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Development of Smart Waste Bin with Segregation System Protoype

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Abstract

In the current era of rapid global development, the substantial generation of electronic, plastic, and biodegradable waste poses a critical environmental challenge, especially in developing nations where waste management is often neglected. Ineffective waste disposal can lead to pollution, health risks, and resource waste. Therefore, the smart waste bin with segregation system prototype connected with Iot dashboard is built to overcome the problems. This work utilizes an Arduino UNO R3 microcontroller, inductive proximity sensors for metal detection, a moisture sensor for gauging waste moisture, and ultrasonic sensors for measuring waste levels together with Servomotors also are enabled to precise the sorting control for the waste collection. The system is integrated with Node-RED user-friendly interface for real-time monitoring. The seamless coordination between the sensor's detection and precise servomotor control ensures accurate sorting of each waste category into designated compartments for further processing or disposal and each type of waste being integrated correctly into their designated compartment with no error. This system also able to indicate the user about its level of waste inside the dustbin and it put a significance result towards the potential of connection towards more than one dustbin. Hence this automation system improves waste sorting effectiveness and boosts the overall efficiency of waste management systems, promoting recycling initiatives and encouraging environmentally responsible practices for wet waste, metal waste, and other waste categories. The system's potential usage in public spaces offers a solution to optimize waste management and contribute to a cleaner and more environmentally conscious public infrastructure. furthermore, .system's usability can be enhanced to provide a platform for effective data management and analysis related to waste management.

1. Introduction

In the current era of rapid global development, there is a substantial generation of undesired waste comprising electronics, plastics, and numerous biodegradable products [1]. Since waste management is one of the most neglected factors in developing nations [2], there is an immediate need to resolve this issue. As a direct and indirect source of environmental harm, waste is one of the most significant environmental factors [3].

There are two primary categories of waste collection: bin collection and door-to-door collection [4]. In the first case, bin size and location are considered, whereas in the second instance, waste is collected directly from homes and other areas by vehicles. Waste management is a significant challenge for cities and communities across the globe [5]. Ineffective waste collection and disposal can result in environmental pollution, health risks, and resource waste [6]. The development of smart waste management systems has acquired prominence in response to these issues [7].

Smart waste management systems employ technology to monitor [8], analyze [9], and optimize [10] the collection and disposal of waste. These systems use a variety of sensors [11], data analytics 12], and communication technologies [13] to collect real-time data to enhance operational efficiency [14] and reduce the environmental impact of waste management [15].

The smart waste bin proposed in this work attempts at sorting waste at the consumer level prior to the collection of waste to the waste disposal and processing centers. The smart waste bin consists of sensors and mechanical sorting system that will be able to sort waste from the beginning in public spaces and households. These sensors, ultrasonic sensors, moisture sensors, and inductive proximity sensors, play a vital role in providing comprehensive data for efficient waste management. Implementing this technology into the existing infrastructure for waste management will increase operational efficiency [16], thereby reducing the risk of contamination [17] and furthering sustainable practices [18].

2. Methodology

Prior to the assembly of the prototype, comprehensive testing procedures are conducted to gain a thorough understanding of the individual components. The following is the flow chart of the process flow as shown in Fig. 1. This pre-assembly testing serves a dual purpose: first, to test functionalities of each component, and second, to pre-emptively address any issues that may arise during the assembly of the prototype by having troubleshooting methods readily available.

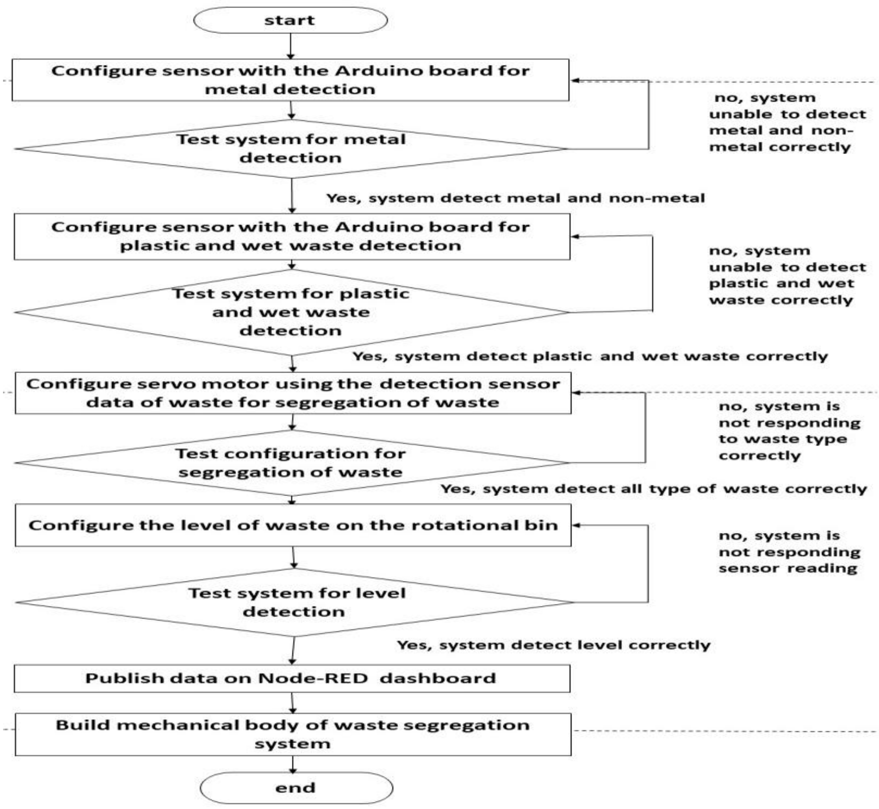

Fig. 1 *Flow chart of the waste management prototype development*

The project begins by configuring different sensors for waste identification: an inductive proximity sensor for metallic waste, a moisture sensor for wet waste, and the absence of detection by both indicating other waste types. After confirming sensor functionality, waste sorting occurs using servo motors to rotate dustbins, ensuring accurate waste deposition into designated compartments. Integration of the Node-RED platform provides detailed information on the smart dustbin's waste level by using the ultrasonic sensor, enhancing monitoring in an academic context.

2.1 Smart waste bin with segregation system prototype design

During the selection process for this work, specific components were carefully identified based on their distinct nature and intended functions. Table 1, which is connected to Fig. 2 outlines the functions of each component in the automated sorting bin for this work.

Table 1 *Function of component*

	Component	Function(s)
1	Power source	Electric power converters
2	Inductive proximity sensor	Metal detection tool using magnetic field
3	Moisture sensor	Moisture detection tool using measure dielectric permittivity
4	Ultrasonic sensor	Measure distance between the waste and the sensor
5	Servo motor	Continuous determination of precise positions, speeds, and torque via control electronics (servo controller)
6	Arduino	Central processing unit to carry out all the process

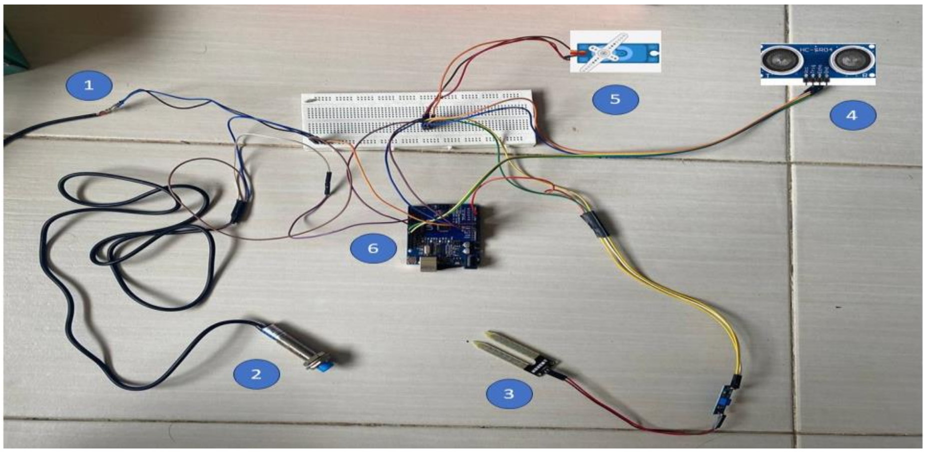

Fig. 2 *Actual diagram of connection to automated sorting bin*

The Arduino connects to the ultrasonic sensor and to an inductive proximity sensor and a soil moisture sensor. The relevant pin connects their relevant pins to corresponding GPIO pins on the Arduino. If specific types of detected by the sensor, the Arduino takes charge as shown in Fig. 3. It coordinates a servo motor's motion to a specified angle, efficiently segregating the waste into the correct compartment.

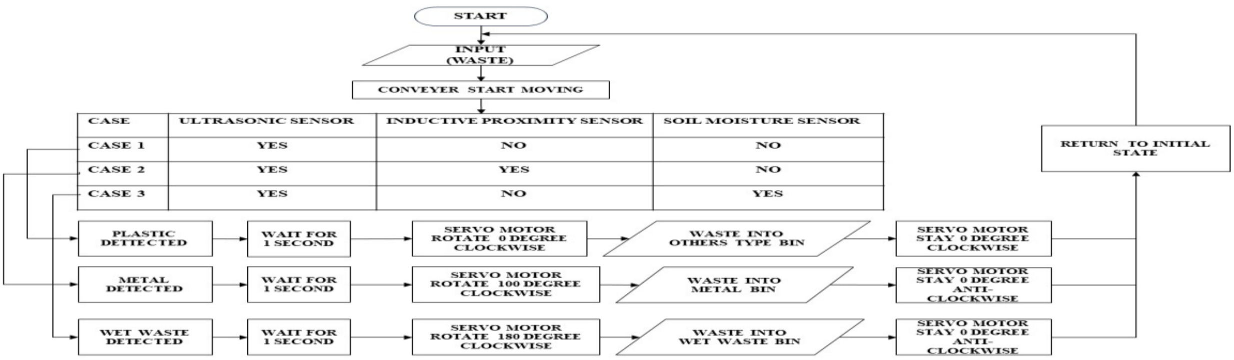

Fig. 3 *Flowchart of the sorting process*

2.2 Conveyor belt system prototype design

When all the testing is done, the circuit for the conveyer belt prototype is constructed, the conveyer belt is assembled by integrating all the components, commencing with the ultrasonic sensor. The functionality of this sensor in identifying the existence of objects within the range. When coupled to an Arduino, the L298N motor driver enables accurate regulation of motors. In contrast to devices such as the ESP8266, the L298N lacks the inherent capability to utilize the RX (Receive) and TX (Transmit) ports for Arduino communication. Fig. 4 shows the circuit constructed for the conveyer belt prototype.

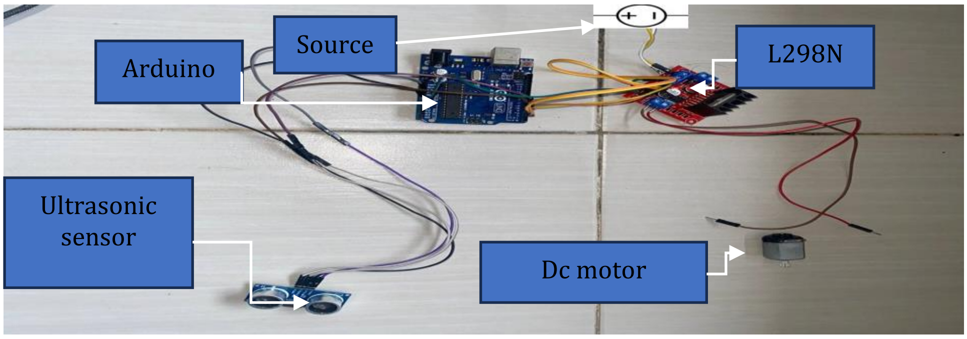

Fig. 4 *Actual diagram of connection to conveyer belt*

Presently, the attention turns to the Arduino, which establishes an interface with both the ultrasonic sensor and the motor driver that powers the conveyor belt. The Arduino initiates operation of the motor driver when an object is detected by the ultrasonic sensor in the smart receptacle. As a result, the conveyor belt is initiated, which aids in the effective administration of waste contained within the intelligent receptacle. By virtue of this synchronized configuration, the intelligent receptacle can react intelligently to the existence of objects. Fig. 5 show the building reference of the conveyer belt for waste segregation system.

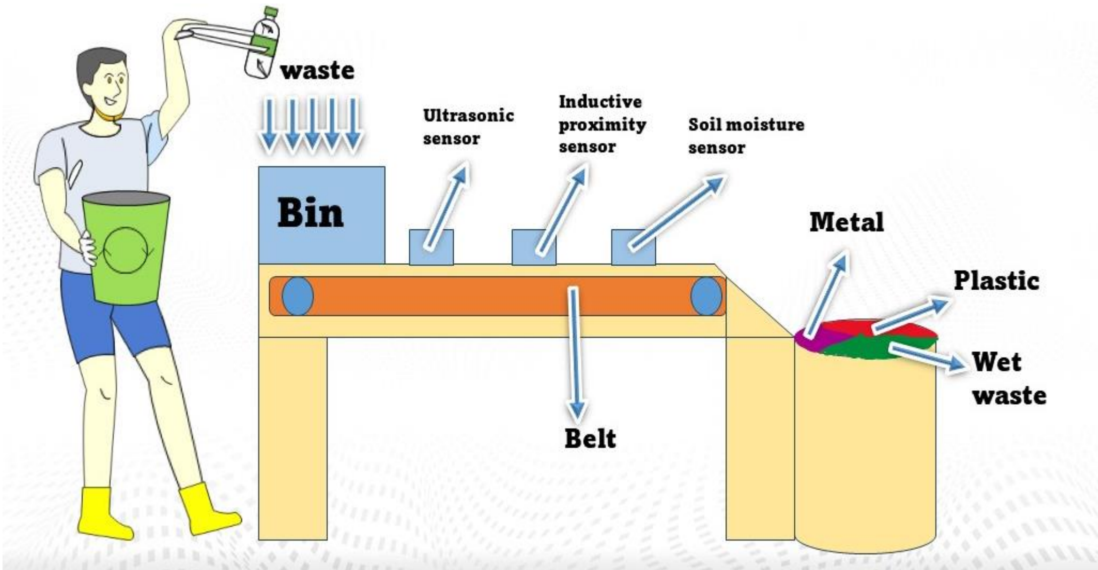

Fig. 5 *Reference of the conveyer belt for waste segregation system*

2.3 Waste level system prototype design

The process of setting up the waste level configuration in the rotating bin for the Node-RED interface entails the implementation of a complex system that incorporates data from an ultrasonic sensor, enabling accurate and detailed measurements of waste accumulation. The configuration was based on two items as it involves the height of the bin and the position of the ultrasonic sensor as being shown in Fig. 6(a) This configuration involves the calibration of the ultrasonic sensor, ensuring its precise positioning within the bin and establishing data transfer protocols for the purpose of providing real-time information to the Node-RED platform using synchronization with Arduino with the Node-red Cloud as being shown in Fig. 6(b).

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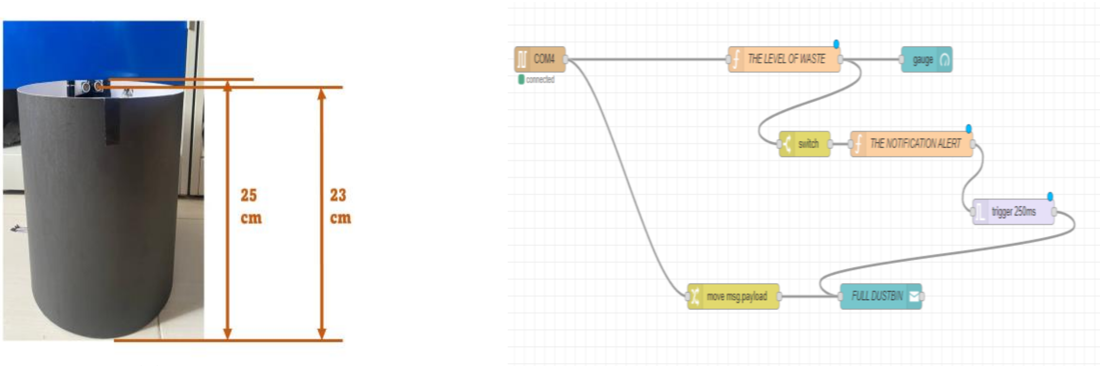
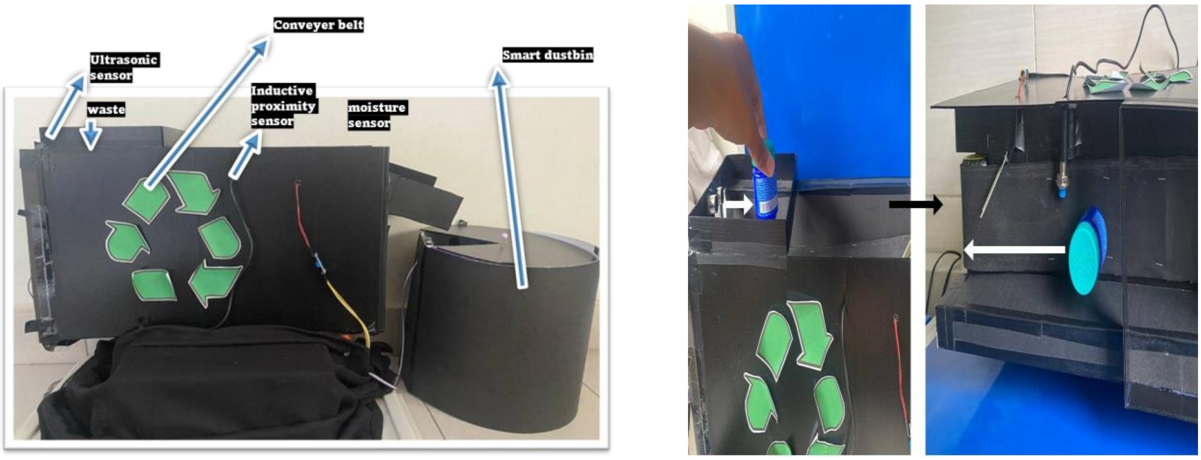


(a) (b)

Fig. 6 *(a) Position of ultrasonic sensor in rotating bin(b) Synchronization with Arduino with the Node-red Cloud*

3. Results and Discussion

Fig. 7 (a) shows actual waste segregation prototype design. 3 involves the incorporation of essential elements, starting with the ultrasonic sensor, which serves a critical function in detecting the existence of items within the receptacle. Shifting focus to the Arduino, it makes connections not solely with the ultrasonic sensor, but furthermore with an inductive proximity sensor and a soil moisture sensor. The supplementary sensors have the function of detecting metal and wet waste, respectively, in addition to other forms of trash that may not be detected by both sensors. Recognition of waste delivers waste to the next phase on the conveyer belt as shown in Fig. 7 (b). Waste passes conveyor belt sensors to enhance management.



(a) (b)

Fig. 7 (a) *Actual waste segregation prototype design* **(b)** *Movement of the object through conveyer belt*

To enhance waste management efficiency and facilitate sustainable waste decomposition and composting, inductive proximity sensors and moisture sensors evaluate waste composition and quality as shown in Fig. 8. When the bin is full, the ultrasonic sensor signals the disposal of trash, preventing overflow and optimizing waste management. The system incorporates Arduino, inductive proximity, ultrasonic, and moisture sensors to transform trash management by measuring ultrasonic distance, inductive proximity, and wetness. This unique waste sorting system utilizes robust mechanical components and state-of-the-art sensor technologies for improved effectiveness.

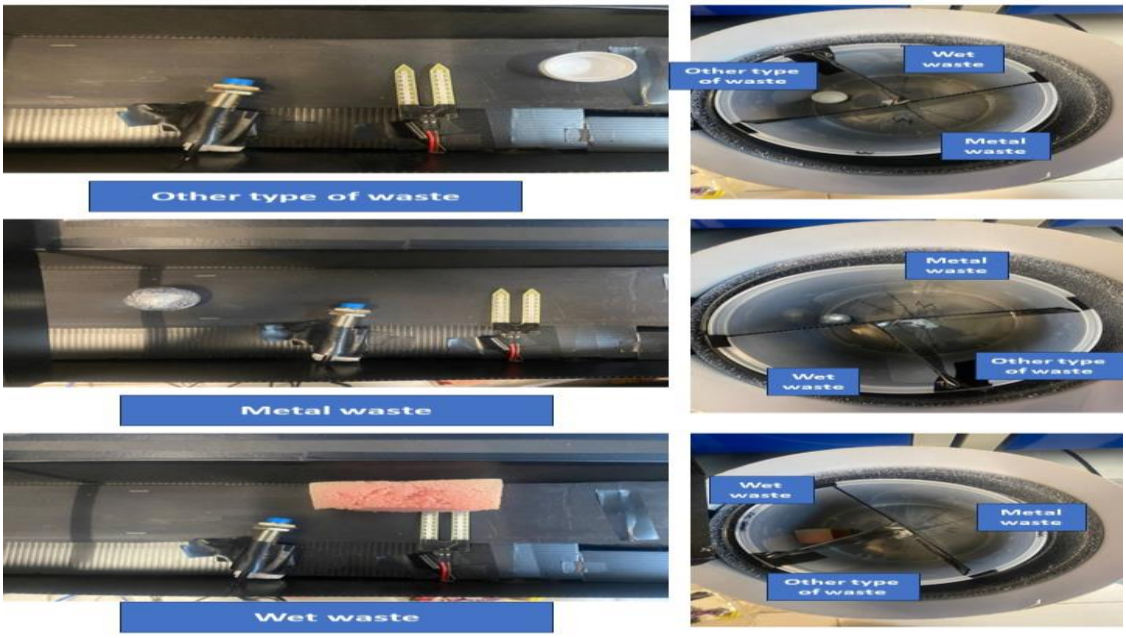


Fig. 8 *Sorted waste into correct compartment.*

When the board connected and in synchronization with Arduino that has been successfully established with the Node-red Cloud with help of ultrasonic sensors that are strategically positioned on the conveyor belt, it operates the belt and -connected to smart dustbin revolving bin measure its level. The visual representation of waste levels through gauges, as depicted in Fig. 9, provides an intuitive and comprehensive overview, aiding authorities in making informed decisions on optimizing collection routes, scheduling pickups, and ensuring timely waste disposal. Moreover, the automated notification system within Node-RED enables quick responsiveness to critical thresholds, preventing potential overflow situations and contributing to a cleaner and healthier urban environment. The integration of Node-RED in public spaces for waste management represents a significant leap forward in optimizing urban sanitation systems. By deploying a network of connected dustbins equipped with sensors to measure waste levels, Node-RED facilitates the seamless transmission of real-time data to a centralized monitoring system. This not only enhances the efficiency of waste collection but also allows for proactive management based on accurate, live information. In densely populated areas, where waste generation is dynamic and varies throughout the day, Node-RED serves as a crucial tool for municipalities and environmental agencies.

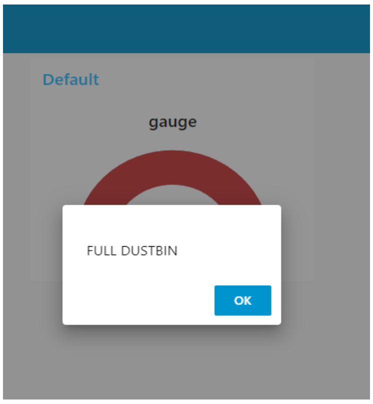


Fig. 9 *The waste level output*

Tables 2, 3, and 4 present the outcomes of the repeatability assessment conducted for each waste type on the sensors. The waste is being subjected to sensor analysis to determine the duration period of the servomotor.

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Table 2 *Results of time response for servo motor to rotate for metal detection.*

Component	No	Acceptance	Time response to rotate
Aluminum foil	1	yes	2.3
	2	yes	4.2
	3	yes	1.9
	4	yes	2.0
	5	yes	3.2
	6	yes	2.2
	7	yes	2.2
	8	yes	2.1
	9	yes	2.5
	10	yes	2.8
	11	yes	2.6
	12	yes	2.1
	13	yes	2.7
	14	yes	2.7
	15	yes	2.7

Table 3 *Results of time response for servo motor to rotate for wet waste detection.*

Component	No	Acceptance	Time response to rotate
Wet sponge	1	yes	3.3
	2	yes	4.8
	3	yes	2.9
	4	yes	2.4
	5	yes	3.6
	6	yes	3.5
	7	yes	3.4
	8	yes	3.4
	9	yes	3.2
	10	yes	3.4
	11	yes	3.5
	12	yes	3.1
	13	yes	3.5
	14	yes	3.3
	15	yes	3.5

Based on the data shown in Table 2 and Table 3, it can be inferred that the time it takes for the servomotor to rotate may vary between metal waste and wet waste. The direct connection of the servo motor to the container is a significant component that needs to be considered while analyzing the system's overall dynamics. The impact of the container's weight on the servo motor's rotational movement depends on the weight of the waste. Hence this needs to be considered for improvement of the system.

Table 4 *Results of time response for servo motor to rotate for other type waste detection. (plastic)*

Component	No	Acceptance	Time response to rotate
Bottle cap	1	yes	0

Table 4 demonstrates that the servo motor remains in its initial state for others type of waste such as plastic bottle caps. This is since the bin's position was initially set to 0 degrees in the coding and it is due to the waste not being detected by the metal and the moisture sensor. The repeatability test was done similar to other sensor showing no rotational movement from the servo motor indicating the system successfully able to separate the waste being introduced to the bin.

4. Conclusion

This project successfully developed a prototype for a smart garbage bin with a segregation system, integrating it with an Internet of Things (IoT) monitoring system. The prototype efficiently sorted wet waste, metal waste and other garbage types with reliable precision for the induvial waste placed into the bin. The incorporation of an IoT dashboard enabled real-time monitoring of bin fill levels and improving decision-making in waste management. The project's use of sensors and technology demonstrates a commitment to sustainable and responsive garbage management, contributing to a cleaner and more environmentally conscious public infrastructure. Additionally, the system's accuracy and reliability were validated, showcasing its potential applicability in diverse public spaces and the connection to the Node-RED dashboard further enhances usability for effective data management and analysis.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: ***study conception and design, data collection, analysis and interpretation of results, and manuscript preparation:*** *Amirul Farhan and Amira Saryati Ameruddin. All authors reviewed the results and approved the final version of the manuscript.*

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