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OPTIMIZING WASTE MANAGEMENT THROUGH THE WASTE SEGREGATOR WITH REVERSE INCENTIVES MACHINE AT AEMILIANUM COLLEGE INC.

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Abstract

In an era of rapidly growing population, waste management has become a major global concern. The primary challenge that people face, is how to minimize waste that has an adverse effect on the environment. Several waste segregators have been developed through modern technologies to reduce waste and as individuals who are more dependent on technology, they are becoming more conscious of using resources sustainably. A waste segregator with a reverse incentives machine aimed to separate biodegradable from non-biodegradable and offered a reward for recycling plastic bottles and cans. Inspired by the need to improve waste management in the school canteen, the researchers designed this system as a practical solution and a teaching tool for environmental education. To proceed with the project, the researchers used the waterfall model as a methodology to help them look into the salient points of project development. Though face with many challenges and hardships, the researchers upon successfully development, was able to gather IT Experts and Electronics Engineers to assess the project which was fitted against an industry accepted standard evaluation – the ISO 25010. The project was deemed highly applicable gaining an overall weighted mean of 4.25. With an outstanding evaluation result, the findings revealed that the Waste Segregator with Reverse Incentive Machine is ready to be deployed for use of ACI. To ensure the functionality of the machine, maintenance is needed. Future project developers may also be able to modify the design and functionality to make sure it will serve its purpose.

Key Words: Aemilianum College, Inc., Recycling Efficiency, Reverse Incentives, Sustainable Practices, Waste Management Optimization, Waste Segregation

Introduction

In an era of increasing population growth, waste management has emerged as a critical concern for communities worldwide, and the main problem that people are facing is how to reduce waste that affects the environment.

According to Jerry Nathanson (2023), solid-waste management is the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. Improper disposal of solid waste can create unsanitary conditions, and these conditions in turn can lead to pollution of the environment and to outbreaks of vector-borne disease that is, diseases spread by rodents and insects.[1]

Through modern technologies, many waste segregators have been invented that help reduce waste and because of these advanced technologies, people are becoming more aware of the need to decrease waste and utilize resources more sustainably as they become increasingly dependent on technology. One potential solution to this problem is the implementation of a Waste Segregator that can segregate different types of wastes, and a reverse Incentives Machine that rewards consumers who throw plastic water bottles or cans into the Reverse Incentives Machine by paying them rewards such as school supplies, and candies, which will add to overall experience and satisfaction of the reverse incentive machine to the users.

The researcher's proposed system employs sensors, microcontrollers, and other components to consistently detect and categorize such plastic water bottles, cans, and other wastes. The technology is designed to be easy to use, making it more accessible to all users at Aemilianum College Inc. while also encouraging better waste management practices on a larger basis. Fortunately, emerging technologies such as reverse incentives machines are assisting in waste management and promoting products that are sustainable consumption that will minimize the impact on the environment. In a time when environmental problems are becoming more intense, the idea of a product that is sustainable consumption has emerged as an important part of minimizing the damage of waste to the environment.

The purpose of this research is to investigate the relationship between a product that is sustainable consumption and the innovative solution of a reverse incentives machine that can correct wrong decisions or consumer choices in the products they buy, as well as possible solutions or waste reduction strategies for a more conscious society. The goal of this research on a waste segregator with a special feature of reverse incentives machine is to examine and design an efficient and sustainable waste management system. The project will concentrate on enhancing the current waste management process by using technology and automation to help all users at Aemilianum College Inc. organize their trash.

This study examined the benefits and ethical challenges underlying technological breakthroughs in an effort to provide a proper understanding of how users can use technological innovations while addressing their potential downsides. As a result, it encouraged all the users at ACI to make mindful choices of what they purchase that favoured environmental protection and economic viability. Amid this change, the rise of waste segregator with reverse incentives machine was a striking example of technological innovation connected with product-sustainable consumption principles.

The study helped maintain a garbage-free and sustainable environment while also making waste collection and management incredibly convenient for every user at ACI. Reverse incentives machines can track inventory levels and usage patterns in real time, allowing them to make more accurate predictions about when products will run out. This reduced the amount of waste generated by vending machines, as operators can stock only the products that were

likely to be purchased. For waste segregator, it can track the level of waste if it was already full and ready to dispose of. Additionally, reverse incentives machines was programmed to offer rewards or incentives for users who choose to purchase more sustainable product options, such as school supplies or other items with minimal packaging.

Reverse incentives machines can also be integrated with other systems and devices to further optimize waste management by using the power of Arduino. The study aims to contribute valuable insight into how to protect the environment and the proper segregation of waste. The purpose of waste segregation was to separate the different types of waste so that it can be more efficiently managed and disposed of. Also, to reduce the amount of waste and to encourage recycling and reuse of materials. It encouraged customers to reduce garbage by offering incentives or rewards in return for depositing recyclable materials such as water bottles or cans. The machine used sensors and technology to recognize and sort various sorts of garbage, making the recycling process more convenient and efficient, as well as facilitating waste disposal and recycling. The new approach sought to uncover the complicated link between the design and performance of waste segregator with reverse incentives machine and their influence on encouraging sustainable consumption of products a habit, therefore contributing to environmental sustainability.

With the increase in the development of smart cities, the idea of keeping the cities clean is the utmost requirement. The amount of garbage produced is too large and the manual efforts required to process it are very tedious. With evolution of technology in every field, automated ways can be adopted to prevent the piling of the garbage. The waste segregator is designed to provide ease in the disposal of waste that is collected.[2]

The use of reverse incentives machine has a number of advantages. They improve the environment by recycling materials and minimizing the requirement for raw materials to manufacture new drinking container. RVMs are also conveniently located in public places like grocery shops, gas stations, schools, and parks, making them easily accessible to users. They are simple to manage because the machine sorts the recyclable materials (plastic, glass, and aluminum) instead of having to do so manually.[3]

Waste segregator with reverse incentives machine is a promising solution for optimizing waste management and promoting products that are sustainable consumption or a product that has a minimal package, offering insights into how they encourage widespread and sustained adoption of responsible waste management practices through investigating the relationship between technology, human behavior, and social dynamics. It can help people progress toward a more sustainable future by decreasing waste and promoting more responsible product consumption habits. In addition, the study will look at the function of rewards and incentives in influencing reducing waste or recycling behaviors, offering insight into the effectiveness of this technique in inspiring users at Aemilianum College Inc. to practice more responsible waste disposal.

Furthermore, the reverse incentive machine that was placed in the project acted not just as a reward system but also segregating waste, encouraging users to properly dispose of their waste while also promoting a circular economy as the machine will dispense rewards that are made from recycled materials such as water plastic bottles or cans. This capstone project aimed to minimize the amount of waste that ended up in landfills. The study aimed to explain the wider social implications of instilling sustainable consumption habits in products that can be reused. Waste segregator with reverse incentives machine served not only as practical tools for waste reduction but also as an educational platform. To give the students wisdom on how to dispose of waste and educate them about the effects of improper waste disposal on the environment. Because of this, ACI students may gain wisdom and become responsible for their wastes. As such, the research attempted to discover the many ways in which reverse incentives machines can be used to promote system change, influence larger

consumption habits, and contribute to the transition to a circular economy.

The combination of sustainable consumption of a product concept and the revolutionary capabilities of reverse incentives machines provides a new approach to addressing the most critical environmental concerns of our time. This study aimed to shed light on the complex connection between technology, human behavior, and sustainable principles, showing how these technologies can enable every student at ACI to become active participants in the development of better relations with the world. Through a delicate nature and exploration of this dynamic relationship, the study contributed to the growing discourse on a product that are sustainable consumption, technology-driven solutions, and the pursuit of a more resilient and environmentally conscious future.

To sum up, the waste segregator with reverse incentives machine iwas a promising innovative solution that addresses waste segregation and recycling through the use of modern technology. Using its intelligent sensors, it identified recyclable or reusable materials and sort them, making it a practical and efficient system. It also includes a reverse incentives machine to encourage everyone at ACI to participate in waste segregation, promoting a sustainable lifestyle. However, the implementation of this technology requires a large amount of investment, and proper maintenance is essential to ensure the efficiency of the system. Overall, this research highlights the potential of waste segregator with reverse incentives machine in reducing waste and promoting school sustainability, to make it easier for a cleaner and more eco-friendly future.

General Objective

The study developed an Optimizing Waste Management Through the Waste Segregator with Reverse Incentives Machine at Aemilianum College Inc., that efficiently categorized and separated three types of waste, recyclable, biodegradable, and non-biodegradable, to improve waste management and encourage users to return used containers through a rewards system.

Specific Objectives

Specifically, this study aimed to:

1. Design and develop an Optimizing Waste Management Through the Waste Segregator with Reverse Incentives Machine at Aemilianum College Inc. with the following features:
   - 1.1 Detecting
   - 1.2 Sorting
   - 1.3 Segregating
   - 1.4 Alarm System
   - 1.5 Monitoring
2. Determine the system quality based on ISO/IEC 25010: 2011 in terms of:
   - 2.1 Functional Suitability
   - 2.2 Reliability
   - 2.3 Performance Efficiency
   - 2.4 Usability
   - 2.5 Security
   - 2.6 Compatibility
   - 2.7 Maintainability
   - 2.8 Portability

Scope and Delimitation

The main objective of this study was to develop a waste segregator that has a reverse incentives machine. Its function was to separate biodegradable from non-biodegradable and the reverse incentives machine, where the used plastic water bottles and cans were placed. Users may receive rewards or incentives in return. These reverse incentives machine was inspired by the researchers' desire to collect recyclable plastic bottles and cans inside the school, especially in the canteen, where the researchers noticed that the wastes were not segregated properly. To avoid contaminating recycled plastic water bottles or cans, the researchers thought of this idea as a way of improving waste management within the school. It served as a

teaching tool, allowing children to gain hands-on experience in reducing waste and environmental protection for it represented the school's dedication to positively involving the community.

While the waste segregator with reverse incentives machine provided convenience and innovation, they have limitations. Project costs may be a limitation, making them less accessible to communities with fewer resources. Due to technological requirements, they may not work well in areas with technical facilities. For the sensors, the capacitive sensor cannot segregate thin plastic, resulting in the waste segregator no longer being automatically segregated. Furthermore, these devices may have difficulty with certain types of waste, such as toxic compounds or large objects. Keeping them in good condition requires regular inspections, which can be costly and difficult to maintain. The items they can offer were limited by size, weight, and customer needs.

The evaluators of this system were the stakeholders who were the school administration, two IT Experts, and two Professional Engineers. The stakeholders, were engaged in the implementation and utilization of the waste segregation and reverse incentives machine. IT professionals play a crucial role in the development of the technological aspects of the waste segregator, ensuring its smooth operation in the implementation of the system. Professional Engineers contributed to the design and functionality particularly focusing on the automation and electronic components involved in the system.

Significance of the Study

This study may be useful and may provide further understanding of the following:

Aemilianum College Inc. It will benefit the school to maintain proper segregation and hygiene. This prototype will help reduce the work of the janitor in separating the garbage for it is already segregated and ready to dispose of and can manage the time to collect garbage around the campus in just one day.

Students Of ACI. Students of Aemilianum College Inc. will be encouraged to use the prototype because of the incentives for each plastic water bottle and can also provide a more convenient and user-friendly experience for students, helping to boost enjoyment and engagement. It will also help them to become responsible when it comes to properly waste disposing.

Electronic Engineering Students. This study will address and provide additional information about the functionality of the Arduino as a microcontroller.

Garbage Collector. Waste Segregator with Reverse Incentives Machine will help to facilitate their work because the main objective of this study is to separate waste into non-biodegradable, biodegradable, and recyclable categories.

Future Researcher. This prototype will encourage future researchers to use Arduino for future projects as it provides practical experience and knowledge of the latest technologies and techniques related to the field of electronics engineering.

In general, the importance of studying the Optimization of Waste Management through Waste Segregator with Reverse Incentives Machine lies in its potential to improve waste management processes, promote environmental sustainability, reduce costs, and promote positive behavioral changes regarding waste disposal.

Gap Bridged by the Study

Waste management and sustainability topics including optimization of waste collection routes, efforts to achieve zero waste cities, the role of technology like IoT and robotics, and the challenges in waste management across different contexts, provide a comprehensive overview of current research in the field. This project demonstrates innovative approaches to address environmental and sustainability challenges. While they may involve different technologies and objectives, they all contribute to the broader

goal of reducing waste and promoting responsible resource management.

According to Espineli, Giron and Gloriani, the Project LOWKEY (Litter Obviation: Waste Keep and Eco-Rewards Yielder) is a way to collect empty beverage containers at the point of use and boost recycling rates through a system of cash incentives. While optimizing waste management through the Waste Segregator with Reverse Incentives Machine is not just a way to collect waste, but focuses on reducing waste and segregating the non-biodegradable and biodegradable waste through the use of Waste Segregator, and it is also a way to encourage every student at the ACI to manage their waste properly and help the community become a much cleaner and more eco-friendly place with the use of Reverse Incentives Machine.

Some study like Project Lowkey and other system regarding Reverse Vending Machine, the incentives or rewards they give for the users is cash or charging a phone, our study instead of cash or any incentives, since students are our main target users, not just any incentives but school supplies that can be helpful to the students of ACI, especially when they don't have enough money to buy things like, for example, a ballpoint pen. With a Waste Segregator with Reverse Incentives Machine and being wise and responsible with their bottles, they can easily purchase a ballpoint pen without spending so much money, which they can use for note-taking or writing important details. This will make the students feel appreciated and motivated to use the machine. Additionally, Waste Segregator with Reverse Incentives Machine does not only offer a ballpoint pen, but it also offers a different type of candies. Waste Segregator with Reverse Incentives Machine will have a big impact not just on our school but on the whole community itself. With this system, students can also donate their bottles to support unprivileged students who have access to the incentives.

Table 3.1 - Hardware Requirements

Hardware Requirements	Specifications	Quantity
Arduino Nano	AT Mega 328P 16MHz, OV- 5V, IV- 7V-12V, 14 Digital & 8 Analog pin	1
Arduino Uno	ATmega328P / Operating Voltage: 5V. / Input Voltage (recommended): 7-12V. Digital I/O Pins: 14 (of which 6 provide PWM output) / PWM Digital I/O Pins: 6. / Analog Input Pins: 6. / DC Current per I/O Pin: 20 mA	1
Arduino Mega	AT Mega 2560 16MHz, OV- 5V, IV- 7V-12V, With 54 Digital and 16 Analog Pins	1
Ultrasonic Sensor	HC-S04 40Hz, Ranging Distance: 3cm-350cm/3.5m, Power Supply: 3.3V-5V, Operating Current: 8mA	4
Infrared (IR) Sensor	Board Size: 3.2 x 1.4cm Operating Voltage and Current: 3.3V: ~23 mA, to 5V: ~43 mA Detection range 2cm – 30cm	3
Adjustable Infrared Sensor	Sensing Range: 3 cm to 80 cm Input Voltage: 5VDC Current Consumption: 300 mA	1

In table 3.1 to table 3.4 shows the hardware requirements while in table 3.5 shows the software requirement. To operate a reverse incentives machine and a waste segregator, think of the Arduino Nano and Uno as a little brain. It's ideal for simple jobs like confirming what you put into the machine, displaying messages on a screen, and making small parts move. So, with a reverse incentives machine, recyclable products like bottles or cans can be identified and handled. Arduino Nano may help a waste segregator in sorting different forms of trash. The Arduino Mega, on the other hand, is like a larger brain for more difficult tasks. Arduino Mega can perform many tasks at once and collaborate with multiple sensors and equipment in a large recycling or garbage sorting system. A reverse incentives machine may keep a database of various commodities as well as conduct more complicated functions. Arduino Mega can handle an important amount of trash sorting and data use for a waste segregator.

In waste segregator and reverse incentives machine, ultrasonic sensors play important roles. This sensor detects approaching trash objects, properly measures distances, avoids collisions, and monitors bin fill levels in waste segregators. This information promotes effective garbage sorting and system security. Ultrasonic sensors in waste segregator and reverse incentives machine recognize inserted recyclables, measure their distance and quality, verify cleanliness, and provide customer feedback, allowing the system to accept qualified products and deliver prizes. Overall, ultrasonic sensors improve the automation, accuracy, and functionality of these systems, allowing for more effective waste segregation and boosting recycling in reverse incentives machines.

Infrared (IR) sensors in waste segregator with reverse incentives machine is used to identify recyclables such as plastics, verify the cleanliness and validity of products, and offer feedback to users on their submissions. IR sensors improve the accuracy and efficacy of recycling activities by simplifying material detection and quality evaluation, eventually contributing to sustainable waste management.

Adjustable IR Sensor is used in waste segregator to conduct distance detecting functions, such as when waste is placed on the conveyor, the conveyor will activate automatically when the Adjustable IR Sensor senses the presence of waste.

Table 3.2
Hardware Requirements

Hardware Requirements	Specifications	Quantity
DC-DC Buck Converter Step Down Module	LM2596 Switching Frequency: 150KHz Input Voltage 4.75V-35V Output Voltage 1.25V-26V(adjustable) Output Current: Rated current is 2A, maximum 3A (additional heat sink is required)	3
Stepper Motor	NEMA17 Rated Voltage: 12V DC Current: 1.2A at 4V Step Angle: 1.8 degree Motor Length: 1.54inch 4-wire, 8inch lead	1
LCD Display Module	Power Voltage: 5V Screen Resolution: 20 Characters by 4 Lines	1

When powering electrical devices such as an Arduino, a DC-DC Buck Converter Step-Down Module is used to maintain a stable and controlled voltage supply. Even when the input source offers a larger voltage, these modules are designed to lower or "step down" the input voltage to a suitable and secure level. This voltage control is essential for protecting sensitive electronic components and guaranteeing dependable and safe functioning.

Stepper motors can be used to provide precise and regulated movement for various mechanical parts in waste segregation systems. Stepper motors are utilized inside the system to regulate the movements of conveyor belts, chutes, gates, and diverters, providing the proper positioning and sorting of waste items based on particular criteria such as material type. The ability to move in incremental stages makes them perfect for activities requiring precise and dependable trash sorting, helping to more efficient and accurate waste management procedures.

Liquid Crystal Display (LCD) screens in reverse incentive machines serve several functions. LCD screens are the key point of

contact between users and the machine, delivering clear instructions, showing transaction data, and providing feedback on the identification of deposited items. They help to improve the user experience by increasing trust and encouraging more people to engage in recycling programs.

Table 3.3

Hardware Requirements

Hardware Requirements	Specifications	Quantity
Servo Motor	MG996 180 Degree Continuous Rotation Voltage: 4.8V – 7.2V DC (5V Typical) Current: 10 mA (typical), 1.3 – 1.5 A (measured)	4
Inductive Proximity Sensor	Sensing distance: 2 mm ± 10%, 4 mm ± 10%, 5 mm ± 10%, 8 mm ± 10%,12 mm ± 10% Differential Travel: max. 10% Object: Ferrous metal Power Supply 12 to 24 VDC Current Consumption: 15 mA max	1
Servo Motor	MG90D 360 Degree Continuous Rotation Voltage: 4.8V – 6V DC (5V Typical) Current: 10 mA (typical), 1.3 – 1.5 A (measured)	4
Buzzer	Piezoelectric Buzzer Rated Voltage: 6V DC Operating Voltage: 4-8V DC Rated Current: 30mA	6
Wires Connector	Stranded Wire (AWG #22) Solid Wire (AWG #22)	100meters
Load Cell Amplifier HX711	OV: 2.7V-5V. Operation Current: < 1.5mA. Sample rate: 10Hz	1
Resistor	220 ohms	10
Potentiometer	Tolerance: ±25% Power rating: .1W @ 70°C max. Rotation torque: 15~170gfcm. 10k ohms	1
Wire Coil		3meters

Servo motors provide accurate and regulated movement in waste segregator and reverse incentives machine. In garbage segregators, conveyor belts, gates, and sorting systems, ensure waste objects are precisely positioned and guided to the appropriate containers based on their kind or content. Servo motors also allow for changeable sorting bins and customizable timing, which accommodates changing needs. The Servo motor handles returned recyclables, assists in item detection, and precisely regulates ejection mechanisms in reverse incentives machine, improving item handling efficiency and accuracy. Furthermore, servo motors may be used to power interactive components such as touchscreens to increase user involvement. The regulated mobility of servo motor improves the dependability and efficacy of recycling and waste management operations in waste segregator and reverse incentives machine.

In a trash bin of reverse incentives machine or waste segregator, the buzzer or alarm is essential for user notification and machine efficiency. Its main objective is to notify consumers when the recycling bin is full, stopping them from depositing things that cannot be accommodated. This not only prevents potential jams or machine damage but also provides a great user experience by providing instant feedback on the machine's status. In addition, the alarm serves as a maintenance reminder, promoting frequent service and emptying of the full bin to ensure operating efficiency. In summary, the buzzer in a Reverse Incentives machine and waste segregator improves machine dependability

encourages recycling and adds to a smooth and efficient recycling experience for consumers. The load cell for the reverse incentives machine will help to easily read load cells to measure weight.

Table 3.4

Hardware Requirements

Hardware Requirements	Specifications	Quantity
Polyvinyl Chloride (PVC Pipe)	57mm (2") x 1 meter	1
Mini Switch (Buttons)	PBS – 33b 2 Pin 12mm, 12V, 1A	7
Trash Bins	15L: 23x15x34 cm	4
LED	2 colors (red and Green) 5mm round (T-1 3/4)	10
Leather		1 meter
L7809	Operating voltage: 9V. Max input voltage: 35V. Max output current:1A Quiescent (standard) current:5A	1
15P Pin	Pin length: 8.5mm Current Rating: 3Amps Contact Material: Phosphor bronze	2

The PVC will be used inside the Reverse incentives machine to create a hold of plastic bottles or cans for the user to insert. And a mini switch is an essential user input device in incentives machines. Users can use the mini switch to make selections or to initiate actions such as selecting a product or starting a transaction. It is the point at which users engage with the vending machine. The system will include two trash bins inside the waste segregator for separating non-biodegradable and biodegradable waste. Additionally, there will be two more trash bins in the Reverse Incentives Machine, specifically designated for two categories of reusable materials: plastic water bottles and cans. An LED was integrated into the waste segregator system to indicate whether the system is in manual or automatic operation.

Table 3.5
Software Requirements

Software Requirements	Specifications
Arduino Complier (IDE)	Used to write, compile and upload code to Arduino and Arduino-compatible microcontroller boards.

The Arduino IDE (Integrated Development Environment) is a simple software platform used to program Arduino microcontrollers and development boards. Arduino IDE makes the process of developing, compiling, and uploading code to these devices easier for both novice and professional programmers. The Arduino IDE has a large library of pre-written functions that may be used to interface with various hardware components and sensors, simplifying the coding process. Its simple interface, real-time code verification, and a large community of users and

resources make it an effective tool for prototyping and creating a wide variety of electronics projects.

Design Phase

To guarantee the validity and reliability of the research findings, the design phase was essential to the project's development. To ensure clear planning and proper implementation of the project, the researchers prepared a Flowchart for the process of the waste segregator and reverse incentives machine and a wiring diagram to show how the waste segregator and reverse incentives machine functioned.

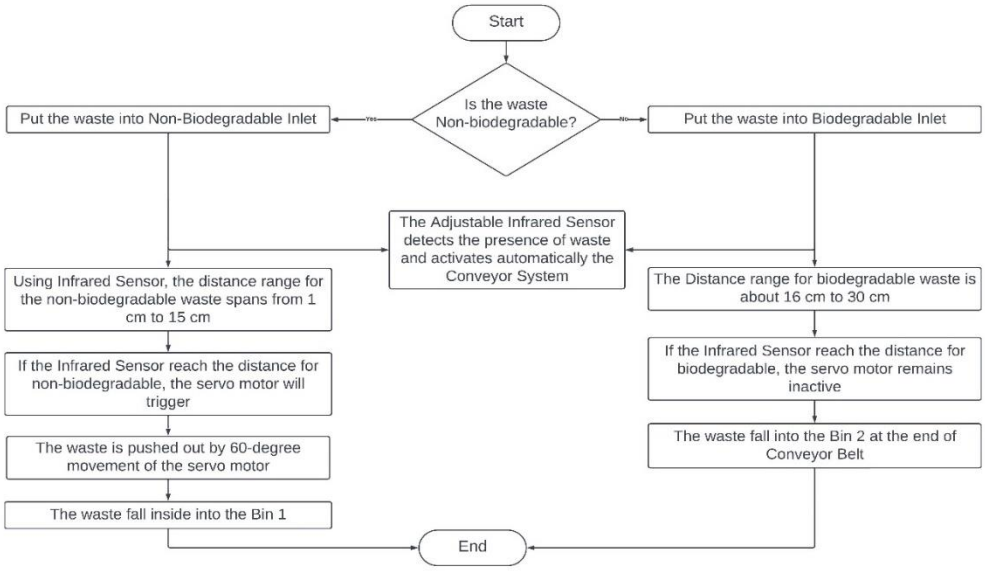

Figure 4.1

Figure 4.1 showed the flowchart for the waste segregator, which explained how the waste segregator works. For example, if the user used the waste segregator, the user puts the waste into the designated category of waste, whether it was biodegradable or non-biodegradable. After that, the Adjustable IR Sensor then detected the waste and automatically activated the conveyor, and using the Infrared Sensor, when they reached the distance for non-biodegradable and biodegradable, the servo motor is activated for non-biodegradable and inactive in biodegradable waste, and the waste fall into their designated trash bin.

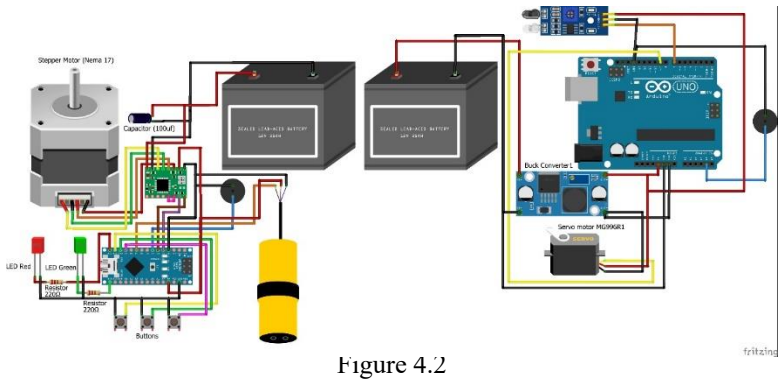

Figure 4.2

In Figure 4.2, the waste segregator system utilized Adjustable IR Sensor to automatically start the conveyor belt once the waste was detected. Infrared Sensor was used to measure the distance of the waste, identifying and guiding it to its assigned bin. The researchers utilized a NEMA 17 stepper motor to operate the conveyor belt. The servo motor allowed for the precise diversion of waste into different bins based on their categories. The system utilized LEDs to signal whether the conveyor system was in manual mode or automatic mode. The green LED signified automatic mode, while the red LED signified manual mode. The researchers also used buttons to adjust the conveyor belt while it was operating in manual mode. These components were connected to different Arduino boards, such as the Arduino Uno and an Arduino Nano, to guarantee the smooth operation of the system.

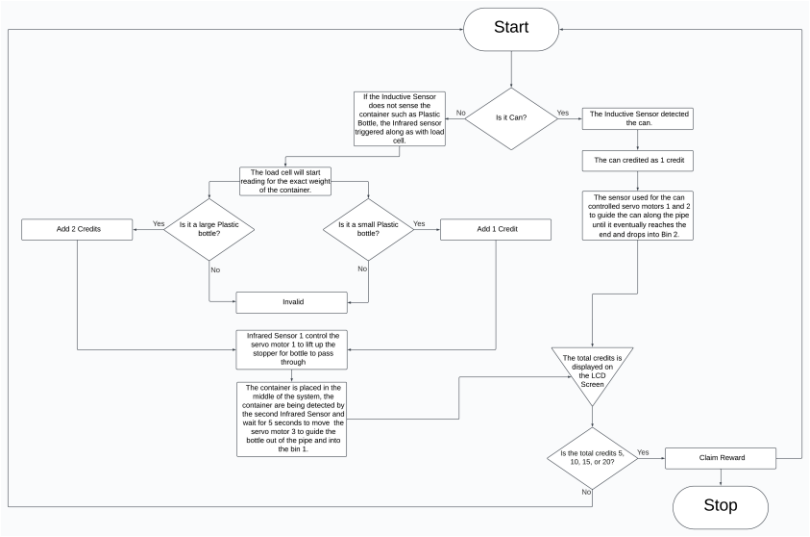

Figure 4.3 Reverse Incentives Machine Flowchart Diagram

Figure 4.3 reflected the flowchart for the Reverse Incentives Machine, which explained how the Reverse Incentives Machine will work. For example, when the user puts the can inside the reverse Incentives machine, the inductive sensor detected the can, and is credited as 1 credit or point. The sensor used for the can was controlled by servo motors 1 and 2 to guide the can along the pipe until it eventually reached the end and drops into bin 2, and the total credit were displayed on the LCD screen. If the user reached the total credits of 5, 10, 15, or 20, the user can then claim the rewards. On the other hand, if the

user puts a bottle into the reverse incentives machine, since the inductive sensor does not sense the container, such as a plastic bottle, the infrared sensor was triggered as well as the load cell. The load cell starts reading for the exact weight of the bottle, whether it is small or large. If the bottle was small, it was considered 1 credit, and if it is large, 2 credits is given. After the load cell reads it, the infrared sensor 1 then controls the servo motor 1 to lift up the stopper for the bottle to pass through, and the bottle is placed in the middle of the system. The bottle was detected by the infrared sensor 2 and waits for 5 seconds to move the servo motor 3 to guide the bottle out of the pipe and make it fall it into bin 1. After which the total credit was displayed on the LCD display. If the user reached the total credits of 5, 10, 15, or 20, the user can then claim the rewards.

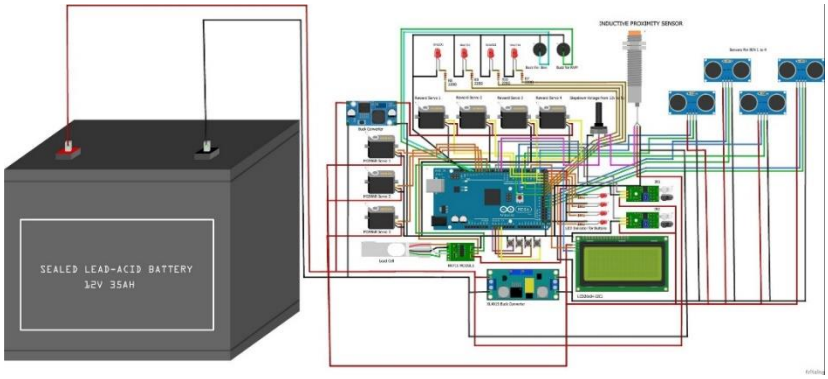

Figure 4.4 Reverse Incentives Machine Wiring Diagram

In figure 4.4, The Reverse Incentives Machine employed sensors such as inductive sensors and infrared sensors to detect plastic bottles and cans. To determine the weight of the plastic bottle, the researchers used a load cell. The exact weight of the plastic bottle was 10 to 40 grams for a small bottle and 40.1 to 90 grams for a big bottle. If the plastic was lighter or heavier than the exact weight of the plastic bottle, the machine will not accept it. An LCD notified users during machine operation. Additionally, a servo motor acts as a stopper for plastic bottles and cans and to operate the rewarding system for the reverse incentives machine. The researchers decided to add another 4-servo motor for the rewards to function. The LEDs prompted the users the rewards they can claim. The Arduino Mega acted as the central processing unit of the system.

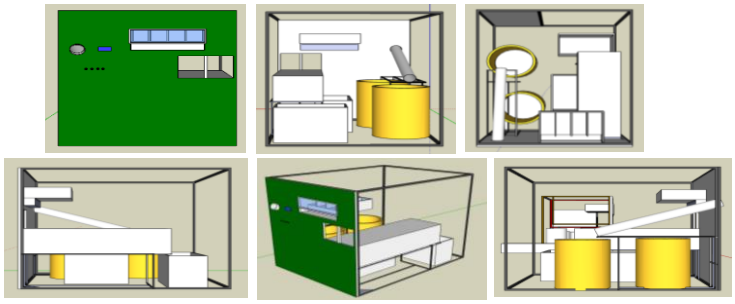

Figure 4.5 Physical Design of Waste Segregator with Reverse Incentives Machine

Figure 4.5 displayed the physical design of the system, where the researchers decided to put it in a box to make it secure and presentable once it is deployed and introduced to the users. The designated waste segregator with reverse incentives machine is contained in a box with a length of 1.4 meters and a height of 1.3 meters. It had four 4(four) trash bins; each designated category of waste has its own trash bin, which are: biodegradable and non-biodegradable for the waste segregator, and a trash bin for bottles and cans for the reverse incentives machine. The materials used to build the system box are plywood, angle bars, plain sheets, deformed bars, and paint. The researchers decided to use plywood as the front of the system and to paint the front view green, as it represents eco-friendliness. The researchers also used an angle bar and a plain sheet to make the system fixed and secured.

Table 4.11
Overall Evaluation of the Waste Segregator with Reverse Incentives Machine

Quality Characteristics		Electronics Engineer (2)	IT Expert (2)	Average	Interpretation
1.0	Functional stability	3.75	4.5	4.1	Highly applicable
2.0	Reliability	3.9	4	3.95	Very applicable
3.0	Performance Efficiency	3.85	4.25	4	Very applicable
4.0	Usability	4.5	4.7	4.6	Highly applicable
5.0	Security	5	4	4.5	Highly applicable
6.0	Compatibility	4.25	4.15	4.2	Highly applicable
7.0	Maintainability	4.5	4	4.25	Highly applicable
8.0	Portability	4.25	4.85	4.5	Highly applicable
	Mean	4.25	4.3	4.2	Highly applicable
	Overall Mean	4.25			Highly applicable

Table 4.11 presents the result of the overall evaluation of Waste Segregator with Reverse Incentives Machine which was evaluated by two (2) Engineers and two(2) IT experts to test its functionality and quality.

Summary of findings

The following findings were obtained from the study:

1. The system is a waste segregator with the special feature of reverse incentives machine that can put your waste into the right place and offer an incentive for the responsible student of ACI.
2. The system is designed for the students and personnel of ACI, it will help students to become more responsible individuals.
3. In the waste segregator, it cannot accurately sense the difference between biodegradable and non-biodegradable waste since no sensor can automatically segregate the waste.
4. In building the system, it really takes enough time and also needs the right budgeting plan since the cost of the components to make the system is expensive and making of the box takes too long,

especially when there are only few workers.
5. In the reverse vending machine, when throwing a can or bottle, it should be one at a time and not at the same time because its point will only be counted as 1 point, which will result in the loss of the user.
6. The system conducted an evaluation using ISO 25010. Two engineers and IT experts evaluated the system, and the result was that it was highly applicable and met the requirements and standards set by ISO 25010. In conducting the evaluation, it provided assistance to researchers to determine what should be improved in the system.

Conclusion

On the basis of the study's findings, the following conclusions were drawn:

1. The system can encourage ethical trash disposal practices among students of ACI, which will help create a more sustainable environment.
2. The collaborative effort of every stakeholder involved faculty, staff, and students has been essential to the accomplishment of this waste management project.
3. The system's primary goal is to separate non-biodegradable from biodegradable waste and provide incentives for a predetermined quantity of bottles and cans.
4. The system is a workable way to raise awareness of environmental issues and improve the effectiveness of waste management in ACI.

The system will not only benefit the environment, but it will also contribute to the students at ACI to become more responsible when it comes to disposing their wastes

Recommendations:

1. Intensify marketing campaigns to raise awareness of the advantages of the reverse incentives system and waste segregation. This might include interactive sessions, educational workshops, and educational materials.
2. Evaluate user feedback and machine performance regularly and make necessary system adjustments, to increase the device effectiveness.
3. Adjust the reverse incentives program to better illustrate the college community's preferences and driving forces. This can include offering a range of rewards or looking into joint ventures with nearby companies to diversify incentives.
4. To ensure convenient use, the system should be inspected or cleaned every five days.
5. For the next researchers, they should come up with new ideas to further enhance the system.
6. For future researchers, they should just remove the waste segregator and focus on how they can improve the reverse incentives machine. If they insist on making the waste segregator, they will have a hard time finding a sensor that can automatically segregate the waste.
7. For safety and alertness, future researchers should install an emergency button, whose main purpose is to alert the maintainer if the system has a malfunction or

something bad happens inside the system.

8. The button to operate the waste segregator is better if it is outside so that the system operates faster and there is no need to go inside to activate it. It also needs to be secured and cannot be opened and damaged if the buttons are on the outside.
9. For the future researchers, it there is a limit to the size of can or bottle that can only be thrown in the reverse incentives machine, it is necessary that the hole is just right for how big they can be thrown to avoid anything that can be done by the users.
10. For future researchers, they should put an alarm system on the reverse incentives machine so that there is a certain amount of time that it has sorted the bottle or can.
11. For the portability of the system, it is better if the materials used to build the system box are durable and not easily damaged.
12. Due to cost constraints, the researchers are not able to put the wiring into a modular wiring system. Therefore, it is suggested for future researchers that it is better to have a modular wiring system to facilitate troubleshooting and improve safety in electrical systems.

For the overall effectiveness and efficiency of the system, the lidar sensor is suggested by the researchers for future researchers. The lidar sensor allows the waste segregator to identify and separate different types of waste precisely.

References

1. Nkechi Chuks Nwachukwu, Frank Anayo Orji, and Ositadinma Chinyere Ugbogu. (2013). Health care waste management: public health benefits and the need for effective environmental regulatory surveillance in the Federal Republic of Nigeria. Current Topics in Public Health 2, 149–178.
2. Olga Rybnytska, Frada Burstein, Andrei V. Rybin, and Arkady Zaslavsky. (2018). Decision support for optimizing waste management. Journal of Decision Systems, 27 (sup1), 68–78.
3. https://www.tandfonline.com/doi/full/10.1080/12460125.2018.1464312
4. Flavio Bonomo, Guillermo Durán, Frederico Larumbe, and Javier Marenco (2013). A method for optimizing waste collection using mathematical programming: a Buenos Aires case study. Waste Management & Research, 30 (3), 311-324.
5. https://journals.sagepub.com/doi/10.1177/0734242X11402870
6. Gonca Harman, Nisa Yenikalayci. (2022): Determination of Science Students' Awareness on Waste Management Journal of Science Learning, 5 (2), 301-320
7. https://files.eric.ed.gov/fulltext/EJ1346281.pdf
8. Abhishek Nandan, Bikarama Prasad Yadav, Soumyadeep Baksi, and Debajyoti Bose. (2017), Recent Scenario of Solid Waste Management in India, World Scientific News, 56–74
9. https://bibliotekanauki.pl/articles/1182742.pdf
10. Jayne Lois San Juan, Carlo James Caligan, Maria Mikayla Garcia, Jericho Mitra, Andres Philip\ Mayol, Charlle Sy, Aristotle Ubando, and Alvin Culaba. (2020): Multi-objective Optimization of an Integrated Algal and Sludge-Based Bioenergy Park and Wastewater Treatment System Sustainability, 12 (18), 7793
11. https://www.mdpi.com/2071-1050/12/18/7793
12. Vella Atienza. (2013), Challenges in the waste management system in the era of
13. globalization: the case of the Philippines International Trade In Recyclable And Hazardous Waste In Asia, 90-115.
14. https://nswai.org/docs/Review%20of%20the%20Waste%20Management%20System%20in%20the%20Philippines.pdf
15. Amado C Gequinto. (2017), Solid waste management practices of select state universities in CALABARZON, Philippines Asia Pacific Journal of Multidisciplinary Research 5 (1), 1-8
16. https://www.apjmr.com/wp-content/uploads/2016/11/APJMR-2017.5.1.01.pdf
17. Jhonvher L De Alday, John Harry S Labita, Melchor S Espinosa II. (2022), Design and Fabrication of Vending Machine with Shredding System Ani: Letran Calamba Research Report 18 (1), 1-1
18. https://ejournals.ph/article.php?id=19054
19. Ma Xena L Bautista, Cheerobie B Aranas, Rina J Arcigal. (2023), Arduino-Based Waste Detector with Alarm System European Journal of Science, Innovation and Technology 3 (1), 146-158
20. https://ejsit-journal.com/index.php/ejsit/article/view/167
21. Jesusimo L Dioses Jr. (2020), Bottle-Segreduino: An Arduino frequency-based bin for tin can and plastic bottle segregation using an inductive proximity effect International Journal 9 (4)
22. https://www.warse.org/IJATCSE/static/pdf/file/ijatcse184942020.pdf
23. Myra G Flores, Jose Tan. (2016), Literature review of automated waste segregation system using machine learning: A comprehensive analysis International journal of simulation: systems, science and technology 11
24. https://ijssst.info/Vol-20/No-S2/paper15.pdf

25. Huma Zia, Muhammad Uzair Jawaid, Hafiza Sundus Fatima, Imtiaz Ul Hassan, Azmat Hussain Sheryar Shahzad, and Muhammad Khurram (2022): Plastic Waste Managemen through the Development of a Low-Cost and Lightweight Deep Learning-Base Reverse Vending Machine Recycling 7 (5), 70
26. https://www.mdpi.com/2313-4321/7/5/70
27. Taeyoung Yoo, Seongjae Lee, and Taehyoun Kim (2021): Dual image-based CNN ensemble model for waste classification in reverse vending machines, Applied Sciences 11 (22), 11051.
28. https://www.mdpi.com/2076-3417/11/22/11051
29. Eline Fidje, Moutaz Haddara, and Marius Langseth (2023): Sustainable Smart WasteManagement Adoption Challenges in Developing Countries, Procedia Computer Science 219, 905–914.
30. https://dl.acm.org/doi/abs/10.1016/j.procs.2023.01.366
31. Elham Shadkam (2022): Cuckoo optimization algorithm in reverse logistics: a network design for COVID-19 waste management. Waste Management & Research, 40 (4), 458–469.
32. https://journals.sagepub.com/doi/abs/10.1177/0734242X211003947
33. Joselito Abierta Olalo. (2022) Pyrolytic Oil Yield from Waste Plastic in Quezon City, Philippines: Optimization Using Response Surface Methodology InternationalJournal of Renewable Energy Development, 11.
34. https://ejournal.undip.ac.id/index.php/ijred/article/view/41457
35. Chang Su Lee, Dong-Won Lim. (2022) CNN-Based Inspection Module for Liquid CartonRecycling by the Reverse Vending Machine Sustainability 14 (22), 14905.
36. https://www.mdpi.com/2071-1050/14/22/14905
37. Jhonvher L. De Alday, John Harry S. Labita, and Melchor S. Espinosa II. (2022) Design and Fabrication of Vending Machines with Shredding Systems, Ani: Letran Calamba Research Report 18 (1), 1–1.
38. https://ejournals.ph/article.php?id=19054
39. Navjot Sidhu, Alberto Pons-Buttazzo, Andrés Muoz, and Fernando Terroso-Saenz. (2021) A collaborative application for assisting thes management of household plastic waste through smart bins: a case study in the Philippines Sensors 21 (13), 4534. https://www.mdpi.com/1424-8220/21/13/4534
40. Nathanson, J. A. (2023). solid-waste management. Encyclopedia Britannica.
41. https://www.britannica.com/technology/solid-waste-management
42. Cherry Agarwal, Chaithali Jagadish , Bhavesh Yewale, (2020), Automatic Waste Segregation and Management, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 06. https://www.ijert.org/research/automatic-waste-segregation-and-management-IJERTV9IS060534.pdf
43. Aco Recyling. (2022). "Benefits of Reverse Vending Machines in Supermarket."
44. https://www.acorecycling.com/blog/benefits-of-reverse-vending-machines-in-supermarket/.
45. Collins. (2023). Optimize. In Collins Dictionary. Retrieved August 30, 2023, from
46. https://www.collinsdictionary.com/dictionary/english/optimize
47. Francisco. E. (2023). Waste Management System. Retrieved August 30, 2023, from
48. https://safetyculture.com/topics/waste-management-system/
49. Axil-IS Blog. (2023). The Importance of Waste Segregation Retrieved October 9, 2023, from https://axil-is.com/blogs-articles/waste-segregation/.
50. Merriam-Webster. (2023). Incentive. In Merriam-Webster.com dictionary. Retrieved
51. October 9, 2023, from https://www.merriam-webster.com/dictionary/incentive
52. Merriam-Webster. (2023). Machine. In Merriam-Webster.com dictionary. Retrieved October 9, 2023, from https://www.merriam-webster.com/dictionary/machine
53. My Adventurous Life: THE AEMILIANUM COLLEGE INC. PHILOSOPHY."
54. https://myadventurouslife-mj.blogspot.com/2012/02/aemilianum-college-inc-philosophy.html.
55. Collins. (2023). Detection. In Collins Dictionary Retrieved October 9, 2023, from
56. https://www.collinsdictionary.com/dictionary/english/detection
57. Meriam-Webster. (2023). Sort. In Meriam-Webster Dictionary. Retrieved August 30,
58. 2023, from https://www.merriam-webster.com/dictionary/sort
59. Meriam-Webster. (2023). Segregate. In Meriam-Webster Dictionary. Retrieved
60. August 30,2023, from https://www.merriamwebster.com/dictionary/segregate
61. Alarm System. In Law insider Dictionary. Retrieved August 30, 2023, from
62. https://www.lawinsider.com/dictionary/alarm-system
63. Meriam-Webster. (2023). Monitoring. In Meriam-Webster Dictionary. Retrieved
64. August 30, 2023, from https://www.merriam-webster.com/dictionary/monitoring
65. Cambridge. (2023). Functional. In Cambridge Dictionary. From
66. https://dictionary.cambridge.org/us/dictionary/english/functional
67. Cambridge. (2023). Suitability. In Cambridge Dictionary. From
68. https://dictionary.cambridge.org/us/dictionary/english/suitability
69. Cambridge. (2023). Reliability. In Cambridge Dictionary. From
70. https://dictionary.cambridge.org/us/dictionary/english/reliability
71. Meriam-Webster. (2023). Security. In Meriam-Webster Dictionary. From
72. https://www.merriam-webster.com/dictionary/security
73. Stocker, D., et. al., (2022). Performance Efficiency Principles. From
74. https://learn.microsoft.com/en-us/azure/well-architected/scalability/principles
75. Cambridge. (2023). Compatibility. In Cambridge Dictionary. From
76. https://dictionary.cambridge.org/us/dictionary/english/compatibility
77. Meriam-Webster. (2023). Maintainability In Meriam-Webster Dictionary. From
78. https://www.merriam-webster.com/dictionary/maintainability
79. Cambridge. (2023). Portability. In Cambridge Dictionary. From
80. https://dictionary.cambridge.org/us/dictionary/english/portability

81. Swapan Das, Bidyut Kr Bhattacharyya. (2015), Optimization of municipal solid waste
82. collection and transportation routes, Waste Management 43, 9–18.
83. https://www.sciencedirect.com/science/article/abs/pii/S0956053X15004432?via%3Dihub
84. Atiq Uz Zaman, Steffen Lehmann. (2013). Urban growth and waste management
85. optimization towards a zero-waste city. City, Culture, and Society 2 (4), 177–187.
86. https://www.sciencedirect.com/science/article/pii/S1877916611000786)
87. Silvia Coderoni and Maria Angela Perito. (2020): Sustainable consumption in the circular economy An analysis of consumers' purchase intentions for waste-to-value food Journal of Cleaner Production 252, 119870
88. https://www.sciencedirect.com/science/article/abs/pii/S0959652619347407
89. Terry Tudor, Guy M. Robinson, Mark Riley, Steven Guilbert, and Stewart W. Barr. (2013) Challenges facing the sustainable consumption and waste management agendas: perspectives on UK households. Local Environment, 16 (1), 51–66.
90. https://www.tandfonline.com/author/Robinson%2C+Guy+M
91. Aarti Sewak, Sameer Deshpande, Sharyn Rundle-Thiele, Fang Zhao, and Renata Anibaldi. (2021): perspectives and engagement in sustainable solid waste management Community (SWM) in Fiji: A socioecological thematic analysis Journal of Environmental Management 298, 113455
92. https://www.sciencedirect.com/science/article/abs/pii/S0301479721015176
93. Erin Walkinshaw. (2011): Medical waste-management practices vary across Canada (Cmaj 183 (18), E1307–E1308).
94. https://www.cmaj.ca/content/183/18/E1307.short
95. Elliott Steen Windfeld, Marianne Su-Ling Brooks. (2015), Medical Waste Management: A
96. Review, Journal of Environmental Management, 163, 98–108
97. https://www.sciencedirect.com/science/article/abs/pii/S0301479715302176
98. S. Anwar, S. Elagroudy, M. Abdel Razik, A. Gaber, CPC Bong, and WS. Ho. (2018). Optimization of solid waste management in rural villages of developing countries. Clean Technologies and Environmental Policy 20, 489–502.
99. https://link.springer.com/article/10.1007/s10098-018-1485-7
100. Tamás Bányai, Péter Tamás, Béla Illés, ivil Stankeviit, and gota Bányai. (2019): Optimization of municipal waste collection routing: Impact of industry 4.0 technologies on environmental awareness and sustainability. International Journal of Environmental Research and Public Health, 16 (4), 634
101. https://pubmed.ncbi.nlm.nih.gov/30795548/
102. Imran Mahmood, Junaid Ahmed Zubairi. (2021): Efficient waste transportation and
103. recycling:Enabling technologies for smart cities using the internet of things. IEEE Electrification Magazine, 7 (3), 33–43, 2019.
104. https://www.researchgate.net/publication/335539835_Efficient_Waste_Transportation_and_Recycling_Enabling_technologies_for_smart_cities_using_the_Internet_of_Things
105. Renato Sarc, Alexander Curtis, Lisa Kandlbauer, Karim Khodier, Karl E. Lorber, and Roland Pomberger. (2019): Digitalization and intelligent robotics in the value chain of circular economy-oriented waste management: a review Waste Management 95, 476-492 https://www.sciencedirect.com/science/article/abs/pii/S0956053X19304234
106. AE Adeniran, AT Nubi, and AO Adelopo. (2017). Solid waste generation and characterization at the University of Lagos for sustainable waste management. Waste Management 67,3–10.
107. https://europepmc.org/article/med/28532622
108. Vella Atienza. (2020), Waste Management in the Philippines: Sustainable Waste
109. Management Challenges in Developing Countries, 270–286,
110. https://www.igi-global.com/chapter/waste-management-in-the-philippines/240080
111. Michael S. Ang, Jensen Duyag, Kimberly C. Tee, and Charlle L. Sy. (2019): A multi-period andmulti-criterion optimization model integrating multiple input configurations, reuse, and disposal options for a wastewater treatment facility. Journal of Cleaner Production, 231, 1437–1449
112. https://www.igi-global.com/chapter/waste-management-in-the-philippines/240080
113. Daniel A. Vallero, Fraser McLeod, and Tom Cherrett. (2019), Waste Collection, 67–89
114. https://www.sciencedirect.com/science/article/abs/pii/B9780128150603000049
115. Yeow Eu Lun, Siti Rozaimah Sheikh Abdullah, Hassimi Abu Hasan, Ahmad Razi Othman, Setyo Budi Kurniawan, Muhammad Fauzul Imron, Osama Abrahiem AL Falahi, Nor Sakinah Mohd Said, Siti Shilatul Najwa Sharuddin, and Nur'Izzati Ismail. (2022) integrated emergent-floating planted reactor for textile effluent: removal potential, optimization of operational conditions, and potential forthcoming waste management strategy. Journal of Environmental Management, 311, 114832
116. https://www.sciencedirect.com/science/article/abs/pii/S0301479722004054
117. Zeba F Alam, AJV Riego, JHRP Samson, SAV Valdez. (2019), The assessment of the
118. genotoxicity of e-waste leachates from e-waste dumpsites in Metro Manila, Philippines International Journal of Environmental Science and Technology 16, 737-754
119. https://link.springer.com/article/10.1007/s13762-018-1719-6
120. SC Athukorala, HMAL Hennayaka, SMLP Rathnayake, M Hariluxman, JR Gamage, RARC
121. Gopura. (2021), A Reverse Vending Machine for Sorting Yoghurt Cups and PET Bottles 2021 Moratuwa Engineering Research Conference (MERCon), 333-338
122. http://dl.lib.uom.lk/handle/123/19173
123. Wisdom Gen P Dumpayan, Matthew Lawrence M De Mesa, Nathalie Danielle F Yucor, EdenT Gabion, Jacqueline D Reynoso, Gabriel Rodnei M Geslani. (2017), Two-way powered microcontroller-based plastic bottles 'drop-and-tap'reverse vending machine with stored value system using radio frequency identification (RFID) scanner technology 2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 1-8
124. https://ieeexplore.ieee.org/abstract/document/8269433/similar#similar
125. Narcisa Morallo. (2017), Smart Bin Design Based on Global System for Mobile
126. Communications Modem and Ultrasonic Sensor Interface using Arduino Uno Board as Platform JPAIR Multidisciplinary Research 29 (1), 28-45, 2017
127. https://philair.ph/index.php/jpair/article/view/512

128. Shilpa Sambhi, Preeti Dahiya(2020): Reverse vending machines for managing plastic waste. International Journal of System Assurance Engineering and Management, 11, 635 640.
129. https://ideas.repec.org/a/spr/ijsaem/v11y2020i3d10.1007_s13198-020-00967-y.html
130. Kuldeep Singh, Gayatri Arora, Pushpa Singh, and Ankit Gupta (2021): IoT-based collection vendor machine (CVM) for e-waste management. Journal of Reliable Intelligen Environments, 7, 35–47, 2021
131. https://www.semanticscholar.org/paper/IoT-based-collection-vendor-machine-(CVM)-for-Singh-Arora/e0bae8ea0a4efdddce45159693a0ebe892227b2e
132. Erikson Ferry Sinaga, Richard Irawan (2022), "Developing a barcode scan system for a small scale reverse vending machine to sort waste beverage containers, TELKOMNIKA (Telecommunication Computing Electronics and Control), 18 (4), 2087–2094.
133. http://telkomnika.uad.ac.id/index.php/TELKOMNIKA/article/view/14776
134. https://www.sciencedirect.com/science/article/abs/pii/S0959652619347006
135. Lynda Andeobu, Santoso Wibowo, and Srimannarayana Grandhi (2022): Artificial
136. Intelligence applications for sustainable solid waste management practices in Australia: A systematic review, Science of the Total Environment, 834, 155389.
137. https://www.sciencedirect.com/science/article/abs/pii/S0048969722024822
138. Aurora del Carmen Mungua-López, Victor M. Zavala, José Ezequiel Santibaez-Aguilar, and José Mara Ponce-Ortega (2020): Optimization of municipal solid waste management using a coordinated framework, Waste Management 115, 15–24.
139. https://pubmed.ncbi.nlm.nih.gov/32721856/
140. Malek Kamal Hussien Rabaia, Concetta Semeraro, and Abdul-Ghani Olabi (2023): Modeling photovoltaics' waste projection and waste management optimization, Journal of Cleaner Production, 388, 135947.
141. https://www.sciencedirect.com/science/article/abs/pii/S0959652622034394
142. Joni Welman Simatupang (2022), Reverse Vending Machine Using TCRT5000 and Inductive Proximity Sensors for Bottles and Cans Sorting, 2022 International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET), 28–33.
143. http://repository.president.ac.id/bitstream/handle/123456789/11131/2.a.%20Reverse_Vending_Machine_Using_TCRT5000%20%282022%29.pdf?sequence=1&isAllowed=y
144. An-nur balqis binti hairullidzam, nur syakila binti nazeri, kee jun yong (2022) smart trash system politeknik sultan salahuddin abdul aziz shah
145. http://repository.psa.edu.my/handle/123456789/3539
146. Kamarudin, Nurisha Hania and Rahim, A'zraa Affizan Ab and Abdullah, Noor Ezan and
147. Halim, Ili Shairah Abdul and Hassan, Siti Lailatul Mohd (2019) Development of Automatic Waste Segregator with Monitoring System, Yogyakarta, Indonesia, pp. 190-195
148. https://ieeexplore.ieee.org/abstract/document/9003813/authors#authors
149. https://www.sciencedirect.com/science/article/pii/S0956053X20305432
150. Lesley Ann Atilano-Tang and Harriette Montefalcon. (2023): Optimization of Sustainable E-Waste Management Strategies in the Philippine Coconut Authority 7(3), 54-62.
151. https://ideas.repec.org/p/osf/osfxxx/dnvk2.html
152. Navid Akbarpour, Amirhossein Salehi-Amiri, Mostafa Hajiaghaei-Keshteli, and Diego Oliva. (2021): An innovative waste management system in a smart city under stochastic optimization using vehicle routing problems. Soft Computing 25, 6707–6727.
153. https://www.scinapse.io/papers/3135029437
154. Michael S. Ang, Jensen Duyag, Kimberly C. Tee, and Charlle L. Sy. (2020): An optimization model integrating multiple input configurations, reuse, and disposal options for a wastewater treatment facility. Journal of Cleaner Production, 231, 1437–1449.
155. https://animorepository.dlsu.edu.ph/faculty_research/1141/
156. Alec Christian M. Cervantes, Ace Vann Cardiff T. Aleria, Christian Carlo B. Taer, and Cresencio Jr. P. Genobiagon. (2021) Development of Small-Scale PETE Plastic Bottle Shredder with Electronic Sensor Controls for Cap Separation: Basis for Reverse Vending Machine, International Conference on Mechanical Engineering Research, 253-264.
157. https://www.scilit.net/publications/12c0e8f59b6f3317756d9027a7dfbc4f
158. Alexa Louisse Espineli, Annfernie Giron, and Yeddah Mariz Gloriani. (2020) Project LOWKEY (Litter Obviation: Waste Keeper and Eco-Rewards Yielder) Ascendens Asia Journal of Multidisciplinary Research Abstracts 3 (5).
159. https://ojs.aaresearchindex.com/index.php/AAJMRA/article/view/2930
160. Hellen Wanini Mwangi, Mpai Mokoena. (2020). Using deep learning to detect polyethylene terephthalate (PET) bottle status for recycling, Glob J Comput Sci Technol 19, 27–31.
161. https://computerresearch.org/index.php/computer/article/view/1890
162. Challiz D. Omorog, Keith Marlon S. Tabal, and Alec Angelo N. Broqueza. (2020) e-Condi: Electronic Condiment Dispensing Machine in Public Markets, 2020, Fourth World Conference on Smart Trends in Systems, Security, and Sustainability (WorldS4), 693 698. https://www.researchgate.net/publication/347155954_eCondi_Electronic_Condiment_Dispensing_Machine_in_Public_Markets
163. Melrose Lopez, Bruce C. Sevilla, Yvonne D. Simborio, and Rolieven P. Caizares. (2021).
164. Reverse Vending Machine with Power Output for Mobile Devices using a Vision-Based System 2021 IEEE 13th International Conference on Humanoid, Nanotechnology,Information Technology, Communication and Control, Environment, and Management (HNICEM), 1-6. https://www.researchgate.net/publication/359276716_Reverse_Vending_Machine_with_Power_Output_for_Mobile_Devices_using_Vision_-_Based_System
165. Oksana Horodytska, Andrea Cabanes, and Andrés Fullana. (2021) Plastic waste
166. management: current status and weaknesses, Plastics in the Aquatic Environment, Part I: Current Status and Challenges, 289–306. https://www.semanticscholar.org/paper/Plastic-Waste-Management%3A-Current-Status-and-Horodytska-Cabanes/e0f115cb4a2f827590076b36e1912d5532284ab0

167. Chor Gene Cheah, Wen Yi Chia, Shuet Fen Lai, Kit Wayne Chew, Shir Reen Chia, and Pau Loke Show. (2022) Innovation designs for industry 4.0-based solid waste management: machinery and digital circular economy Environmental Research 213, 113619. https://pubmed.ncbi.nlm.nih.gov/35700763/
168. N. A. G. Macasaet, E. R. R. Martinez and E. M. Vergara, "Automatic Segregation of Limited
169. Wastes through Tiny YOLOv3 Algorithm," (*2022) 13th International Conference on Computing Communication and Networking Technologies (ICCCNT)*, Kharagpur, India, 2022, pp. 1-6 https://ieeexplore.ieee.org/abstract/document/9984545

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