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Intelligent Automation of Segregation and Monitoring System for Sustainable Waste Management

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Abstract

This study examined the development and acceptability of an intelligent automation system designed for waste segregation and monitoring at Cebu Technological University–Main Campus. The system integrated artificial intelligence (AI) and Internet of Things (IoT) technologies to improve waste segregation efficiency, support real-time monitoring, and enhance sustainable waste management practices. A descriptive research design was applied. Data were gathered through a structured questionnaire administered to faculty members, technical experts, and students with National Certificate II (NCII) qualifications in electronics-related fields. The evaluation of

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the developed system followed selected dimensions of Garvin's Quality Model, including performance, features, reliability, and durability, together with the Technology Acceptance Model (TAM) indicators of perceived usefulness and perceived ease of use. Statistical analysis involved frequency distribution, percentage computation, weighted mean, and correlation analysis. The findings indicated high levels of positive perception regarding the system's performance, operational reliability, functional features, and durability. Respondents also expressed strong acceptance of the system, particularly in terms of its ease of operation, efficiency in waste monitoring, and usefulness in improving waste management processes. Correlation analysis revealed significant relationships between perceived quality dimensions and system acceptability, suggesting that improvements in system performance and reliability increased user acceptance. The results demonstrate that intelligent automation technologies can support efficient waste segregation and monitoring while promoting environmental sustainability. The study recommends continued development of AI- and IoT-based waste management solutions, user training programs, and further system evaluation to enhance long-term operational effectiveness and adoption in institutional waste management programs.

Keywords: Intelligent Automation, Artificial Intelligence, Internet Of Things, Waste Segregation, Sustainable Waste Management.

1. Introduction

The rapid growth of global waste generation has created serious environmental, economic, and public health challenges. Municipal solid waste continues to increase due to urbanization, population expansion, and changes in consumption behavior. Recent global estimates indicate that approximately 2.1 billion tons of municipal solid waste are produced annually worldwide, and this volume is projected to reach about 3.8 billion tons by 2050 if effective waste management strategies are not implemented (United Nations Environment Programme [UNEP], 2024). Poor waste management practices contribute to environmental pollution, climate change, and ecosystem degradation. Improper disposal also increases health risks, as uncollected waste becomes a breeding ground for disease vectors that affect communities, particularly in developing countries (World Health Organization [WHO], 2023). The growing waste crisis therefore highlights the need for improved systems that can manage waste efficiently and sustainably.

The waste management problem is particularly significant in developing nations, where large portions of waste remain improperly handled. Studies estimate that developing countries account for more than 90% of mismanaged waste worldwide, resulting in environmental contamination and increased greenhouse gas emissions (World Bank, 2024). Plastic waste has become a major concern because millions of tons of plastic enter marine ecosystems every year, threatening biodiversity and disrupting ocean environments (Jambeck et al., 2023). In the Philippines, the situation remains critical as the country generates around 21 million tons of solid waste annually, with a steady annual increase. A large proportion of this waste consists of plastic materials, many of which end up in waterways and coastal environments (Department of Environment and Natural Resources [DENR], 2023). Despite the implementation of Republic Act No. 9003 or the Ecological Solid Waste Management Act of 2000, challenges remain in waste segregation, recycling implementation, and waste monitoring systems. These persistent gaps demonstrate the need for technological innovations that can improve waste management practices.

Advances in digital technologies offer potential solutions to address these challenges. Artificial intelligence (AI) and the Internet of Things (IoT) have emerged as promising tools for improving waste management efficiency. AI technologies can analyze data patterns to predict waste generation, optimize waste collection routes, and automate waste classification processes. At the same time, IoT-based sensors enable real-time monitoring of

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waste levels, environmental conditions, and waste composition through interconnected devices and data networks. These technologies allow waste management systems to become more responsive, efficient, and data-driven. The integration of AI and IoT can therefore support intelligent waste segregation and monitoring systems that reduce operational costs, improve recycling efficiency, and promote sustainable environmental practices. The development of such intelligent automation systems can play a significant role in strengthening waste management programs and supporting broader sustainability initiatives in institutions and communities.

Aim of the Study

The study aimed to develop and evaluate an intelligent automation system for waste segregation and monitoring designed to support sustainable waste management. The system integrates artificial intelligence and Internet of Things technologies to improve waste sorting efficiency, enable real-time monitoring of waste levels, and enhance operational decision-making in waste management processes.

Research Questions

The study sought to answer the following research questions:

1. What are the technical requirements in developing the intelligent automation system for waste segregation and monitoring in terms of:
   1.1 design,
   1.2 construction, and
   1.3 materials and cost?
2. What is the level of perception of the respondents regarding the developed intelligent automation system based on selected dimensions of quality, specifically:
   2.1 performance,
   2.2 features,
   2.3 reliability, and
   2.4 durability?
3. What is the level of acceptability of the intelligent automation system based on the Technology Acceptance Model criteria in terms of:
   3.1 perceived ease of use, and
   3.2 perceived usefulness?
4. Is there a significant relationship between the respondents' perception of quality and the acceptability of the intelligent automation waste segregation and monitoring system?
5. Based on the findings of the study, what intelligent automation waste segregation and monitoring system can be recommended for adoption?

Null Hypothesis

There is no significant relationship between respondents' perception of the quality of the intelligent automation waste segregation and monitoring system (in terms of performance, features, reliability, and durability) and the acceptability of the system (in terms of perceived ease of use and perceived usefulness).

Theoretical Framework

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This study was anchored on several theories that explain technological systems, technology adoption, and system quality evaluation. These theories provide the conceptual basis for understanding the development and acceptance of an intelligent automation waste segregation and monitoring system.

General Systems Theory by Bertalanffy (1968) explains that a system consists of interconnected components that function together to achieve a common goal. In this study, the intelligent automation system operates as an integrated structure composed of sensors, microcontrollers, software, and monitoring platforms that collectively perform automated waste segregation and monitoring.

The Technology Acceptance Model (TAM) developed by Davis (1989) was used to explain how users accept and utilize new technologies. The model emphasizes two main determinants of technology adoption: perceived usefulness and perceived ease of use. These factors were used in this study to evaluate the acceptability of the intelligent automation system among users.

Garvin's Eight Dimensions of Quality (1987) also guided the evaluation of the system. Selected quality dimensions such as performance, features, reliability, and durability were used to assess respondents' perceptions of the developed system. These dimensions provided indicators for determining whether the intelligent automation system meets operational expectations and user requirements.

Conceptual Framework

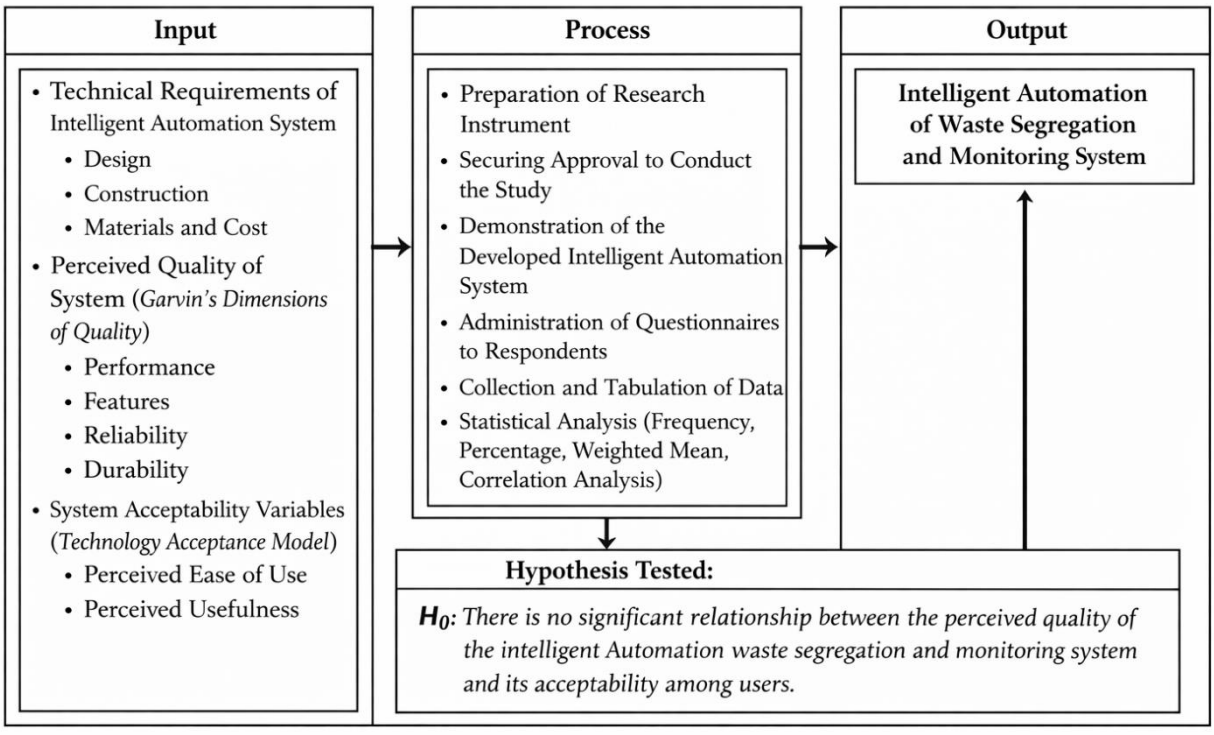

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Figure 1. Input–Process–Output (IPO) Conceptual Framework of the Study

Figure 1 illustrates the Input–Process–Output (IPO) framework used in the study. The **input** includes the technical requirements of the intelligent automation system such as design, construction, materials, and cost, as well as the perceived quality dimensions of the system including performance, features, reliability, and durability. The framework also considers system acceptability variables derived from the Technology Acceptance Model, specifically perceived ease of use and perceived usefulness. The **process** represents the procedures undertaken in the study, including preparation of the research instrument, securing approval to conduct the study, demonstration of the developed system, administration of questionnaires, data collection, and statistical analysis. The **output** of the study is the developed intelligent automation waste segregation and monitoring system. The framework also presents the hypothesis tested in the study, which states that there is no significant relationship between the perceived quality of the system and its acceptability among users.

2. Review of Related Literature

The rapid growth of municipal solid waste has intensified the search for more efficient waste management systems capable of supporting environmental sustainability. Traditional waste collection and segregation processes often rely heavily on manual labor and fixed collection schedules, which can lead to operational inefficiencies, higher costs, and increased environmental risks. Recent research has highlighted the potential of artificial intelligence (AI) technologies to improve waste management practices through predictive analytics, automated classification, and data-driven decision making. Machine learning algorithms can analyze historical waste generation patterns to forecast waste volumes and optimize waste collection routes. These capabilities allow organizations and municipalities to allocate resources more efficiently while reducing fuel consumption and operational costs. In addition, computer vision and deep learning techniques have been successfully applied in automated waste classification systems, enabling more accurate identification of recyclable materials and reducing contamination within recycling streams (Ahmad et al., 2025; Alhathlaul, 2025).

Alongside AI technologies, the Internet of Things (IoT) has emerged as a key enabler of smart waste management systems. IoT technologies utilize interconnected sensors, devices, and communication networks to collect and transmit real-time data regarding waste levels, environmental conditions, and operational performance. Smart bins equipped with sensors can detect the fill level of waste containers and automatically send alerts when collection is required. Such monitoring capabilities help waste management operators optimize collection schedules and reduce unnecessary collection trips, thereby improving operational efficiency and lowering environmental emissions. IoT-based systems can also support environmental monitoring by tracking factors such as air quality and temperature around waste disposal areas, which contributes to improved environmental management and public health protection (Ishaq et al., 2023).

The convergence of AI and IoT technologies has led to the development of intelligent waste management systems that combine automated sorting, predictive analytics, and real-time monitoring capabilities. Studies have demonstrated that the integration of these technologies can significantly enhance recycling efficiency, improve waste segregation accuracy, and support more sustainable urban waste management strategies. Intelligent systems are capable of continuously learning from operational data, allowing them to adapt to changes in waste composition and generation patterns. This adaptive capability strengthens decision-making processes and promotes more responsive waste management operations. Furthermore, AI-IoT integrated systems contribute to broader sustainability initiatives by reducing landfill waste, improving resource recovery, and supporting smart city infrastructure development (Ahmed et al., 2024; Lakhouit, 2025). As research continues to expand in this field,

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intelligent automation is increasingly recognized as a critical technological pathway toward achieving more sustainable and efficient waste management systems.

3. Methodology

Research Design

The study employed a descriptive research design to examine the development and acceptability of the intelligent automation waste segregation and monitoring system. The descriptive method was used to present detailed information regarding the planning, design, and construction of the system and to evaluate respondents' perceptions of its quality and acceptability. A normative survey approach was applied to collect data from selected respondents using a structured questionnaire. This approach enabled the researcher to obtain systematic feedback on the system's performance and usability.

Research Environment

The study was conducted at the Electrical–Electronics Department Laboratory of Cebu Technological University–Main Campus, located at the corner of M.J. Cuenco Avenue and R. Palma Street in Cebu City, Philippines. The laboratory served as the primary venue for the development, testing, and evaluation of the intelligent automation waste segregation and monitoring system. The location was considered appropriate because it provided access to the necessary technical facilities, equipment, and respondents with expertise in electronics and automation technologies.

Respondents of the Study

The respondents of the study consisted of faculty members and technical experts from the Electrical and Electronics Technology departments as well as students with National Certificate II (NCII) qualifications who possess technical knowledge relevant to electronics and automation systems. A purposive sampling technique was employed to select participants who were capable of evaluating the developed system. The total number of respondents included 12 faculty members and technical experts and 50 students with NCII certification, resulting in 62 respondents in the study.

Research Instrument

The study utilized an adapted and modified questionnaire derived from related literature and existing studies on system quality and technology acceptance. The questionnaire consisted of two main sections. The first section collected the respondents' demographic information and technical background. The second section measured respondents' perceptions of the developed system based on selected Garvin's dimensions of quality, namely performance, features, reliability, and durability, as well as the Technology Acceptance Model (TAM) constructs of perceived ease of use and perceived usefulness. Responses were measured using a five-point Likert scale.

Data Gathering Procedure

Prior to data collection, permission was secured from the appropriate authorities to conduct the study. After obtaining approval, the researcher demonstrated the intelligent automation waste segregation and monitoring system to the respondents to ensure that they understood its functions and features. Following the

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demonstration, the questionnaires were distributed to the respondents. The participants were requested to evaluate the system based on their perceptions of its quality and usability. The completed questionnaires were then collected, organized, and prepared for statistical analysis.

Statistical Treatment of Data

The data gathered from the questionnaires were tabulated and analyzed using several statistical tools. Frequency and percentage were used to describe the distribution of responses. Weighted mean was used to determine the respondents' level of perception regarding the quality and acceptability of the system. To examine the relationship between the perceived quality dimensions and system acceptability, a two-tailed t-test and correlation analysis were applied. These statistical methods helped determine whether a significant relationship existed between the perceived quality of the intelligent automation system and its level of acceptability among the respondents.

4. Results and Discussion

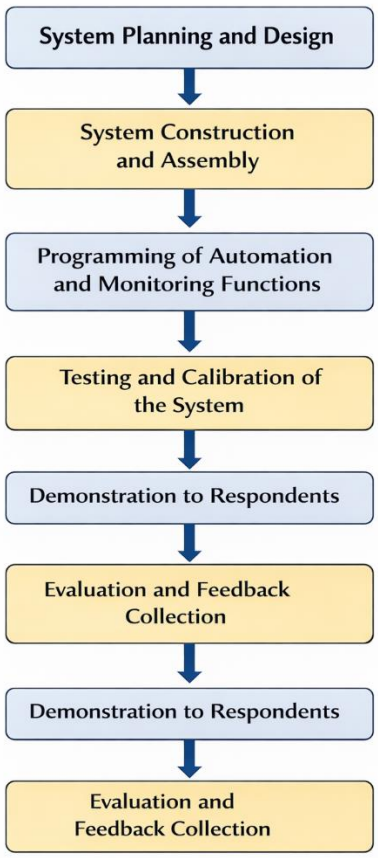

Figure 2. Development Process of the Intelligent Automation Waste Segregation and Monitoring System

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Figure 2 illustrates the development process followed in the creation of the intelligent automation waste segregation and monitoring system. The process begins with system planning and design, where the overall architecture, operational requirements, and system components are identified. This is followed by system construction and assembly, which involves the physical development of the device using the required electronic components, sensors, and structural materials. The next stage involves the programming of automation and monitoring functions, where the system software was developed to enable automated waste detection, segregation, and monitoring capabilities.

After programming, the system underwent testing and calibration to ensure that all components functioned properly and that the system could accurately perform its intended tasks. Finally, the developed system was demonstrated to the respondents, after which evaluation and feedback were collected through a structured questionnaire. The results of the evaluation were then used to determine the system's performance, quality, and level of acceptability.

Figure 3. Prototype of the Intelligent Automation Waste Segregation and Monitoring System

Figure 3 presents the developed prototype of the intelligent automation waste segregation and monitoring system. The prototype consists of a structured enclosure containing multiple waste bins designed for different waste categories such as biodegradable, paper, plastic, and metal. The system integrates several electronic

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components, including a camera module for waste detection and classification, sensors for identifying waste input, and a microcontroller that processes the collected data and controls the automated segregation mechanism. Indicator lights and a touchscreen display provide visual feedback on system status and operational information.

The prototype also incorporates Internet of Things (IoT) connectivity, allowing real-time monitoring of waste levels and system performance through a digital dashboard. The automated mechanism directs waste into the appropriate bin based on the detected category, improving waste segregation efficiency while reducing manual intervention. The prototype demonstrates how intelligent automation technologies can be applied to support sustainable waste management through automated sorting, monitoring, and data-driven waste management operations.

Table 1. Technical Requirements of the Intelligent Automation Waste Segregation and Monitoring System

Category	Components / Specifications	Description
Design	Conveyor-based automated segregation system with sensor detection	The system was designed to automatically detect and classify waste using sensors and a microcontroller that controls the segregation mechanism.
Construction	Control box, conveyor mechanism, waste bins, electronic circuitry	The machine was assembled using a conveyor-driven sorting mechanism where sensors detect waste and trigger servo motors that direct waste to appropriate bins.
Materials	ESP32 microcontroller, ultrasonic sensors, laser beam sensor, servo motor, relay module, buck converter, centralized power supply, conveyor motor	These electronic components enable automated waste detection, sorting, and system control.
Monitoring System	Blynk IoT platform with ultrasonic sensors	The monitoring system measures bin fill levels and transmits data to the Blynk application for real-time monitoring and notifications.
System Output	Automated waste segregation and bin monitoring	The developed prototype performs automated sorting of waste and provides real-time monitoring of bin levels.

Table 1 presents the technical requirements used in developing the intelligent automation waste segregation and monitoring system. The system was designed as a sensor-based automated waste sorting machine integrated with IoT monitoring technology. The construction involved assembling a conveyor-driven segregation mechanism supported by electronic components such as the ESP32 microcontroller, ultrasonic sensors, laser sensor, servo motors, and relay modules. These components allow the system to detect and classify waste automatically. In addition, the system incorporates the Blynk IoT platform, which enables real-time monitoring of waste bin levels through sensors and mobile application notifications. The integration of these design, construction, and material components forms the foundation of the intelligent automation system for sustainable waste management.

Table 2. Level of Perception on Performance of the Intelligent Automation Waste Segregation and Monitoring System

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Performance Indicators	Mean	Verbal Description
The system is accurate in sorting different types of waste.	4.30	Strongly Agree
Achieves its full operational speed without compromising quality.	4.13	Agree
Meets expected output for its manual operation.	4.19	Agree
The system satisfies the physical and structural characteristics of the intended application.	4.19	Agree
The system is effective in monitoring waste levels and providing relevant insights.	4.24	Strongly Agree
Adapts to changes or variations in waste types and volumes.	4.24	Strongly Agree
Average Mean	**4.22**	**Strongly Agree**

Table 2 presents the respondents' evaluation of the system in terms of performance. The results indicate that the developed intelligent automation waste segregation and monitoring system received a high level of agreement from the respondents, with an overall mean score of 4.22, interpreted as Strongly Agree. The highest rating was given to the system's accuracy in sorting different types of waste, with a mean score of 4.30, indicating that respondents perceived the system as effective in performing automated segregation tasks. The system's ability to monitor waste levels and adapt to variations in waste types and volumes also received strong agreement. These results indicate that the developed system performs efficiently and meets the operational expectations of the respondents in supporting sustainable waste management practices.

Table 3. Level of Perception on Features of the Intelligent Automation Waste Segregation and Monitoring System

Feature Indicators	Mean	Verbal Description
User-friendly on the system's navigation and interface	4.36	Strongly Agree
Effective features in providing insights and actionable information on waste management	4.17	Agree
Customization options are available in the system	4.16	Agree
Useful real-time notification features	4.32	Strongly Agree
The system integrates with other platforms or tools used for waste management	4.23	Strongly Agree
Average Mean	**4.25**	**Strongly Agree**

Table 3 presents the respondents' evaluation of the system in terms of features. The overall mean of 4.25 indicates a Strongly Agree interpretation, which shows that the respondents perceived the developed system as highly functional and useful. The highest mean was obtained by the indicator on the user-friendliness of the system's navigation and interface with 4.36, followed by the real-time notification features with 4.32. The system's ability to integrate with other waste management tools also received a strong rating. These findings show that the developed intelligent automation waste segregation and monitoring system possesses practical and relevant features that support efficient waste management operations.

Table 4. Level of Perception on Reliability of the Intelligent Automation Waste Segregation and Monitoring System

Reliability Indicators	Mean	Verbal Description
The system runs consistently without failure and performs steadily	4.28	Strongly Agree
The system can produce quality tasks during continuous use	4.24	Strongly Agree

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Reliability Indicators	Mean	Verbal Description
The system is durable and can withstand very unfavorable working conditions	4.17	Agree
The system runs efficiently and does not require frequent service and repair	4.20	Strongly Agree
The system performs reliably under different working conditions	4.22	Strongly Agree
Average Mean	**4.22**	**Strongly Agree**

Table 4 presents the respondents' perception of the intelligent automation waste segregation and monitoring system in terms of reliability. The overall mean score of 4.22, interpreted as Strongly Agree, indicates that the respondents perceived the system as dependable and capable of performing its intended functions consistently. The highest rating was given to the system's ability to run consistently without failure, with a mean score of 4.28. Respondents also strongly agreed that the system can perform quality tasks during continuous operation and operate efficiently without requiring frequent repairs. These findings suggest that the developed system demonstrates strong operational reliability and stability under different working conditions.

Table 5. Level of Perception on Durability of the Intelligent Automation Waste Segregation and Monitoring System

Durability Indicators	Mean	Verbal Description
The system performs in varying environmental conditions	4.18	Agree
Satisfied with the longevity and lifespan of the hardware components used in the system	4.20	Strongly Agree
Easy to fix or maintain the system when faults arise	4.34	Strongly Agree
Quality of the materials used in the construction of the system	4.17	Agree
Average Mean	**4.22**	**Strongly Agree**

Table 5 presents the respondents' evaluation of the intelligent automation waste segregation and monitoring system in terms of **durability**. The results show an overall mean score of **4.22**, which is interpreted as **Strongly Agree**, indicating that the respondents perceived the system as durable and capable of sustaining regular operation. The highest rating was obtained by the indicator related to the **ease of fixing or maintaining the system when faults arise**, with a mean score of **4.34**. The respondents also expressed satisfaction with the **longevity of the hardware components** used in the system. These results suggest that the developed system demonstrates good structural quality and maintenance capability, which supports its potential for long-term application in waste management operations.

Table 6. Level of Acceptability of the Intelligent Automation Waste Segregation and Monitoring System in Terms of Perceived Ease of Use

Perceived Ease of Use Indicators	Mean	Verbal Description
The system is simple for users of varying skill levels	4.36	Strongly Agree
The system's learning curve is minimal	4.32	Strongly Agree
The system requires less effort to master its functions and features	4.25	Strongly Agree
The system's instructions and interface are not complicated to operate	4.25	Strongly Agree
The system is easy to maintain and keep in working condition with minimal effort	4.16	Agree
Average Mean	**4.27**	**Strongly Agree**

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Table 6 presents the respondents' evaluation of the intelligent automation waste segregation and monitoring system in terms of perceived ease of use. The results reveal an overall mean score of 4.27, interpreted as Strongly Agree, indicating that the respondents found the system easy to operate and manage. The highest mean score of 4.36 was obtained by the indicator stating that the system is simple for users of varying skill levels, suggesting that the system is accessible even to individuals with limited technical experience. The respondents also strongly agreed that the system has a minimal learning curve and requires less effort to master its functions. These findings indicate that the developed system demonstrates a high level of usability, which contributes positively to its overall acceptability.

Table 7. Level of Acceptability of the Intelligent Automation Waste Segregation and Monitoring System in Terms of Perceived Usefulness

Perceived Usefulness Indicators	**Mean**	**Verbal Description**
The system helps save time in managing waste operations	4.29	Strongly Agree
Improves the efficiency of the waste management process	4.17	Agree
The system provides insights and data to enhance decision-making regarding waste management	4.21	Strongly Agree
Contributes to improving recycling rates in the operation	4.17	Agree
Satisfied with the reports and insights generated by the system regarding waste management	4.25	Strongly Agree
Average Mean	**4.22**	**Strongly Agree**

Table 7 presents the respondents' evaluation of the intelligent automation waste segregation and monitoring system in terms of perceived usefulness. The results show an overall mean score of 4.22, interpreted as Strongly Agree, indicating that the respondents perceived the system as beneficial in improving waste management practices. The highest mean score of 4.29 was obtained by the indicator stating that the system helps save time in managing waste operations, suggesting that the system enhances operational efficiency. Respondents also strongly agreed that the system provides valuable insights for decision-making and generates useful reports related to waste management. These findings indicate that the developed intelligent automation system contributes **positively to improving waste management efficiency and supports sustainable waste management practices.**

Table 8. Correlation Between Respondents' Perception of Quality and Acceptability in Terms of Perceived Usefulness

Respondent Group	**Quality Dimension**	**p-value**	**Remarks**
Technical Experts	Reliability	0.0511	Not Quite Significant
	Performance	0.0001	Statistically Significant
	Features	0.6112	Not Statistically Significant
	Durability	0.6291	Not Statistically Significant
NCII Students	Reliability	0.0378	Statistically Significant
	Performance	0.0001	Statistically Significant
	Features	0.0378	Statistically Significant

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Respondent Group	Quality Dimension	p-value	Remarks
	Durability	0.0010	Statistically Significant

Table 8 presents the correlation between respondents' perception of system quality and the acceptability of the intelligent automation waste segregation and monitoring system in terms of perceived usefulness. Among the technical experts, only the performance dimension showed a statistically significant relationship with perceived usefulness (p = 0.0001), while reliability, features, and durability did not show significant relationships. In contrast, the responses from NCII students indicated statistically significant relationships across all quality dimensions, including reliability, performance, features, and durability. These findings suggest that the perceived usefulness of the system is strongly influenced by system quality attributes, particularly among student respondents. The results also imply that system performance plays a critical role in determining how useful the system is perceived by users.

Table 9. Correlation Between Respondents' Perception of Quality and Acceptability in Terms of Perceived Ease of Use

Respondent Group	Quality Dimension	p-value	Remarks
Technical Experts	Reliability	0.0420	Not Quite Significant
	Performance	0.0227	Statistically Significant
	Features	0.5213	Not Statistically Significant
	Durability	0.6229	Not Statistically Significant
NCII Students	Reliability	0.0001	Statistically Significant
	Performance	0.0001	Statistically Significant
	Features	0.2431	Not Statistically Significant
	Durability	0.0001	Statistically Significant

Table 9 presents the correlation between respondents' perception of system quality and the acceptability of the intelligent automation waste segregation and monitoring system in terms of perceived ease of use. Among the technical experts, only the performance dimension showed a statistically significant relationship with perceived ease of use (p = 0.0227), while reliability, features, and durability did not show significant relationships. On the other hand, the responses of NCII students showed statistically significant relationships between perceived ease of use and the quality dimensions of reliability, performance, and durability, while the feature dimension did not show a significant relationship. These findings suggest that system performance and reliability influence how easily users perceive the system can be used, particularly among student respondents.

Table 10. Summary of Hypothesis Testing on the Relationship Between System Quality and System Acceptability

Variables Tested	Result	Decision
Relationship between perceived system quality (performance, features, reliability, and durability) and perceived usefulness	Partially Significant	Reject the null hypothesis
Relationship between perceived system quality (performance, features, reliability, and durability) and perceived ease of use	Partially Significant	Reject the null hypothesis

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Table 10 presents the summary of the hypothesis testing conducted in the study. The results indicate that there are significant relationships between selected dimensions of system quality and the acceptability of the intelligent automation waste segregation and monitoring system. The findings show that system performance, reliability, and durability have significant relationships with the acceptability dimensions of perceived usefulness and perceived ease of use, particularly among the student respondents. Based on these results, the null hypothesis stating that there is no significant relationship between the perceived quality of the system and its acceptability is rejected. This implies that the perceived quality of the developed system influences the level of acceptance among users.

Table 11. Proposed Intelligent Automation Waste Segregation and Monitoring System

System Component	Description	Purpose
Waste Detection Sensors	Ultrasonic sensors and laser sensors used to detect incoming waste and bin levels	To identify waste presence and monitor bin capacity in real time
Control Unit	ESP32 microcontroller integrated with relay modules and power supply	To control system operations and process sensor data
Segregation Mechanism	Conveyor mechanism with servo motors directing waste into appropriate bins	To automatically separate waste according to its classification
Monitoring Platform	IoT-based monitoring using the Blynk application	To provide real-time monitoring of waste levels and system status
Structural Framework	Enclosure housing waste bins and electronic components	To support the system's physical structure and ensure operational stability

Table 11 presents the proposed intelligent automation waste segregation and monitoring system developed in the study. The system integrates several electronic and mechanical components to perform automated waste segregation and monitoring functions. Sensors are used to detect waste input and measure bin levels, while the ESP32 microcontroller processes the collected data and controls the operation of the segregation mechanism. The conveyor system and servo motors automatically direct waste into the appropriate bins, reducing the need for manual sorting. In addition, the system utilizes an IoT-based monitoring platform through the Blynk application, allowing users to monitor waste levels and system status in real time. The structural framework houses the components and ensures the stability and durability of the system during operation. This integrated design demonstrates how intelligent automation technologies can support efficient and sustainable waste management practices.

Summary of Results and Findings

The study focused on the development and evaluation of an intelligent automation waste segregation and monitoring system designed to support sustainable waste management practices. The findings revealed that the system was successfully developed using an integrated design composed of sensors, a microcontroller, servo motors, and an Internet of Things–based monitoring platform. These components enabled the system to perform automated waste detection, segregation, and monitoring functions. The evaluation of the system showed that respondents rated its performance highly, with results indicating that the system effectively performs automated waste sorting and monitoring operations. The system's features were also evaluated positively, suggesting that the functionalities and operational capabilities of the system are useful in supporting waste management processes.

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In terms of system reliability and durability, the respondents expressed strong agreement that the developed prototype can operate consistently and withstand continuous usage under normal operating conditions. The high ratings in these quality dimensions indicate that the system demonstrates stable operational performance and structural integrity. The acceptability of the system was also evaluated using the constructs of perceived ease of use and perceived usefulness. The results indicated that respondents found the system easy to operate and maintain, suggesting that it can be effectively used even by individuals with varying levels of technical skills. Respondents also perceived the system as useful in improving the efficiency of waste management operations by reducing manual sorting efforts and providing monitoring capabilities.

The correlation analysis further revealed that selected dimensions of system quality have significant relationships with the acceptability of the intelligent automation waste segregation and monitoring system. In particular, system performance, reliability, and durability were found to influence users' perceptions of usefulness and ease of use. These findings indicate that the quality of the developed system plays an important role in determining its acceptance among potential users. Overall, the results of the study demonstrate that the intelligent automation waste segregation and monitoring system is a viable technological solution that can improve waste segregation efficiency and contribute to more sustainable waste management practices.

5. Conclusion

The study aimed to develop and evaluate an intelligent automation waste segregation and monitoring system designed to support sustainable waste management practices. Based on the findings, the developed system successfully integrated automation technologies and sensor-based monitoring mechanisms to perform automated waste segregation and real-time monitoring of waste levels. The results of the evaluation showed that the system obtained high ratings in terms of performance, features, reliability, and durability. These findings indicate that the developed prototype functions effectively and demonstrates the capability to perform its intended operations in waste management environments.

The results also showed that the system achieved a high level of acceptability among respondents in terms of perceived ease of use and perceived usefulness. This indicates that the system is user-friendly and can be easily operated and maintained by individuals with varying levels of technical knowledge. The respondents recognized that the system contributes to improving efficiency in waste segregation processes while also providing useful monitoring information that can support decision-making in waste management operations.

Furthermore, the results of the correlation analysis revealed that certain dimensions of system quality significantly influence the acceptability of the intelligent automation waste segregation and monitoring system. This finding suggests that improving the quality characteristics of automation systems can enhance user acceptance and encourage the adoption of intelligent waste management technologies. Overall, the developed system demonstrates strong potential as a technological solution for improving waste segregation efficiency and supporting sustainable waste management initiatives.

6. Recommendations

Based on the findings of the study, several recommendations are proposed. First, further improvements may be made to enhance the system's capability to classify a wider variety of waste materials, particularly those with complex or mixed compositions. Enhancing the classification mechanism may further improve the accuracy and efficiency of the automated segregation process.

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Second, future studies may expand the implementation of the system in real waste management environments such as schools, communities, and public facilities to evaluate its long-term operational performance. Conducting field-based testing may provide additional insights regarding the system's durability, operational efficiency, and practical usability in large-scale waste management operations.

Third, additional features may be integrated into the system to strengthen its monitoring and reporting capabilities. For example, advanced data analytics and reporting tools may be incorporated to generate more comprehensive waste management insights that can support environmental planning and resource management.

Finally, future researchers may explore the integration of more advanced technologies such as machine learning and computer vision to further enhance the system's capability to identify and classify different waste materials automatically. Such technological advancements may contribute to the continuous improvement of intelligent waste management systems and support broader sustainability efforts.

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