

Optimizing waste management: An Arduino Uno auto-locking waste monitoring system with SMS alert and RFID

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Abstract

This study aimed to develop an Arduino Uno-based automatic locking system that incorporates RFID authentication, a waste level monitoring system, and SMS alerts to increase the effectiveness of waste collection and optimize school cleaning personnel's workflow. The researchers used experimental and applied research designs to develop and test the product. The materials used to create the product were the following: an Arduino Uno board, a battery holder, a breadboard, a buck converter, an ultrasonic sensor, jumper wires, a Li-ion battery, an LCD, a servo motor, a SIM800L V2 GSM module, an RFID reader and tag, a brass cup hook, a PVC ceiling panel, a plastic trash bin, and a trash bag. The researchers encoded a program into the components and installed it on the housing. To gather data, the researchers distributed a validated questionnaire to 15 respondents, including 5 janitors and 10 students. They let the respondents try the product to test its performance level in sending SMS, auto-locking the lid, opening the lid using RFID, and its effectiveness. The findings show that the system performed well and effectively reduced waste overflow. Findings reveal that the waste monitoring system significantly assisted the cleaning staff by reducing the need for manual waste monitoring and enhancing overall waste management. To further improve the product, the researchers recommend integrating radio communication for faster response on full trash bins, an automated air purification system for odor control, weatherproof housing materials for the product's durability, and integrating solar panels for continuous, self-sustained operation.

Keywords: waste monitoring system, Arduino Uno, auto-locking, RFID, waste management

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1. Introduction

Poor waste management on a global scale is a significant international issue with grave effects on human health as well as the environment. Uncontrolled waste contributes to various environmental problems, causing air and water pollution, soil contamination, and habitat destruction. According to the UN Environment Programme (n.d.), the decomposition of the organic component of solid waste accounts for around 5% of greenhouse gas emissions, and an estimated 11.2 billion tons of solid waste are collected globally each year. Furthermore, it endangers human health by spreading contagious diseases, respiratory disorders, and other health concerns. This challenge is particularly acute in emerging countries that are rapidly urbanizing, as waste management and sanitary systems typically fail to keep up with population growth.

Despite global attempts to develop effective and environmentally sound waste management procedures, many countries still struggle with inadequate systems. One of the key causes of poor waste management is a lack of trash collection and transportation networks, as well as restricted processing and disposal capacity. This often leads to overflowing bins, illegal dumping, and the accumulation of waste in public spaces. Furthermore, a lack of public awareness, discipline, and education increases the problem. By fostering a community with responsible citizens who consistently follow proper waste management practices, an effective waste management system and the foundation for a cleaner and healthier environment will be attained.

The world is facing serious environmental, economic, and social issues due to the growing trash epidemic. The problem is complicated, but it is not impenetrable. In a study by Manas (2023), the Philippines is a significant waste producer in Southeast Asia, mainly contributing to oceanic plastic pollution. According to the Department of Environment and Natural Resources (2024), the Philippines enhanced solid waste management using the Ecological Solid Waste Management Act, also known as RA 9003. Two of their priority projects are the closure of dumpsites and the establishment of material recovery facilities. Citizens also contribute to waste reduction through recycling, composting, developing new technologies, and public awareness campaigns.

At present, smart trash bins with sensors and automated features are becoming more common in urban settings. These systems may look effective in monitoring bin fill and providing real-time data to waste management systems; their active prevention of overflowing bins is still insufficient to prevent unpleasant odors, attract pests, and create unhygienic conditions. Previous research about innovative waste bin technology has explored integrating different components, like status indicators, SMS notification systems, Arduino Uno microcontrollers, and motion detectors. Developing this existing work further, this research aims to enhance smart waste bin functionality by introducing an automated locking system to prevent overflowing. The researchers came up with the idea to improve the efficiency and effectiveness of waste collection processes by featuring advanced functionalities. The proposed solution seeks to lower operational expenses, optimize service quality, and promote a cleaner and more sustainable environment. A sustainable future depends on efficient waste management, and an Arduino-based auto-locking waste monitoring system using RFID technology and SMS notifications significantly contributes to this area. Because of its potential to address several waste management concerns and result in increased efficiency, lower costs, and advantages for the environment, this system has significant research value. The proposed plan will transform waste collection from reactive to proactive, ensuring that resources are utilized more effectively and waste is managed more efficiently.

Statement of the Problem - This study focused on developing and determining the effectiveness of the Arduino Uno auto-locking waste monitoring system with SMS alert and RFID in optimizing waste collection. This study aimed to answer the following questions: (1) What is the level of performance of the Arduino Uno

auto-locking waste monitoring system with RFID and SMS alert in terms of sending SMS, automatically locking the lid, and opening the lid using RFID? (2.) What is the level of effectiveness of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert in reducing waste overflow? (3.) To what extent does the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert help the school cleaning staff in their work? (4.) Is there a significant relationship between implementing an Arduino Uno auto-locking waste monitoring system with RFID and SMS alert and optimizing waste management?

Significance of the Study - In this study, the researchers sought to evaluate the effectiveness of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert in optimizing waste collection. The findings benefited specific individuals and groups of people, and the benefits they gained were as follows: this study helped the school cleaning staff by reducing their workload and making waste collection more efficient. To the faculty of Divine Word College of San Jose, this study ensured a more pleasant and sanitary teaching environment. With a more organized and clean campus, faculty members focused on their teaching and academic responsibilities without concerns about waste-related issues. This study helped encourage the Divine Word College of San Jose students to be more mindful of their waste disposal habits. With the Arduino Uno auto-locking waste monitoring system in place, students could no longer discard rubbish in overflowing bins, instilling a higher sense of responsibility in waste management for future researchers. This study provided information for future researchers interested in building automated waste management systems. Researchers could use this work to investigate advancements in innovative waste collection systems.

Scope and Delimitation of the Study - The primary goal of this research was to examine the efficacy of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alerts in improving waste collection. The researchers focused on one waste bin equipped with the Arduino-based system to gather necessary data according to the level of performance of the Arduino Uno auto-locking waste monitoring system, specifically in terms of (a) sending SMS, (b) automatically locking the lid, and (c) opening the lid using RFID. However, the study evaluated the Arduino Uno autolocking waste monitoring system's performance only under typical conditions, neglecting external factors like school events and holidays. The study was conducted within the premises of Divine Word College of San Jose to test the efficiency of the Arduino-based product.

Upon conducting this study, the researchers came up with the following limitations. First is the type of waste to be disposed of; the product can only be used to dispose of dry waste, as the components are sensitive to wet waste, causing damage. Regarding sensing capabilities, the ultrasonic may malfunction due to dirt, moisture, or physical damage. The RFID also has several limitations: (a) metal—it can absorb or reflect RFID signals; (b) liquids—significantly, water; (c) dense materials—it can attenuate RFID signals, reducing the range or causing detection failures; (d) damaged tags—fail to read the tag; and (e) tag collision—multiple tags in proximity. Regarding the SMS feature, failure to send an SMS may occur due to poor connectivity. Lastly, in the performance of metric water, the response time of the ultrasonic sensor and RFID takes ten seconds. The fill level is also inaccurate, as the ultrasonic sensor may sense other objects, such as the trash bag.

2. Methodology

Research Design - This study employed an applied research approach, which generally aimed at measuring the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert technology and its impact on improving waste management. The system's performance was proven using a controlled experiment. Questionnaires were used to gather data on students' and school cleaning staff's satisfaction. Using the data gathered, the system's effect on waste management efficiency was measured by comparing data gathered before and after the implementation of the system.

Participants of the Study - The study's respondents were the five (5) school cleaning staff and 10 Divine Word College of San Jose students. The selection process of respondents adopted a purposive sampling procedure to ensure that each eligible respondent was appropriately chosen. This approach minimized selection bias and

enhanced the validity of the research findings. The participants interacted with the waste management system and completed a self-administered questionnaire to provide feedback. After completing the survey, all the data collected were summarized and analyzed to yield significant insights into the system's effectiveness and user satisfaction.

Data Gathering Procedure - The researcher created a questionnaire to assess the performance of the Arduino UNO auto-locking waste monitoring system with RFID and SMS alerts. To evaluate its validity and reliability, the researcher sent the questionnaire to experts in science and research from the senior high school department. To gather the necessary data from the respondents, the researchers sought approval from the senior high school coordinator of the Divine Word College of San Jose by submitting a request letter to conduct the study at the Divine Word College of San Jose, senior high school department. Upon validation of the instrument and securing the permit, the researchers prepared and reproduced it to administer the questionnaire to the respondents personally. Respondents evaluated the product's performance in decreasing garbage overflow by monitoring fill levels and giving alerts to cleaning staff. The researchers also examined how the method helps cleaning staff manage waste more efficiently. Finally, the study investigated whether the waste monitoring system provided convenience and benefits to students and cleaning professionals. During the questionnaire administration, the respondents were informed that their anonymity and privacy would be treated ethically and confidentially. The respondents were given enough time to complete the questionnaire after the product was tested. After the respondents had filled out the questionnaires, the results were carefully consolidated and tabulated. The data gathering process took three days to complete the assembly of materials, construction, and product functionality testing.

Research Process: Stage 1 Preparation and Gathering of Materials

The researchers carefully selected and acquired the most suitable materials and advanced technological tools to develop their revolutionary product. This approach ensured both precision and economic efficiency. The materials used were the following:

- For waste bin housing: Brass Cup Hook, PVC Ceiling Panel, Plastic Trash Bin, Trash Bag
- For the automation: Arduino Uno Board with USB Cable, Battery Holder, Breadboard, Buck Converter, HC-SR04-Ultrasonic Sensor, Jumper wires, Li-ion Battery, LCD, Servo Motor, SIM800L V2-GSM Module, RFID Reader and Tag

Stage 2: Building and Development of the Project



Figure 1. Actual Product of Waste Monitoring System

After gathering all of the materials, the researchers assembled the prototype. After securing the components, they integrated the ultrasonic sensors and servo motors with Arduino UNO to monitor the waste inside the bin by its height. For the auto-locking feature to work, they incorporated servo motors with a hook triggered once the waste reaches its height limit. For the SMS alert feature, a GSM module was integrated to notify the cleaning

personnel once the trash bin reached capacity and the auto-locking mechanism was activated. An LCD was added to display the current status of the bin, indicating whether it was full, locked, or unlocked. To enable the components and their functions to work, they were connected to Arduino via a breadboard and wires.

Stage 3: Experimental Stage, Observation, and Data Recording

During the experimental stage, the researchers first observed the performance of the trash bin, especially its automated features, noting any issues or areas for improvement. In the observation and data collection phase, researchers let the respondents systematically assess the prototype's functionality through a series of tests. They began by examining the trash bin's sensor under different waste levels, testing its accuracy and response time in measuring fill levels. Observations then focused on the servo motor, where they tested its ability to lock the lid upon reaching the maximum waste height. They verified the displayed information's accuracy and assessed the LCD's responsiveness in updating information. The SMS alert functionality was tested for accuracy and reliability by checking and verifying each alert sent to the users after the waste reached its height limit and locked the lid. They further examined the RFID system by testing it with RFID cards, collecting data on its accuracy in recognizing and authenticating authorized users. Finally, the respondents evaluated the overall effectiveness of the waste monitoring system. The respondents spent an hour assessing the performance of the automated trash bin. It took three days to finish the data gathering, observation, and recording.

Statistical Treatment of Data - This study employed both descriptive and inferential statistics. For descriptive statistics, the weighted mean was used to determine the level of performance and effectiveness of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert in terms of sending SMS, automatically locking the lid, and opening the lid using RFID. Moreover, Pearson's *r* correlation was used to evaluate whether the developed product helps the school cleaning staff in their work and determine if there is a significant relationship between implementing an Arduino Uno auto-locking waste monitoring system with RFID and SMS alert and optimizing waste management.

3. Results and Discussions

Table 1

Level of Performance of the Arduino Uno Auto-locking Waste Monitoring System with RFID and SMS Alert in terms of Sending SMS, Automatically Lock the Lid, and Open the Lid using RFID

Sending SMS	Cleaning Staff Weighted Mean	Descriptive Equivalent	Students Weighted Mean	Descriptive Indicator
The system sends SMS notifications promptly when the bin is full.	4.0	High Level	3.9	High Level
The SMS alert provides accurate information about the bin's status.	4.0	High Level	3.5	High Level
The SMS system has improved waste collection scheduling.	4.0	High Level	3.4	High Level
The SMS alert helps me respond faster to full bins.	4.0	High Level	3.6	High Level
Composite Mean	4.0	High Level	3.6	High Level
Automatically Locks the Lid				
The bin automatically locks when it reaches full capacity.	4.0	High Level	3.9	High Level
The locking mechanism prevents waste from spilling out.	4.0	High Level	3.9	High Level

The auto-locking mechanism functions smoothly without errors.	3.4	High Level	3.4	High Level
The auto-locking system prevents students from opening the bin once it is complete.	3.4	High Level	4.0	High Level
Composite Mean	3.7	High Level	3.8	High Level
Open the Lid Using RFID				
The RFID system allows me to unlock the bin easily when needed.	3.4	High Level	3.8	High Level
The RFID scanner reads the tag quickly and does not cause delays.	3.4	High Level	3.1	Moderate Level
The system ensures that only authorized personnel can access full bins.	4.0	High Level	3.7	High Level
The trash bin with RFID access is more efficient than traditional bin-opening methods.	4.0	High Level	3.4	High Level
Composite Mean	3.7	High Level	3.5	High Level

Legend: 3.26 - 4.00 High Level, 2.51 - 3.25 Moderate Level, 1.76 - 2.50 Low Level, 1.00 - 1.75 Very Low Level

Table 1 presents the data gathered through the validated questionnaire from cleaning staff and students, along with their respective weighted means and descriptive indicators. Based on the results, the SMS alert system of the waste monitoring was consistently rated to be performing well, with an overall average of 4.0 from the cleaning staff, indicating that the SMS alert system is efficient in sending timely alerts about the bin conditions to the cleaning staff. In the case of students, the highest mean gathered was 3.9, given to the system's ability to send prompt SMS notifications when the bin is full, while the lowest rating for the SMS alert was 3.4, given to the system's role in improving waste collection scheduling, resulting in an overall mean of 3.6. The slightly lower ratings from students may suggest that while the system effectively sends timely updates, their experience with its functionality may differ in comparison with the school cleaning staff who directly manage waste collection. Nonetheless, both composite means from the cleaning staff and students fall within the range, indicating "high level" and suggesting a positive perception of the system's effectiveness in notifying users about the waste level. These findings align with Balasubramanian (2023) and Malar et al. (2021), who emphasized that SMS is a widely used and reliable communication tool for transmitting information across different devices. The system's ability to send real-time notifications efficiently supports previous studies recognizing SMS as a universal and accessible method for delivering short messages. Furthermore, the survey conducted by Sankeerth et al. (2020) demonstrated that SMS alerts play a vital role in improving waste management efficiency, as they notify garbage truck drivers when waste reaches a critical level.

Moreover, the cleaning staff rated "strongly agree" with most of the questions about automatically locking the lid, indicating that the system performs well, leading to an overall average of 3.7. In contrast, students rated it slightly higher at 3.8. Among the cleaning staff, items 1 and 2 received the highest ratings, highlighting the accuracy of the auto-locking mechanism and its ability to prevent waste spillage. However, not all cleaning staff respondents strongly agreed with item 4 or that the bin prevents students from opening it once it is full. Students, meanwhile, gave the highest rating to item 4, which the cleaning staff rated 3.4, followed by items 1 and 2. As for the smoothness of the auto-locking mechanism, both groups gave it a 3.4 rating. While the auto-locking feature generally worked well with high-level performance, a few respondents experienced some difficulties that affected its rating on its smoothness. Moreover, this supports the findings of Abkar et al. (2023), highlighting that the auto-locking mechanism minimizes human error and enhances efficiency for cleaning staff in waste management. Eliminating constant supervision ensures proper waste disposal and contributes to a cleaner environment. Additionally, it aligns with Widiyanto and Munahar (2016), who emphasize that auto-locking

systems reduce human effort by regulating entry points, granting access only under specific conditions, improving security, and preventing unauthorized access.

Furthermore, the results indicate that the performance of the RFID system in opening the lid of the trash bin was rated as efficient as measured by the cleaning staff's responses, with the highest mean score of 4.0 and the lowest mean of 3.4, resulting in an overall mean of 3.7. This indicates that the RFID system is a practical and user-friendly solution for opening trash bins. The system's ability to unlock the bin effortlessly and the speed of the RFID scanner were particularly well-received. Students also provided positive feedback, with the highest mean score of 3.8 and the lowest mean of 3.1, yielding an overall mean of 3.5. However, the RFID system's ability to read the tag quickly got the lowest rating from both students and cleaning staff, indicating that users have encountered issues with the RFID system in reading the tag. Despite this, overall average means from the cleaning staff and students fall within the range, indicating "high level," suggesting that the RFID opening mechanism is generally perceived as efficient and effective. The findings of this study align with the applications of RFID technology discussed in several studies. Soni et al. (2021) demonstrated the feasibility of using RFID for access control systems, where an RFID tag can trigger door opening with only authorized personnel. Similarly, in this study, the RFID enables the trash bin lid to open exclusively for cleaning staff. Furthermore, the effective operation of the RFID system supports Babylakshmi's (2023) study that RFID can enhance waste management by optimizing waste collection efforts and assisting cleaning personnel. The user experiences reported by both cleaning personnel and students further confirm the potential of RFID technology to improve waste management systems.

Table 2 presents the effectiveness of the Arduino Uno Auto-locking Waste Monitoring System with RFID and SMS Alert in reducing waste overflow. Based on the result, the system is rated to be an effective waste monitoring system. It reduces waste overflow for its mechanisms of having an auto-locking system, SMS alert, and RFID access, having the highest positive response anchor: "strongly agree." The lowest rating from the cleaning staff was 3.4, and the highest was 4, resulting in an overall mean of 3.7. The lowest rating of the students was 3.5, and 3.6 was the highest, having a composite mean of 3.55. This evaluation of the automated waste monitoring system demonstrates that it is highly effective in addressing the school's key aspects of waste control.

Table 2

Level of effectiveness of the Arduino Uno Auto-locking Waste Monitoring System with RFID and SMS Alert in reducing waste overflow

Overall System Effectiveness	Cleaning Staff Weighted Mean	Descriptive Equivalent	Students Weighted Mean	Descriptive Indicator
The system has helped prevent waste overflow in the school.	4	Highly Effective	3.6	Highly Effective
The system is generally reliable.	4	Highly Effective	3.5	Highly Effective
The system helps ensure that trash is properly disposed of.	3.4	Highly Effective	3.5	Highly Effective
I find the system user-friendly and easy to operate.	3.4	Highly Effective	3.6	Highly Effective
Composite Mean	3.7	Highly Effective	3.55	Highly Effective

Legend: 3.26 - 4.00 Highly Effective, 2.51 - 3.25 Moderately Effective, 1.76 - 2.50 Less Effective, 1.00 - 1.75 Not Effective

The school cleaning staff and students consistently provided high ratings, indicating intense satisfaction with the system's performance. One of the findings is that the system effectively prevents waste overflow, having received a 4.0 from school cleaning staff and 3.6 from the students, suggesting that the system successfully

reduces the risk of unsanitary conditions and maintains cleanliness. The assessment of the system's overall reliability was also rated 4.0 by the school cleaning staff and 3.5 by the students, signifying that the system operates consistently without notable failures. Additionally, ensuring proper waste disposal was rated as 3.4 by the school cleaning staff and 3.5 by the students, suggesting that the system effectively assists in organizing waste disposal and reducing human intervention. Lastly, the system's user-friendliness and ease of operation were highly rated. With 3.4 from the school cleaning staff and 3.6 from students, highlighting its ease of use without requiring extensive technical knowledge. These findings align with the study of Yusof et al. (2017): the components that have undergone several tests to determine their functionality are effective in the management of waste disposal, such as the ultrasonic sensor, which is a key component in monitoring waste. In addition, according to Ramson et al. (2020), waste monitoring bins are a solution to waste problems and are promoted as a more efficient way of managing waste. The system's monitoring mechanism effectively eradicates the overflowing of bins, providing immediate clearance of waste with its functions of real-time data on fill levels, SMS sending features, an auto-locking system, and RFID-based access control.

Table 3

Extent of Assistance Provided by the Arduino Uno Auto-Locking Waste Monitoring System with RFID and SMS Alert to School Cleaning Staff

Indicator	Weighted Mean	Descriptive Indicator
1. Sending SMS	4	High Extent
2. Automatically lock the lid	3.7	High Extent
3. Open the lid using RFID	3.7	High Extent
Composite Mean	3.8	High Extent

Legend: 3.26 - 4.00 High Extent, 2.51 - 3.25 Moderate Extent, 1.76 - 2.50 Low Extent, 1.00 - 1.75 Very Low Extent

Table 3 presents the extent of assistance the Arduino Uno Auto-Locking Waste Monitoring System provides to school cleaning staff with RFID and SMS alerts. The results indicated that the Arduino Uno auto-locking waste monitoring system with SMS alert and RFID was rated as highly effective in helping the school cleaning staff in their work. The SMS alert feature received the highest rating of 4.0, while the rest of the variables, such as automatically locking the lid, opening the lid using RFID, and the overall effectiveness, received the same rating of 3.7, having an overall mean of 3.78, which falls within the "High Extent" category. This indicates that the system significantly helps the school cleaning staff. Having received the highest rating, the SMS alert feature highlights its reliability in notifying the school cleaning staff when the waste bin is full.

The automatic lid-locking feature and RFID access system, rated at 3.7, also contribute to a more organized and controlled waste disposal process. These features ensure that waste bins do not overflow and that only authorized users can access them. Lastly, with the overall effectiveness rated as 3.7, the system streamlines waste management and reduces the workload of school cleaning staff. Therefore, based on the findings, the system improves the efficiency and effectiveness of waste disposal, making the cleaning staff's task easier and more manageable. These findings align with the study of Abdurahman et al. (2018), highlighting the Arduino Uno can be used as a central control unit of the waste monitoring system. This means that the auto-locking feature, SMS alert, and opening of the lid using RFID can be integrated so that the system works effectively. Respondents' positive and high ratings confirm that the system minimizes workload, ensures timely waste disposal, and enhances sanitation. With this, it can be said that the extent of the system's impact is substantial, as it provides a reliable solution that helps the school cleaning staff in their work.

Table 4*Correlation Between Waste Monitoring System Functions and Overall System Effectiveness*

Waste Monitoring System Functions	Waste Monitoring System Functions Overall Mean	Overall Effectiveness of the System Mean	Descriptive Indicator
Sending SMS	3.8	3.8	Highly Effective
Automatically Lock the Lid	3.8	3.8	Highly Effective
Open the Lid Using RFID	3.6	3.5	Highly Effective
Pearson's r Coefficient	0.993944		Very Strong Correlation

Legend: 3.26 - 4.00 Highly Effective, 2.51 - 3.25 Moderately Effective, 1.76 - 2.50 Less Effective, 1.00 - 1.75 Not Effective

Legend: 0.00 - 0.199 Very Weak Correlation, 0.20 - 0.399 Weak Correlation, 0.40 - 0.599 Moderate Correlation, 0.60 - 0.799 Strong Correlation, 0.80 - 1.00 Very Strong Correlation

Table 4 evaluates results about the Arduino-UNO auto-locking waste monitoring system with SMS alerts and RFID functions and capabilities. The system's three key functions, such as sending SMS to staff, automatically locking the lid when it's complete, and opening the lid using RFID, display positive ratings for the system's functions overall mean: 3.8, 3.8, and 3.6, respectively, and the mean of the system's overall effectiveness: 3.8, 3.8, and 3.5, respectively, indicating a highly efficient performance. A high Pearson's r coefficient of 0.993944 demonstrates a positive and very strong correlation between the system's functionality and effectiveness. The results suggest that the system's function is directly proportional to its effectiveness: improvements in any specific function directly translate to enhanced overall system performance. This strong correlation shows that implementing such a monitoring system would significantly improve waste management by providing reliable tracking of waste levels, real-time SMS alerts, and secure access control using RFID. These findings align with the study conducted by Debrah et al. (2021), which highlights the importance of education in making people care about waste management and effectively managing waste in developing nations.

Additionally, Table 4 outlines that the system could be applied in schools and communities to illustrate effective waste management techniques reinforced with lessons by Debrah et al. (2021). This combination of practical technology and education leads to more effective waste disposal practices and sustainable strategies. The data given also supports the study by Ramson et al. (2020), which shows that waste monitoring bins are a highly efficient means of waste management. The research shows the effectiveness of the automated bins in optimizing waste-related processes. In addition, several studies are justified by the gathered data: auto-locking systems have been suggested by Widiyanto and Munahar (2016), while Malar et al. (2021) discuss SMS alerts, and then Soni et al. (2021) and Raju et al. (2023) prove the work, efficacy, and management factors of automated waste management.

4. Conclusions

Based on the study's findings, the following were concluded about the research problems stated: the level of performance of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert function consistently through sending SMS, automatically locking the lid once the bin is detected as complete, and opening it through authorized RFID. The level of effectiveness of the Arduino Uno auto-locking waste monitoring system with RFID and SMS alert has proven effective in preventing waste overflow by automatically securing bins and notifying users when they reach capacity. The cleaning staff found the product helpful in contributing to efficiency in waste management in their work, as it allowed them to monitor waste levels in real time, respond promptly to full bins, and optimize their cleaning schedules for a more organized and systematic waste disposal process. Implementing an Arduino Uno auto-locking waste monitoring system with RFID and SMS alert has a positive relationship with optimizing waste management, as it has a high overall efficiency.

Recommendation - The following recommendations were presented based on the conclusions: The school administrator may explore implementing direct radio communication instead of SMS for waste management coordination. The Divine Word College of San Jose cleaning staff uses radios to communicate across campus locations, making direct radio communication more efficient than SMS by ensuring faster response times and improved coordination. The researchers recommend that future researchers conduct further investigations into integrating automated air purification systems into trash bins to help reduce unpleasant odors, particularly in enclosed spaces such as offices, classrooms, and hallways where trash bins are frequently placed. Future researchers may incorporate force sensors and buzzers to provide additional information about trash bin fill levels, preventing users from disposing of waste in already full bins by alerting them when capacity is reached and they still try to open it. Moreover, the researchers recommend that future researchers and users use weatherproof and fire-resistant materials in trash bin construction to enhance durability, safety, and overall user experience. These materials protect bins from harsh environmental conditions, such as rain, extreme temperatures, and humidity, while ensuring long-term functionality and safety, particularly for outdoor installations. The researchers also recommend that engineers incorporate solar panels to enhance efficiency by enabling bins to operate continuously throughout the day without reliance on external power sources, allowing trash bins to function effectively outside the establishments.

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