify circuit integrity and functional correctness. The embedded firmware was developed using the Arduino IDE and follows a modular programming structure to ensure ease of debugging and future scalability. Designed for low power consumption, the system is adaptable to residential buildings, institutions, and public spaces. By combining sensing technologies, automation, mobile-based visualization, and intelligent alerts, the proposed prototype significantly reduces human intervention while promoting efficient and sustainable waste management. By transforming conventional bins into self-regulating, IoT-enabled units, the system contributes meaningfully to cleaner and smarter urban environments
[8][9].

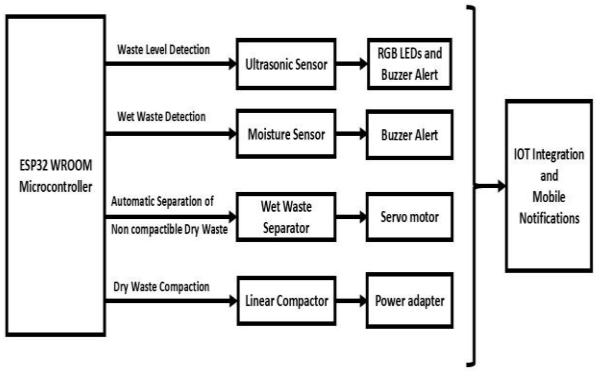

Fig:1. Block diagram of the IoT-based smart trash compactor system

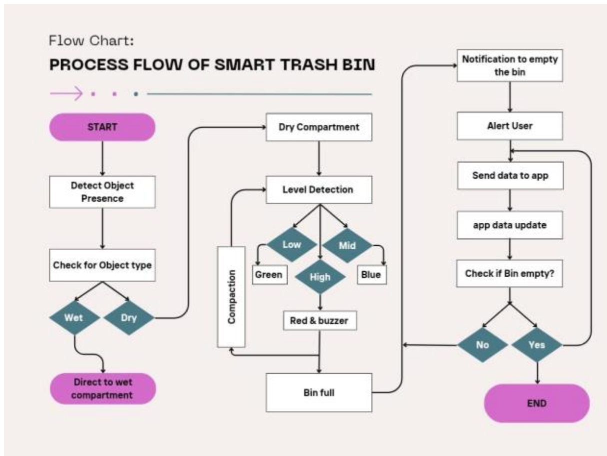

Fig:2. Flowchart of Smart Trash Bin Operation

3.1. Implementation

The implementation of the proposed system was carried out in two major stages, namely simulation and hardware realization. During the simulation phase, the complete circuit design was developed and verified using the Wokwi online Arduino simulator to ensure component correctness and functional reliability. The ESP32 microcontroller was programmed to acquire and process data from an ultrasonic sensor that continuously measured the fill level of the bin. Based on the measured distance values, condition-specific LED indicators—green for low, blue for medium, and red for full—were activated to visually represent the current status of the bin. In addition, a buzzer generated an audible warning as the waste level approached the predefined upper threshold, providing early notification. This simulation stage proved useful in validating sensor behaviour, alert timing, and overall control logic before physical deployment, allowing effective debugging and performance optimization
[1][3][10].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

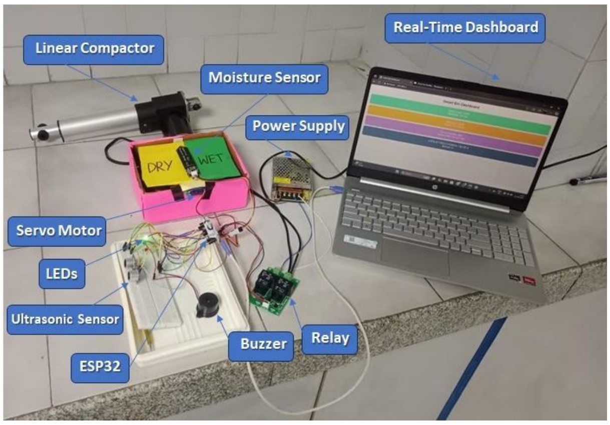

Fig:3. Circuit Integration

During the hardware realization phase, a functional prototype was assembled on a breadboard using the ESP32 controller, ultrasonic sensor, LEDs, and buzzer module. The integrated system was mounted onto a model dry waste bin, as illustrated in Fig. 3, and experimental testing confirmed accurate sensor responses and reliable alert activation. Real-time bin-level data were transmitted to the Firebase Cloud platform and synchronized with a Flutter-based mobile application to enable continuous remote monitoring. The application displayed live parameters such as distance measurements, level status, and alert messages, while push notifications informed users and municipal personnel whenever the bin neared capacity, ensuring timely collection and efficient operational planning [2][4][6]. To enhance automation, the implemented system incorporates a flipper mechanism that efficiently guides incoming waste into the bin and initiates an automatic compaction process once a predefined level is reached. This mechanism significantly reduces waste volume and improves storage utilization. A moisture sensor is also employed to distinguish between wet and dry waste, thereby maintaining hygiene and enhancing recycling quality. Collectively, these subsystems constitute a self-regulating and intelligent prototype operating with minimal human intervention, with reliable system performance.

4. RESULTS AND DISCUSSION

The proposed IoT-enabled Smart Trash Compactor was successfully designed, simulated, and implemented to evaluate its accuracy, responsiveness, and integration efficiency. The complete system was validated through two major stages: software simulation and hardware realization. Simulation was performed using the Wokwi platform, while real-world implementation was carried out using the ESP32 microcontroller. The system integrates essential components, including an ultrasonic sensor, a moisture sensor, RGB LEDs, a buzzer, a servo-driven flipper mechanism, a motorized compactor, and a Flutter-based mobile application connected to Firebase Cloud for real-time IoT monitoring. The primary objective was to precisely detect trash levels, identify waste type, automatically initiate compaction at predefined thresholds, and provide continuous real-time monitoring through cloud connectivity. During the simulation phase, the ESP32 accurately processed distance values from the ultrasonic sensor to compute the bin's fill percentage. Based on these readings, RGB LEDs dynamically changed color to indicate the current bin status. When the bin was at a low fill level, the green LED illuminated, indicating sufficient available capacity, as shown in Fig. 4. At a medium fill level, the blue LED was activated to represent a moderate waste condition, as shown in Fig. 5. These visual indicators enabled quick status identification without the need for manual inspection, improving user convenience and system transparency. As the trash level approached the maximum threshold, the system activated the red LED and simultaneously triggered the buzzer to provide clear visual and audible alerts, as illustrated in Fig. 6. This alert mechanism ensured immediate notification to users or service personnel, thereby preventing bin overflow and improper waste accumulation. All threshold events were recorded and transmitted to the Firebase Realtime Database, enabling systematic logging and further analysis.

Fig:4. Low Level - Green LED

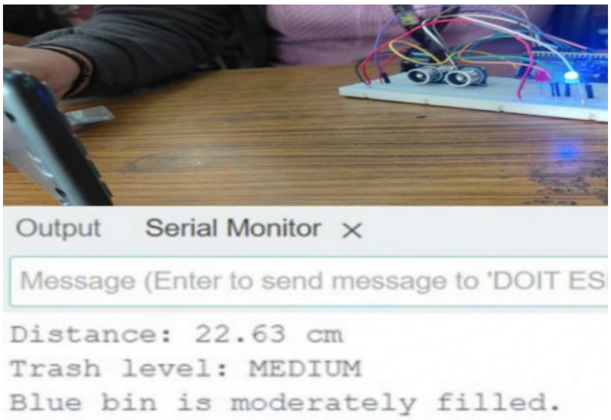

Fig:5. Medium Level - Blue LED

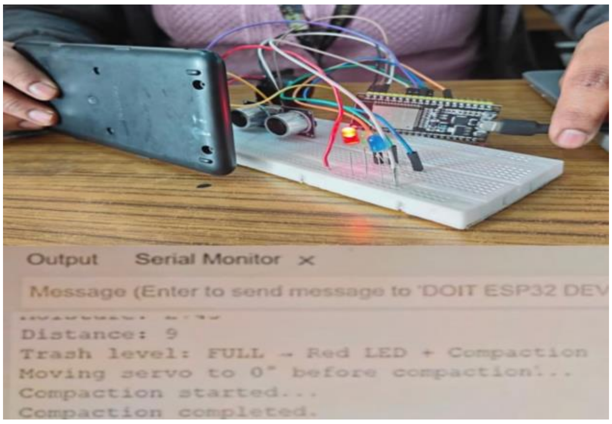

Fig:6. High Level - Red LED

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To ensure hygienic waste handling, a moisture sensor was employed to differentiate between wet and dry waste. When dry waste was detected, a servo-based flipper mechanism rotated to approximately 140°, directing the waste toward the compaction chamber, as shown in Fig. 7. In contrast, when wet waste was identified, the flipper rotated to around 70°, diverting the waste to a separate container to prevent odour formation and cross-contamination, as shown in Fig. 8. This segregation at the source significantly improved cleanliness and recycling efficiency.

To maintain hygienic waste handling and effective segregation, a moisture sensor was incorporated to distinguish between dry and wet waste. When dry waste was detected, the servo-driven flipper mechanism guided the waste into the compaction chamber by rotating approximately 140°, as illustrated in Fig. 7. Conversely, when wet waste was identified, the flipper rotated to around 70°, diverting the waste into a separate container to prevent odour formation and cross-contamination, as shown in Fig. 8. This controlled segregation at the source improved recycling efficiency and reduced health concerns. Once the bin reached its maximum capacity, the motorized compaction mechanism was automatically triggered. The compactor efficiently compressed the accumulated dry waste, increasing effective bin capacity

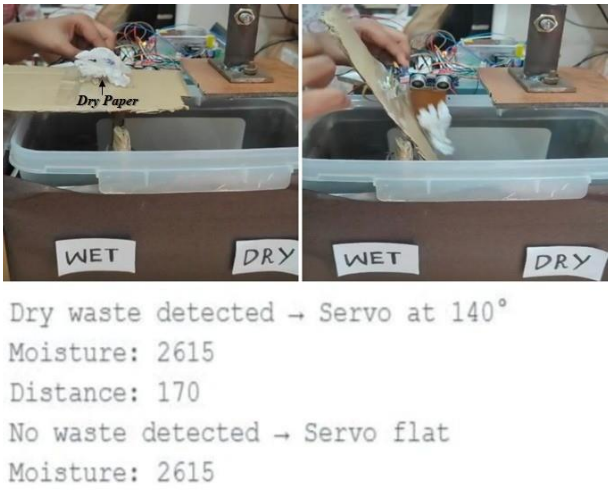

Fig:7. Dry Waste Detected

Fig:8. Wet Waste Detected

and reducing the frequency of manual disposal. The compaction process and its operational sequence are illustrated in Fig. 9. This automated volume reduction substantially improved space utilization while lowering operational energy consumption, thereby demonstrating the effectiveness of the overall design.

The Smart Bin Dashboard developed using the Flutter framework provided real-time visualization of the system by retrieving live data from Firebase Cloud. The mobile application displayed critical parameters such as trash level, moisture value, servo position, compaction status, and LED–buzzer indications. As shown in Fig. 10, the mobile interface dynamically updated its status indicators, displaying green for low level, blue for medium level, and red when the bin reached full capacity. All sensor readings and threshold events were continuously uploaded to the Firebase Cloud for real-time storage and synchronization, as shown in Fig. 11. The cloud database maintained key parameters such as trash level, moisture status, compaction activity, and alert indicators, enabling reliable data logging and traceability. This centralized data management supported seamless communication between the ESP32 hardware and the Flutter mobile application, as shown in Fig. 11.

Fig:9. Compaction Process

The fully assembled hardware prototype of the proposed IoT-enabled smart dry trash bin was developed, deployed, and evaluated under realistic operating conditions. The prototype cohesively integrates the ESP32 microcontroller, ultrasonic

International Journal of Engineering Research & Technology (IJERT)
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Vol. 14 Issue 12 , December - 2025

sensing unit, moisture detection module, servo driven flipper mechanism, and motorized compaction assembly within a compact and functional structure. Clear physical separation between the wet and dry waste compartments ensures hygienic handling while improving segregation reliability. The linear-actuator-based compaction mechanism efficiently compresses dry waste upon reaching a predefined threshold, thereby enhancing space utilization. The complete working model illustrating waste segregation, compaction, and real-time monitoring capability is presented as shown in Fig. 12.

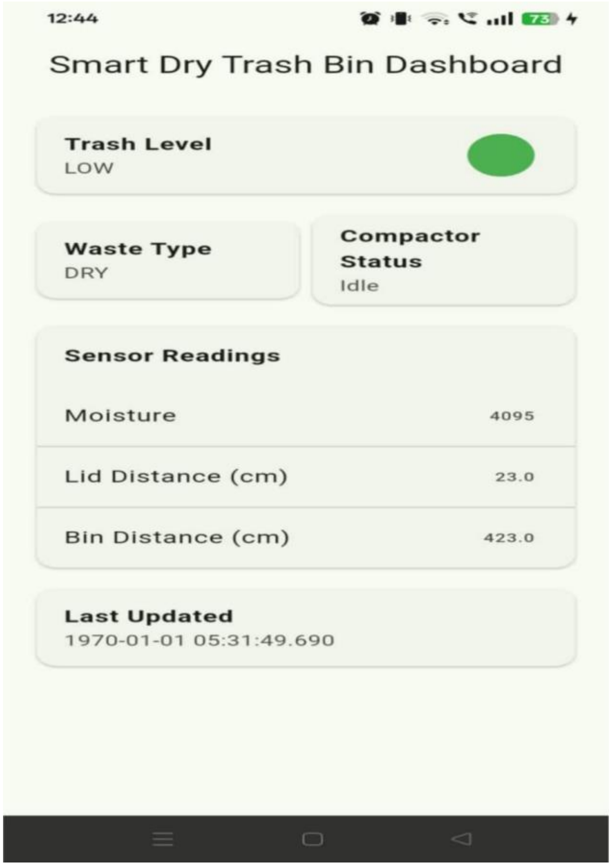

Fig:10. Mobile App View

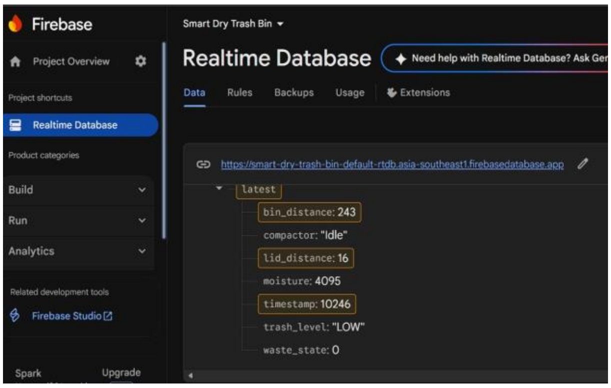

Fig:11. Firebase Data Log

5. CONCLUSION

The proposed IoT-enabled Smart Dry Trash Bin with Wet Detection and Compaction successfully demonstrates how automation, sensing, and connectivity can be harmoniously integrated into a single, efficient waste-management framework. The prototype achieved accurate waste-level detection through ultrasonic sensing, effective wet–dry differentiation using a moisture sensor, and smooth operational control via the ESP32 microcontroller. The incorporation of

Fig:12. Working Prototype Model

the compaction mechanism reduced waste volume considerably, improving storage efficiency and minimizing manual intervention. Visual indicators and buzzer alerts provided clear, real-time feedback that enhanced user awareness and response. The developed real-time dashboard implemented using a Flutter mobile application and synchronized with Firebase Cloud as the real-time database proved instrumental in continuously monitoring system parameters and ensuring stable hardware performance during testing. Both simulation and hardware evaluations validated the design's accuracy, responsiveness, and reliability, confirming that the system performs consistently under varying conditions. The compact architecture and low power consumption make it adaptable for deployment across residential, institutional, and public environments. By merging embedded control with Flutter based IoT visualization and Firebase cloud connectivity, the project delivers a cleaner, safer, and more sustainable approach to waste handling. Overall, this work highlights how intelligent automation can transform ordinary bins into proactive, data-driven systems capable of supporting the broader objectives of smart city infrastructure and environmental sustainability.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

6. FUTURE SCOPES

The proposed smart dry trash compactor system has considerable potential for future enhancement and large-scale implementation. Its IoT interface can be extended beyond the existing dashboard to a dedicated mobile or web-based platform, allowing users and municipal authorities to access live updates, receive alerts, and manage operations remotely. This addition would improve system accessibility, visualization, and scalability across various environments. Incorporating solar-powered operation could further reduce energy dependence, supporting a sustainable and eco-conscious design. Further developments may include predictive analytics and machine learning to anticipate waste accumulation patterns and optimize collection schedules. Such intelligence can minimize redundant trips, conserve fuel, and lower carbon emissions. Introducing inter-bin communication would enable multiple bins to share data, forming a coordinated waste network for efficient route planning. In the long term, AI-based decision systems could manage compaction cycles, detect anomalies, and predict maintenance needs autonomously. These advancements would transform the prototype into a proactive smart infrastructure component ready for smart city deployment.

7. ACKNOWLEDGMENT

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8. REFERENCES

[1] Jyoti Lamani, Ashwini Kolkar, Uday Bhajantri, Abhishek Nagannavar, Akshata Patted, and Supanna S. Shirguppe. "Design and Fabrication of Low-Cost Solar Powered Trash Compactor for Smart Cities." Department of Electrical and Electronics Engineering, SGBIT Belagavi, Karnataka, India, 2022.

[2] Siti Sarah Md Ilyas, Muhammad Amirul Rosyad Mohd Halim, Nadia Abdul Wahab, and Norfiza Ibrahim. "IoTBased Smart Garbage Monitoring." Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perlis Branch, Arau Campus, 2021

[3] Sandhya, Anjali N, and M. Prabhakar. "Smart DustbinGarbage Segregation and Trash Level Indicator Using IoT." International Scientific Journal of Engineering and Management, vol. 2, no. 4, Apr. 2023.

[4] R. Raguvaran, M. Z. Othman, and M. K. Aiman, Dustbin Compactor, Final Year Project Report, Dept. of Mechanical Engineering, Politeknik Sultan Salahuddin Abdul Aziz Shah, 2022.

[5] S. M. Sasireka, P. Vidhyalakshmi, M. Sakthivigneshwari, R. Prakash, and C. K. Vishal, "Level Triggered Garbage Compressor Bin," in Proceedings of the 2023 International Conference on Energy, Materials and Communication Engineering (ICEMCE), Madurai, India, Dec. 2023.

[6] Abba, S., and Ihechukwu, C. (2020). "IoT-Based Framework for Smart Waste Monitoring and Control System: A Case Study for Smart Cities." Presented at the 7th Electronic Conference on Sensors and Applications. Available online: https://ecsa7.sciforum.net/.

[7] Bhuvaneswari.T, HossenJ.Amir Hamzah, N.Velrajkumar, P., and Jack, O. H.(2020). "Internet of Things (IoT) Based Smart Garbage Monitoring System." Indonesian Journal of Electrical Engineering and Computer Science, 20(2), 736–743. DOI: 10.11591/ijeecs.v20.i2.pp736-743.

[8] Matta, P., Pamula, S., Singh, R. K., and Bojja, P. (2024). "Development of Waste Management System for Solid Waste Bin Level Detection and Performance Evaluation." AIP Conference Proceedings, 2512(1). https://doi.org/10.1063/5.0160102.

[9] M.Mohan, R. M. K. Chetty, V. Sriram, M. Azeem, P. Vishal, and G. Pranav, "IoT Enabled Smart Waste Bin with Real-Time Monitoring for Efficient Waste Management in Metropolitan Cities," International Journal of Advanced Smart Convergence (IJASC), vol. 1, no. 3, pp. 013, Sep. 2019. DOI: 10.22662/IJASC.2019.1.3.013.

[10] Pallavi Bansod, Sonali Shende, Rajat Gajbhiye, Sujata Sardare, Aslam Ghodke, and S. S. Sawwashere. "IoT Based Smart E-Waste Management System." International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 10, no. 7, July 2022, pp. 881-XX, ISSN: 2321-9653. Available at: www.ijraset.com.