

WasteWise: A Waste Segregation System with Wi-Fi and Charging Reward

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Abstract

This study developed WASTEWISE, an automated waste segregation system designed to address the challenges of improper waste disposal and low recycling motivation in school environments. Traditional manual sorting is often inefficient and prone to human error; therefore, this project integrated sensor-based detection with a reward mechanism to encourage positive behavioral changes. Utilizing a Developmental Research Method, the researchers constructed a prototype equipped with inductive, capacitive, and infrared sensors connected to an Arduino microcontroller and a Raspberry Pi. The system automatically classifies waste into plastic, metal, or general categories and provides digital incentives—such as Wi-Fi access or device charging time—via a captive portal.

The system's effectiveness was evaluated using the ISO/IEC 25010 quality model, gathering data from IT experts and student respondents. Findings revealed high levels of acceptability, with IT experts validating the system's technical robustness and students reporting high satisfaction with its usability and motivational features. Specifically, the system achieved high weighted means in functional suitability (4.85) and usability (4.83). The study concludes that WASTEWISE is a technically sound and innovative solution that significantly enhances waste management efficiency while fostering a culture of environmental responsibility within educational institutions.

INTRODUCTION

Today, waste management service is of utmost importance to our society. However, even with the existence of the Republic Act 9003, which aims to support waste segregation, there still exist inefficiencies that contribute to pollution, abuse of landfills, and wastage of resources in recycling processes (Philippine Statistics Authority, 2022). To overcome these challenges, automation of waste separation using artificial intelligence (AI) coupled with deep learning provides a credible solution (Hannan, Al-Sakkaf, & Ker, 2020). By comparing the proposed WASTEWISE: An Automated Waste Segregation System with Wi-Fi and Charging Reward, which employs IoT technology and various sensors, such as inductive proximity, capacitive, and IR sensors, to automatically detect and classify waste materials, with the traditional manual waste sorting methods, this study aims to evaluate its accuracy, efficiency, and practical feasibility in real-world implementation. Previous studies, such as those by Jeyapriya et al. (2019) and Kadalagereet al. (2023), demonstrated that sensor-based automation significantly improves waste segregation accuracy and operational speed compared to conventional

methods. Moreover, research by Bhavya et al. (2024) and Indumathi et al. (2025) highlighted the potential of reward-driven waste management systems in encouraging proper disposal behavior through user incentives integrated with IoT-enabled bins. Building upon these findings, the proposed system combines automation and user motivation through a captive portal managed by a Raspberry Pi server, offering digital rewards such as Wi-Fi access and charging privileges to users who properly dispose of waste. In the long run, this study seeks to advance sustainable waste management by promoting technological innovation, reducing reliance on landfills, and enhancing public participation in environmental conservation initiatives within and beyond the Philippines. Waste mismanagement is still a persisting problem in the Philippines where the nation produces about 61,000 metric tons of waste per day (Philstar Global, 2023). Notwithstanding the provisions of Republic Act 9003, or the Ecological Solid Waste Management Act of 2000, illegal disposal of waste and poor segregation persist to add pollution, harm the environment, and pose public health threats (Philippine Statistics Authority, 2022). Conventional waste sorting schemes are based on manual segregation, which is time-consuming, inaccurate, and not efficient in managing the increasing amount of waste. One of the most urgent challenges of the cities with the rapid growth of the urban population is the need for intelligent waste management that will solve the waste sorting process in the most efficient way with the use of innovative technologies. Artificial intelligence (AI), machine learning (ML), and computer vision-based classification systems are the most recent and promising options to the traditional method. According to the World Bank (2021), The Philippines is among the world's leading countries in terms of plastic waste production, with approximately 2.7 million tons of plastic waste created every year. These are further very startling figures that only 9% of plastic waste is reused for the right purpose. Inefficient waste sorting systems are a big drawback for the recycling venture of which it's also causing pollution to the environment. Research findings signify that rounds of talks reflect the main of many challenges in this sector, and among them are the household and community levels are the worst in terms of proper segregation (Plastic Bank, 2023). In contemporary developments concerning IoT-enabled waste segregation systems, automation and user engagement in the waste management process have reached a more practical and efficient level. Recent studies have shown that integrating sensors and microcontrollers such as capacitive, inductive proximity, and IR sensors can significantly enhance the accuracy of waste sorting and reduce human error (Jeyapriya et al., 2019; Kadalagere et al., 2023). Moreover, innovative systems that incorporate reward mechanisms, for instance, providing incentives to users for proper waste disposal have been found effective in promoting environmental responsibility and public participation (Bhavya et al., 2024; Indumathi et al., 2025). Building upon these advancements, the proposed Waste Segregation System with Wi-Fi and Charging Reward utilizes IoT integration and automated sensing technologies to identify and classify waste materials efficiently. Additionally, it introduces a unique user incentive feature managed by a Raspberry Pi-based captive portal, offering digital rewards such as Wi-Fi access and 13 charging privileges. These developments demonstrate a promising direction for sustainable and technology-driven waste management in both urban and rural settings across the Philippines. Although advancements have been made, there are still complications such as incorrect labeling, restricted datasets, and time-consuming processing. With that being said, conventional waste segregation relies heavily on manual sorting, which is often labor-intensive, time-consuming, and prone to error. These limitations create a demand for innovative technologies that promote automation and accuracy in waste processing. To address this, the researchers developed the Waste Segregation System with Wi-Fi and Charging Reward, which is a project that integrates

automation, Internet of Things (IoT), and user incentive systems. This system utilizes sensors and microcontrollers to identify and segregate metal and plastic waste automatically. It is also connected to a captive portal managed by a Raspberry Pi server that provides digital rewards such as Wi-Fi access and charging privileges to users who properly dispose of their waste. Through this technology, the study aims to promote sustainable waste practices by combining automation and motivation. The integration of hardware components such as Arduino Uno, proximity sensors, servo motors, and network-based reward systems allows for efficient segregation while encouraging users to participate actively in maintaining a clean environment.

METHODS

This study employs both descriptive and developmental research designs to effectively address and analyze the development of the WASTEWISE: An Automated Waste Segregation System with Wi-Fi and Charging Reward. The descriptive design is appropriate because the project aims to identify and understand the needs of the intended users, the system’s core functionalities, and the evaluation process of its performance. This design enables the researchers to gather data regarding current waste disposal habits and assess how an automated segregation and reward-based system can encourage more sustainable behavior without altering the natural environment. Meanwhile, the developmental research design is utilized to guide the actual creation and continuous improvement of the waste segregation system. It supports the 37 systematic process of designing, developing, testing, and refining the prototype that automatically detects and classifies plastic bottles and metal cans, while converting them into reward points redeemable for free Wi-Fi access or charging time. By combining both approaches, the study provides a comprehensive understanding of user needs and waste management practices, while demonstrating how a reward-based automation system can improve traditional segregation methods in terms of accuracy, efficiency, and environmental impact.

Table 1: Tabulated Results of level of acceptance in terms of Functionality (IT Experts)

Description	Weighted Mean	Interpretation
The inductive sensor accurately detects and identifies metal cans.	4.80	Highly Functional
The capacitive sensor accurately detects and identifies plastic bottles.	4.80	Highly Functional
The IR proximity sensor correctly detects the presence of waste before classification.	4.80	Highly Functional
The system correctly classifies waste based on combined sensor readings.	4.80	Highly Functional
The system correctly classifies waste based on combined sensor readings.	4.60	Highly Functional
The servo motor correctly directs waste to the proper bin based on sensor classification.	4.80	Highly Functional
Reward points (plastic = 1, metal = 2) are correctly assigned.	4.80	Highly Functional

The system successfully activates Wi-Fi or charging rewards after correct disposal.	4.60	Highly Functional
AVERAGE WEIGHTED MEAN	4.74	HIGHLY FUNCTIONAL

Table 1: presents the level of acceptance of the WASTEWISE system in terms of Functionality as evaluated by IT Experts, showing consistently high ratings across all indicators. The inductive sensor’s ability to detect metal accurately received a weighted mean of 4.80, indicating reliable recognition of metallic waste. Similarly, the capacitive sensor’s accurate detection of plastic also scored 4.80, reflecting strong sensitivity to dielectric properties. The IR sensor’s correct detection of waste presence earned another 4.80, confirming its effectiveness in initiating the classification process at the right moment. The system’s waste classification, based on combined sensor inputs, likewise scored 4.80, while overall classification accuracy received 4.60, suggesting only minor variations in borderline cases. The servo motor directing waste to the proper bin scored 4.80, demonstrating precise mechanical response. Reward point assignment also earned 4.80, showing consistent and correct computation after proper disposal. Lastly, the system’s reward activation process received a 4.60, indicating reliable operation with minimal delay. With an average weighted mean of 4.74, the WASTEWISE system is rated Highly Functional, meeting expert expectations for accuracy, consistency, and effective performance across all components.

Table 2: Tabulated Results of level of acceptance in terms of Efficiency (IT Experts).

Description	Weighted Mean	Interpretation
The sensors detect waste with minimal delay.	4.80	Highly Efficient
Consistent during continuous use.	4.60	Highly Efficient
Hardware components respond quickly and reliably.	4.80	Highly Efficient
The captive portal loads quickly and operates smoothly.	4.60	Highly Efficient
AVERAGE WEIGHTED MEAN	4.7	HIGHLY EFFICIENT

Table 2 shows the level of acceptance of the WASTEWISE system in terms of Efficiency as evaluated by IT Experts. The sensors’ ability to detect waste with minimal delay received a weighted mean of 4.80, indicating that detection happens quickly and without noticeable lag. The system’s consistency during continuous use was rated 4.60, showing that it maintains stable performance even after repeated operations. Hardware components were also rated 4.80, reflecting fast and reliable responses from the servo motors and sensors. Meanwhile, the captive portal’s loading speed earned a 4.60, indicating smooth reward activation with only occasional minor delays.

Overall, the average weighted mean of 4.70 signifies that the WASTEWISE system is Highly Efficient, performing tasks promptly and maintaining smooth operation throughout its use.

Table 3: Tabulated Results of level of acceptance in terms of Usability (IT Experts)		
Description	Weighted Mean	Interpretation
LCD instructions are clear and easy to understand.	4.80	Highly Usable

The captive portal interface is simple and user-friendly	4.80	Highly Usable
Reward redemption is easy to complete.	4.80	Highly Usable
System messages are clear.	4.80	Highly Usable
AVERAGE WEIGHTED MEAN	4.80	HIGHLY USABLE

Table 3 presents the level of acceptance of the WASTEWISE system in terms of Usability as evaluated by IT Experts, showing consistently high ratings across all usability indicators. The clarity and understandability of LCD instructions received a weighted mean of 4.80, indicating that users find the system easy to follow during operation. The captive portal interface also scored 4.80, demonstrating that the reward system is simple, intuitive, and user-friendly. Reward redemption earned a matching rating of 4.80, showing that users can easily claim Wi-Fi or charging rewards without confusion or unnecessary steps. Likewise, system messages were rated 4.80, confirming that the prompts and notifications displayed throughout the process are clear and helpful. With an overall weighted mean of 4.80, the WASTEWISE system is rated Highly Usable, reflecting its straightforward interface, accessible instructions, and smooth user experience for both first-time and repeated users.

Table 4: Tabulated Results of level of acceptance in terms of Reliability (IT Experts).		
Description	Weighted Mean	Interpretation
The system operates continuously without malfunction.	4.60	Highly Reliable
Sensors perform reliably over extended use.	4.60	Highly Reliable
The system correctly rejects unclassified waste.	4.80	Highly Reliable
The system recovers properly after minor errors.	4.80	Highly Reliable
AVERAGE WEIGHTED MEAN	4.70	HIGHLY RELIABLE

Table 4 presents the level of acceptance of the WASTEWISE system in terms of Reliability as evaluated by IT Experts, showing strong performance across all reliability indicators. The system’s ability to operate continuously without malfunction received a weighted mean of 4.60, indicating stable operation during prolonged use. The sensors’ reliability over extended periods was also rated 4.60, demonstrating consistent accuracy even after repeated detection cycles. The system’s ability to correctly reject unclassified waste earned a higher rating of 4.80, reflecting dependable classification logic that prevents incorrect sorting. Likewise, the system’s capability to recover properly after minor errors also scored 4.80, showing that it can resume normal operation quickly without requiring manual reset. With an average weighted mean of 4.70, the WASTEWISE system is rated Highly Reliable, confirming that it performs dependably, manages errors effectively, and maintains consistent functionality during continuous operation

Description	Weighted Mean	Interpretation
The system correctly classifies waste into plastic bottles, metal cans, and other non-reward waste categories.	4.67	Highly Functional
The system provides all necessary features for automated waste classification.	5.00	Highly Functional
The rewards system offers Wi-Fi or charging access in exchange for proper waste disposal.	4.87	Highly Functional
AVERAGE WEIGHTED MEAN	4.85	HIGHLY FUNCTIONAL

Table 33 presents the weighted mean scores and corresponding interpretations for the functional suitability of the waste segregation system as evaluated by students across three key criteria. All criteria received scores above 4.5, indicating a positive assessment. The ability of the system to correctly classify waste scored 4.67, while the provision of necessary features for automated classification scored a perfect 5.00. The rewards system offering Wi-Fi or charging access scored 4.87. The overall average weighted mean of 4.85 confirms that the system is considered functional, meeting student expectations for accuracy, features, and incentives, which supports its effectiveness in the intended context.

Description	Weighted Mean	Interpretation
The detects and classifies plastic bottles, metal cans, and other waste in real- time as soon as the user drops an item	4.33	Efficient
The system maintains consistent performance even with continuous use.	4.33	Efficient
The system provides accurate time or minute allocation based on the bottle or can you drop.	4.40	Efficient
The system’s classification speed is faster than manual sorting methods	2.73	Somewhat Efficient
AVERAGE WEIGHTED MEAN	3.95	EFFICIENT

Table 34 shows that the WASTEWISE system is rated Efficient with an average weighted mean of 3.95. Users rated its real-time detection and consistent performance at 4.33, indicating that the system reliably identifies and processes plastic bottles and metal cans as soon as they are dropped. The highest score, 4.40, shows that the system provides accurate reward time allocation based on the item detected. The lowest rating, 2.73, reflects that its classification speed is slower than manual sorting due to sensor reading and servo movement. Overall, results confirm that the system performs efficiently, with minor improvements needed for faster sorting speed

.Table 35: Tabulated Results of level of acceptance in terms of Usability (Users)		
Description	Weighted Mean	Interpretation
The system lets you quickly get a voucher code when you drop a bottle or can.	4.73	Highly Usable
The device is easy to use and understand.	4.67	Highly Usable
The system provides clear and understandable feedback to the user.	4.93	Highly Usable
The interface enhances the user experience immediately showing the available reward options which are free Wi-Fi or charging after successfully depositing a plastic bottle or metal can.	4.87	Highly Usable
The rewards system encourages users to dispose of waste properly.	4.93	Highly Usable
AVERAGE WEIGHTED MEAN	4.83	HIGHLY USABLE

Table 35 presents the level of acceptance of the WASTEWISE system in terms of Usability as evaluated by users, with all indicators receiving high ratings. The system’s ability to quickly provide a voucher code after depositing a bottle or can receive a weighted mean of 4.73, showing that users find the reward process fast and convenient. The device’s ease of use scored 4.67, indicating that users experience minimal difficulty in operating the system. Clear and understandable feedback messages were rated 4.93, demonstrating strong user confidence in the system's ability to guide them through each step. The interface, which immediately displays available reward options such as free Wi-Fi or charging time, earned a rating of 4.87, reflecting an enhanced and engaging user experience. Lastly, the rewards system encouraging proper waste disposal received a 4.93, showing that users view the incentive mechanism as highly motivating.

With an overall weighted mean of 4.83, the WASTEWISE system is rated Highly Usable, confirming that it is intuitive, user-friendly, and effective in guiding and motivating users during operation.

Table 36: Tabulated Results of level of acceptance in terms of Reliability (Users)		
Description	Weighted Mean	Interpretation
The system operates consistently without unexpected errors	4.07	Reliable
The device continues to operate even during unexpected issues, such as power outages.	4.07	Reliable
The device can handle any waste thrown without causing an error.	4.21	Reliable
The system quickly recovers from errors or failures during operation.	4.33	Reliable
AVERAGE WEIGHTED MEAN	4.17	RELIABLE

Table 36 presents the level of acceptance of the WASTEWISE system in terms of Reliability as

evaluated by users, showing consistently positive ratings across all indicators. The system’s ability to operate without unexpected errors received a weighted mean of 4.07, indicating that users generally experience stable and predictable performance during normal use. The device’s continued operation during unexpected issues, such as minor power interruptions, also scored 4.07, reflecting acceptable stability in challenging conditions. The ability of the system to handle different types of waste without malfunction earned a higher rating of 4.21, showing that users find the device dependable when processing various waste inputs.

Additionally, the system’s quick recovery from errors or failures was rated 4.33, suggesting that users appreciate its capacity to resume functioning without requiring extensive troubleshooting. With an overall weighted mean of 4.17, the WASTEWISE system is rated Reliable, indicating that users find it stable, dependable, and capable of maintaining consistent performance during regular operation.

Table 37: Tabulated Results of level of acceptance in terms of Maintainability (Users)

Maintainability		
Question	Weighted Mean	Interpretation
The device is easy to clean and allows for easy disposal of waste.	4.87	Highly Maintainable
It is easy to identify and fix issues in the device when they occur.	4.33	Maintainable
New features can be added without major changes to the system’s core functions.	4.47	Maintainable
AVERAGE WEIGHTED MEAN	4.56	HIGHLY MAINTAINABLE

Table 37 presents the level of acceptance of the WASTEWISE system in terms of Maintainability as evaluated by users, showing strong and consistently positive ratings. The device’s ease of cleaning and its ability to support proper waste disposal received a high weighted mean of 4.87, indicating that users find the system simple to maintain during routine use. The ability to identify and fix issues when they occur earned a rating of 4.33, suggesting that users consider troubleshooting manageable, though occasional challenges may arise. The indicator assessing whether new features can be added without major modifications scored 4.47, showing user confidence that the system can support future enhancements without requiring significant redesign. With an overall weighted mean of 4.56, the WASTEWISE system is rated Highly Maintainable, demonstrating that users find it easy to clean, straightforward to troubleshoot, and adaptable for future improvements

CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis of the results obtained from surveys, expert evaluations, and system testing, the following conclusions were formulated to address each statement of the problem. These conclusions summarize the overall performance of the WASTEWISE system, the conditions of waste segregation within the institution, and the effectiveness of the applied technologies in meeting the objectives of the

study.

Based on the conclusions drawn from the study, the following recommendations are proposed to further improve waste management practices within the institution and enhance the overall performance, reliability, and sustainability of the WASTEWISE automated waste segregation system. These recommendations aim to guide future development, institutional implementation, and system optimization in response to the challenges and results identified in each statement of the problem.

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