PAMANTASAN NG LUNGSOD NG MAYNILA
UNIVERSITY OF THE CITY OF MANILA

Drop&Treat: A Reverse Vending Machine using Raspberry Pi and Image Processing

A Project Presented to the
Faculty of College of Engineering
Pamantasan ng Lungsod ng Maynila

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Chapter I

INTRODUCTION

1.1 Background of the Study

The present world is now facing the challenge of proper management and resource recovery of the enormous amount of plastic waste. Lack of technical skills for managing hazardous waste, insufficient infrastructure development for recycling and recovery, and above all, lack of awareness of the rules and regulations are the key factors behind this massive pile of plastic waste *(Kibria et al., 2023).* Plastic bottle waste is a material that pollutes the environment if it is not recycled, thousands of tons of plastic bottle waste is produced from beverage product waste, especially mineral water. *(Munib & Pitana, 2022).* According to *Vasquez (2023),* plastic pollution is one of the most significant environmental challenges of our time. More than 430 million tons of plastic are produced each year, two-thirds of which is cast aside as waste after just one use *(The Plastic Waste Problem Explained, 2021).*

The Project Drop&Treat is a Reverse Vending Machine. It is a machine where people can return empty beverage containers like bottles and cans for recycling. The machine often gives back a deposit or refund amount to the end user.

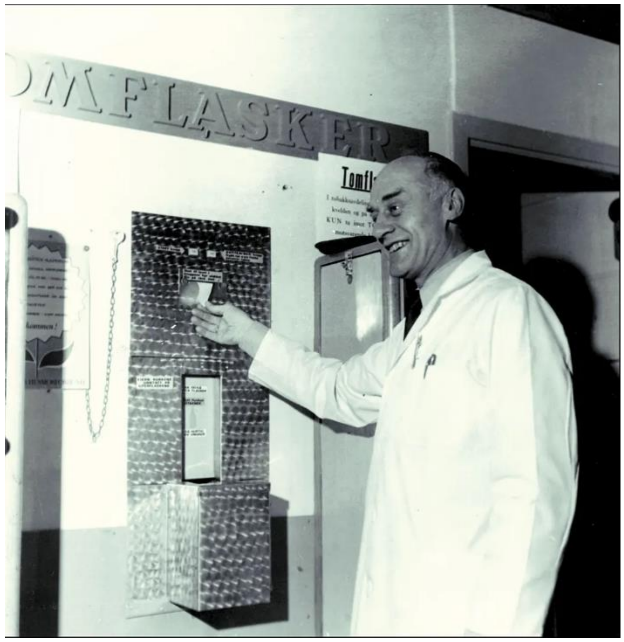

Figure. 1. The first TOMRA RVM prototype installed in a Norwegian grocery store

As shown in Figure 1 is the first fully-automated reverse vending machine that was created by TOMRA in 1972. The name of reverse vending machines is sometimes shortened to RVMs. They are also known as redeem machines, recycling returns machines, or can and bottle recycling machines. Asa (2017)

Figure 2. How Does a Reverse Vending Machine Works

As you insert your containers, the reverse vending machine will scan the containers' barcodes, materials or shapes, to identify the type of packaging and give the correct deposit refund. The machine will then sort the containers into different types. Depending on the containers in your region, refillable containers are moved to one storage area in the machine, while containers that can't be refilled are crushed and stored in different bins.

The students of Pamantasan ng Lungsod ng Maynila develop a Reverse Vending Machine using Raspberry Pi and Image Processing for the Barangay 800 zone 87 San Andres, Manila to reduce the plastic waste problem the world is encountering today. The researchers chose Elementary Student as beneficiaries because of the potential positive impact of this project to the youth. According to *Acharya (2013),* Young people can play an active role in protecting and improving the environment. They can change their lifestyle and how it affects the environment where can make homes, schools and youth organizations more environmentally friendly by adopting environmentally friendly practices, recycling of different materials. Engaging youth in environmental protection not only creates a direct impact on changing youth behaviors and attitudes, but possibly influences their parents, relatives and families.

1.2 Statement of the Problem

The community of Barangay 800 Zone 87 faces a concerning challenge regarding the management of plastic waste. Despite efforts to promote recycling, a substantial amount of the plastic bottles remains uncollected, contributing to environmental degradation. This accumulation of plastic waste poses a significant problem for the community's cleanliness and sustainability initiatives. Consequently, there is a pressing need to devise innovative solutions that incentivize and facilitate the proper disposal of plastic bottles while simultaneously offering practical benefits to residents. The proposed Reverse Vending Machine utilizing Raspberry Pi and Image Processing technology aims to address this issue by encouraging residents to exchange their plastic bottles for essential items like toothpaste, shampoo, and more.

1.3 Objectives of the Study

a. General Objective

This study aims to develop a Reverse Vending Machine that actively promotes plastic waste reduction and instills eco-consciousness. This innovative machine, utilizing image processing technology, will assess and classify plastic bottles based on their size. It will exchange plastic bottles for rewards, such as facemask, shampoo, sanitary napkins, etc., with the primary objective of encouraging environmentally responsible behavior among residents of Barangay 800. The project's core goal is to provide a practical and tangible solution for reducing plastic waste, while simultaneously offering an incentive for responsible waste disposal.

b. Specific Objectives

- To develop an Image Processing Module that design and implement an image processing module capable of classifying and sorting plastic bottles based on their size. The module will utilize image recognition and processing techniques to accurately differentiate bottles.
- To design an Automatic Dispensing Module that creates an automatic dispensing mechanism that efficiently returns the appropriate incentives or rewards to residents once their plastic bottles have been accurately identified and sorted.

- To develop a Comprehensive Software Application that develops a user-friendly software application that records data, generates reports on machine's activity, and provides real-time notifications regarding the status of plastic bottle storage and goods stock in the machine.

1.4 Significance of the Study

This study will be a significant endeavor focused on a Reverse Vending machine Using Raspberry Pi Image Processing, where it is a vending machine that dispenses hygiene materials when a plastic bottle is deposited, intended for implementation at Barangay 800 Zone 87 San Andres, Manila, is multifaceted. This project aims to instill a sense of environmental responsibility and sustainability among community. By providing an incentive for proper disposing of plastic bottles in the form of a hygiene materials reward, it promotes eco-friendly behavior. According to Lafferty, C. (2021) There are so many great resources, books, and tools to get excited, educated, and aware of why recycling and sustainability is so important these days. This not only contributes to a cleaner and greener community environment but also imparts valuable lessons about proper disposing and conservation that the residents in barangay can carry with them throughout their lives. The Residents in barangay 800 will learn useful technological skills from our vending machine that they cannot learn from traditional academic resources like books. It acquires this knowledge through learning activities in the real-life environment, hands-on and real-time experience. (Roller, L. n.d). Also, the project serves as a practical and engaging way to introduce Residents in barangay 800 to emerging technologies, building an interest in related fields. Recycling by community nowadays will provide them more motivation to continue this "habit" (Athena, B. 2012). Furthermore, the project has the potential to reduce litter and promote the proper disposal of plastic bottles, which can help address the plastic waste problem faced by many urban areas, including San Andres, Manila. Specifically, this project will benefit the following:

- **Residents at Barangay 800 zone 87.** The residents at barangay 800 are the project's main beneficiary, and they expect to gain significantly from it in several aspects. The project provides a practical educational opportunity that promotes responsibility for the environment. Residents will gain significant knowledge about resourcefulness, proper disposing, and the effect of their decisions on the environment through the usage of disposing of plastic bottles. Additionally, this project offers to the residents of barangay 800 an engaging and enjoyable way to connect with eco-consciousness, boosting their understanding of sustainability. The hygiene material dispenser, which gives hygiene material such as Shampoo, Wipes, Tissue, or Facemasks in exchange for plastic bottles, is not just a fun machine; it's a hands-on learning experience. It helps the barangay, specifically the residents become responsible citizens who appreciate the importance of proper disposing of used plastic bottles and promoting creativity and environmental awareness.
- **Barangay Community.** Every member of the Barangay community—residents, employees, and families—stands to gain greatly from this project. It raises the level of community involvement in sustainability by offering an interactive, modern platform for encouraging environmentally responsible behaviors. The appropriate disposal of plastic

bottle waste by community members can lead to a decrease in stress for maintenance and support workers, improving the barrio environment and making it cleaner and more sustainable. Additionally, by encouraging parents and guardians to adopt eco-friendly practices and take a more active role in their children's development, this project helps to create a barangay community that is engaged, well-rounded, and ecologically conscious.

- **Future Researchers.** This project is a great help and example of how to investigate the complex relationships between technology, education, and sustainability in the particular setting of Barangay 800, Zone 87. It is a clear example of how new technologies might improve citizens' comprehension of environmental challenges. The study's results and insights might serve as a strong basis for further research projects that delve further into modern teaching strategies and eco-friendly behavior. The study might result in the development of more effective methods for encouraging sustainability in the barangay. This initiative aims to inspire and enlighten future scholars in the fields of environmental science, technology, and education by offering a tangible and relevant case study for continuous research and development.

1.5 Scope and Limitation

This study centers on the pervasive issue of plastic waste encountered in daily life. As reported by the World Wildlife Fund (2019), over 8 million metric tons of plastic find their way into the oceans annually, presenting a substantial threat to marine ecosystems. The growing accumulation of plastic waste poses a significant challenge to the environment. To address this challenge, the project aims to develop a reverse vending machine to operate within the Barangay 800 zone 87 San Andres, Manila. The core purpose of the reverse vending machine is to revolutionize the way plastic waste is handled. Instead of using traditional coins for vending, Community will have the opportunity to exchange plastic bottles for items, with equal offers being contingent on the quantity of the plastic bottle deposited. This innovative solution is specifically designed to address plastic bottle waste and raise awareness about responsible waste management and recycling practices within the Barangay. In addition, the project will incorporate a notification application for the Barangay official to monitor the status of the machine and a weekly reporting system to track the quantity of plastic bottles collected and items dispensed, facilitating data-driven adjustments and optimization while maintaining a localized focus.

It is crucial to acknowledge the limitations inherent in this endeavor. Firstly, the project exclusively targets plastic bottle waste, excluding other types of containers such as coke in cans and glass bottles. Consequently, the scope is confined to addressing one specific facet of the broader plastic waste issue. Moreover, the plastic bottles to be input into the reverse vending machine are sourced and facilitated by the Barangay 800 zone 87 San Andres, Manila administration, which further limits the variety and quantity of plastic waste being addressed. Secondly, the project's reach is localized, focusing solely on the small community. This limited scope restricts the generalizability of the project's findings to a broader context. Lastly, while the endeavor strives to promote responsible waste management, it does not encompass the comprehensive complexities of global plastic pollution issues and their intricate recycling processes, as its primary emphasis remains the technical attributes of the vending machine and its localized impact.

CHAPTER II

CONCEPTUAL FRAMEWORK

A.Review of Related Literature and Studies

1. Plastic Waste

The study conducted by the World Bank Organization in 2021 delves into the critical issue of plastic pollution within the Philippines, offering insights into the severe environmental challenges stemming from improper disposal of plastic waste. Waste, primarily referring to plastic waste in this context, presents a multifaceted challenge with far-reaching consequences. According to Dela Cruz (2021) waste is an inevitable byproduct of human activities encompassing manufacturing, consumption, and daily life, manifested in various forms, including plastic products and packaging. The report underscores that the mismanagement of this waste poses substantial environmental threats. The study brings to the forefront the staggering volume of plastic waste generated annually in the Philippines, a daunting 2.7 million tons. This magnitude starkly underscores the gravity of the issue. Notably, the longevity of plastic waste in the environment, taking hundreds of years to degrade, intensifies concerns. A pivotal issue highlighted in the report is the disconcerting revelation that 20 percent of the plastic waste in the Philippines ultimately finds its way into the ocean. This equates to approximately 540,000 tons of mismanaged plastic waste infiltrating the marine ecosystem. The consequences of such oceanic plastic waste are profound, causing harm to marine life, ecological disruption, and contributing to broader global predicaments, including climate change.

The Philippines had the largest share of global plastic waste discarded in the ocean in 2019. The country was responsible for 36.38% of global oceanic plastic waste, far more than the second-largest plastic polluter, India, which in the same year accounted for about 12.92% of the total. Contrary to popular belief, most plastic waste does not enter the sea directly. Conversely, it makes its way to the sea from smaller water streams. According to Meijer (2021), 80% of plastic waste comes from rivers and seven of the top ten plastic-polluted rivers in the world are in the Philippines. The Pasig River even dethroned the previously most polluted river in 2017, the Yangtze River of China.

As stated by Ramos (2023) the Philippines has a peculiar culture of consuming products in small quantities. For example, instead of buying a regular bottle of shampoo, many people opt for sachets sold at local stores at a much lower price. With a reported 20 million people living below the poverty line in 2021, the country's widespread poverty leaves citizens hunting for the cheapest alternative. Large corporations exploit this situation by offering palm-sized packages of products and building a "sachet economy", further exacerbating plastic pollution in the country. Nonetheless, it is said that there is no other material that offers safer and quicker transportation of food like plastic does.

Instead of merely focusing on reducing plastic use, governments should also consider increasing the accessibility to proper disposal facilities. Indeed, the head of Philippine Alliance for Recycling and Materials Sustainability Crispian Lao states that 70% of Filipinos lack access to disposal facilities, which steers plastic waste directly to oceans. With minimal exposure to environmentally-friendly options for plastic disposal, the population often lacks awareness of plastic pollution. This highlights another problem, the lack of government action.

Among the reasons behind plastic pollution being such a big issue in the Philippines is government mismanagement. More specifically, the government is criticized for merely having good laws surrounding waste disposal but often failing to properly enforce them. In 2001, the government established the Waste Management Act to tackle the nation's growing solid waste problem through methods such as prohibition of open dumps for solid waste and by adopting systematic waste segregation. Two decades later, the Commission on Audit stated that there has still been a "steady" increase in waste generation.

2. The Impact of Environmental Education on the Socioeconomic of Plastic Pollution

Vicente-Molina et al. (2018) observed a positive correlation between individual environmental knowledge and environmental behavior among university students, suggesting that a 1% increase in environmental knowledge leads to a 0.4% increase in pro-environmental behavior. This underscores the significance of educational interventions in fostering environmentally responsible actions. Gifford and Nilsson (2018) found that individuals with higher levels of education exhibit greater concern for environmental issues, reinforcing the notion that education positively influences environmental awareness and concern. This relationship is pivotal in the context of plastic pollution, where increased awareness can drive behavior change. Soares et al. (2021) established a direct connection between a higher level of education and increased environmental awareness and pro-environmental behavior regarding plastic issues, emphasizing the role of education in shaping individuals' responses to plastic pollution. Nature-based environmental education in primary and secondary schools is particularly promising in mitigating plastic pollution among young people, as indicated by studies like Hammami et al. (2019), Mandrikas et al. (2021), and Soares et al. (2021). Programs such as Plastic Free Schools aim to reduce plastic pollution in educational settings through a combination of environmental education, awareness campaigns, and curriculum innovation, encouraging responsible behavior among students. Environmental education extends beyond schools to encompass public guidance on consumption behavior, reuse, and recycling. These efforts play a crucial role in reducing plastic waste at both pre-consumption and post-consumption stages. Strategies promoting the reduction and replacement of disposable products in daily life can swiftly and effectively tackle plastic pollution at the usage stage, as suggested by Borrelle et al. (2020) and Lau et al. (2020). Additionally, post-consumption initiatives related to plastic waste management, such as disposal, collection, and recycling, demonstrate the potential to reduce microplastic pollution significantly.

3. Vending Machine Technology

The demand for automated machines has seen significant growth in recent years, as they not only simplify tasks but also enhance efficiency (Kumar, 2020). These machines often require minimal human intervention and feature multiple inputs and outputs to cater to customer needs (Raagu, 2018). Mechatronics, a collective field combining electronics, mechanical engineering, and electrical engineering, underpins the operation of these automatic machines.

Supermarkets have become increasingly crowded, causing inconvenience to customers and income loss for vendors (Sibanda, 2020). Customers often touch products, like vegetables, to assess their quality, raising concerns about the transmission of infectious diseases. The declining hygiene and quality of products necessitate additional manual labor to maintain standards. This leads to increased labor costs and security issues, especially with cash transactions. To address these challenges, the design of vending machines has emerged as an ideal solution (Sibanda, 2020). Vending machines, as highlighted by Soni (2020), can be categorized as either product-oriented or service-oriented, offering a wide range of items, from snacks and beverages to public transit tickets and jewelry. The benefits of vending machines include reduced labor requirements, flexibility in operation hours, time-saving, cost reduction, and increased profitability.

The COVID-19 pandemic has further driven the adoption of vending machines on a global scale (Pandey, 2019). The vending machine market was estimated at US$134.4 billion in 2020, and this figure is projected to reach US$146.6 billion by 2027. However, vending machine owners are currently grappling with challenges such as hacking and vandalism, driven by changing customer preferences. Customers increasingly favor unmanned retail models and cashless payment methods. Lack of innovation and inefficient machine operation can also impact profitability.

To address these challenges, the development of touch-less, IoT-based, voice-recognized, and face-recognized vending machines has gained prominence. IoT applications are crucial for monitoring environmental conditions, identifying issues, and resolving them without human intervention (Wiyanti, 2019). However, these applications come with security concerns related to data sharing and privacy. Therefore, implementing robust security techniques is essential to safeguard confidential and important information and protect devices from internet security threats.

In recent times, vending machine developers have integrated machine learning and artificial intelligence technologies. This integration enables real-time data collection, enhances sales, improves operational efficiency, and meets customer desires by identifying their preferences (Sibanda, 2020). These developments hold promise for the future of vending machines and offer innovative solutions to evolving market demands.

3.1 History and Evolution of Vending Machine

According to Bellis (2019) the vending machine, known as automatic retailing, has a rich history that dates back to antiquity. Greek mathematician Hero of Alexandria is credited with inventing one of the earliest known vending machines, a device that dispensed holy water within Egyptian temples

- **Early Coin-Operated Machines:** In the early 1880s, commercial coin-operated vending machines made their debut in London, England, primarily at railway stations and post offices. These machines provided a convenient way to purchase envelopes, postcards, and notepaper. Additionally, the Sweetmeat Automatic Delivery Co. was founded in 1887, marking the beginning of vending machine servicing.

- **The American Expansion:** Vending machines reached the United States in the late 19th century when the Thomas Adams Gum Co. introduced machines that sold Tutti-Fruiti gum on New York's elevated subway platforms in 1888. The Pulver Manufacturing Co. added illustrated figures to their gum machines in 1897, contributing to the evolution of vending machines.

- **Coin-Operated Restaurants:** The concept of coin-operated restaurants, known as automats, gained popularity in the early 20th century. Notably, Horn & Hardart, a fully coin-operated restaurant, opened in Philadelphia in 1902, lasting until 1962. These automats were known for their affordability and attracted a diverse clientele, including struggling artists and celebrities of the era.

- **Diversification of Products:** Vending machines expanded their product offerings, from cigars and stamps to a variety of items, including beverages and cigarettes. In 1926, William Rowe introduced the cigarette vending machine in the United States, although concerns about underage buyers eventually led to their decline in popularity. In contrast, countries like Germany, Austria, Italy, the Czech Republic, and Japan continued to use cigarette vending machines with age verification mechanisms.

- **Specialty Machines:** Vending machines evolved to dispense an array of specialty products, ranging from fish bait and lottery tickets to books, electronics, hot foods, and even automobiles. Notably, in 2016, Autobahn Motors in Singapore introduced a luxury car vending machine offering Ferraris and Lamborghinis. These developments coincided with the advent of credit card scanners on vending machines, enabling the sale of high-priced items.

- **Japanese Innovations:** Japan emerged as a leader in innovative vending machine applications, offering fresh fruits, vegetables, sake, hot foods, batteries, flowers, clothing, and even sushi. Japan boasts the highest per capita rate of vending machines globally, showcasing their remarkable versatility and integration into daily life.
- **The Future of Vending Machines:** The latest trend in vending machines involves the integration of smart technology, facilitating cashless payments, facial, ocular, or fingerprint recognition, and social media connectivity. Future vending machines are poised to personalize offerings based on consumers' preferences, such as recognizing their previous purchases and suggesting familiar items. Market research anticipates that by 2020, 20% of vending machines will be smart, with over 3.6 million units designed to cater to individuals' unique preferences.

4. Reverse Vending Machine

In accordance with the insights presented in the International Journal of Computer Science Trends and Technology (2020), the Reverse Vending Machine (RVM) has been conceptualized as a strategic initiative to foster recycling behaviors. This approach involves incentivizing depositors with rewards in the form of points for each recycled item, as elucidated in the study. The global acknowledgment of the merits associated with RVM has led to the widespread adoption of these machines by numerous countries. These innovative devices are designed to accommodate a range of materials, including beverage cans, glass bottles, and plastic bottles, contingent on the specific machine type. The overarching goal of the RVM concept is to streamline the collection of recyclable materials, consequently amplifying recycling endeavors on a global scale.

Efficient waste management is recognized as pivotal to the success of recycling initiatives. One particularly effective and incentivized method for waste collection is the utilization of Reverse Vending Machines (RVMs). Noteworthy in this context is the proactive stance taken by the Malaysian government. Commencing on September 2, 2015, a comprehensive campaign has been initiated to encourage waste separation at the household level. The implementation of this initiative would necessitate the adoption of an Act to facilitate the waste separation process, marking a significant step towards a more sustainable waste management approach.

The central objective underlying the deployment of Reverse Vending Machines (RVMs) is the proficient management of waste to bolster recycling efforts and mitigate pollution. In this envisioned RVM model, users actively participate by depositing plastic items into the machine, thus triggering its operational cycle. Looking ahead, the potential integration of Reverse Vending Machines is not limited to specific locales but holds promise for widespread adoption, encompassing subways, railway stations, colleges, public places, and beyond. An interesting facet worth noting is the technological backbone supporting these machines. Many Vending Machines, including Reverse Vending Machines, rely on advanced technologies such as microcontrollers, CMOS, and SED, as discussed by Gaur et al. (2018). This technological underpinning enhances the efficiency and functionality of these machines, contributing to their effectiveness in waste management and recycling endeavors.

5. Raspberry Pi

Functioning as a Single Board Computer (SBC), the Raspberry Pi is self-sufficient, capable of running a complete operating system and starting up without extra hardware. It's known for its versatility, supporting various operating systems with only a power source needed for booting. What sets it apart is its accessibility as commodity hardware, compatibility with high-level programming languages, and the ability to run popular Unix-like operating system variants. This makes the Raspberry Pi an excellent choice for a wide range of applications.

According to Sekyere-Siedu's (2018) research, Raspberry Pi emerges as an accessible, cost-effective, efficient, and impactful solution for the development of automation systems. The study underscores the platform's user-friendly development process and scalability. Notably, Raspberry Pi finds versatile applications, including robot control, temperature monitoring, security camera operations, and cosmic computer functionalities (Edirisinghe, 2018). Across all iterations, Raspberry Pi incorporates budget-friendly yet potent processors, ensuring optimal performance with minimal power consumption. Additionally, its provision of connectors and interfaces facilitates seamless integration with a diverse range of peripheral devices. This versatility positions Raspberry Pi as a compelling choice for the implementation of automation systems, aligning with the demands of contemporary technological landscapes.

5.1. History

In 2006 concluded by Team, D.E (2023), a group of dedicated computer scientists, including Eben Upton, Rob Mullins, Jack Lang, and Alan Mycroft, embarked on a transformative journey at the University of Cambridge's computer laboratory. Their collective mission was crystal clear: to equip new students with a profound understanding of computing's technical intricacies. They were deeply concerned about the trend in computer science education, which was gradually shifting towards the superficial use of computers, rather than delving into the inner workings of these machines. Initially, their focus was on university-level students, but soon, their vision expanded to encompass school-age children.

Fueled by their unwavering commitment to democratize computing knowledge, they laid the foundation for what would become the Raspberry Pi project. Over six years of relentless effort, they toiled to create an affordable and accessible device, designed specifically for educational purposes in schools, with a primary goal of teaching programming and demystifying the inner workings of computers. Their aspiration was clear: to develop a tool that could help students truly grasp the essence of computing.

Reflecting on the project, Eben Upton remarked, "Given how far we've come, it's sort of funny to remember how parochial our ambitions were at the start." Their journey began with a recognition of the alarming decline in computer science applicants. It was their belief that by providing young minds with the right hardware and educational tools at a critical stage in their lives, they could potentially reverse this trend.

In February 2012, the Raspberry Pi Foundation made its first groundbreaking release. Over the years, the board has undergone numerous revisions and refinements, evolving into two distinct models, Model A and Model B, spanning multiple generations. This journey, guided by a passionate team of visionaries, has left an indelible mark on the world of education and computing, ensuring that the principles of computer science are accessible to all.

This timeline showcases the remarkable evolution and growth of the Raspberry Pi platform:

- 2006: Early development work on the Raspberry Pi project initiated by Eben Upton, Rob Mullins, Jack Lang, and Alan Mycroft at Cambridge University.

- February 2012: The first commercial release of the Raspberry Pi, marking a significant milestone.
- September 2012: Manufacturing of Raspberry Pi units relocated to the UK, with Sony's facility in Wales taking charge.
- July 2014: Introduction of the Raspberry Pi Model B+, enhancing the capabilities of the platform.
- November 2014: Announcement of the Raspberry Pi Model A+, a compact and affordable variant.
- February 2015: Introduction of the Raspberry Pi 2, bringing improved performance and features.
- November 2015: Launch of the Raspberry Pi Zero, the smallest and most budget-friendly version to date.
- February 2016: Unveiling of the Raspberry Pi 3, featuring enhanced hardware and capabilities.
- April 2016: Introduction of the Raspberry Pi Camera v2.1, expanding the platform's imaging capabilities.
- March 2018: Introduction of the Raspberry Pi 3 Model B+, featuring upgraded hardware and connectivity options.
- November 2018: Launch of the Raspberry Pi 3 Model A+, offering a more compact alternative.
- June 2019: Release of the Raspberry Pi 4 Model B, a powerful and versatile iteration.

- May 2020: Announcement of an 8GB version of the Raspberry Pi 4, providing increased memory capacity.
- October 2020: Introduction of the Compute Module 4, designed for industrial and commercial applications.
- November 2020: Launch of the Raspberry Pi 400, an all-in-one keyboard-computer solution.
- January 2021: Introduction of the Raspberry Pi Pico, a microcontroller board.
- October 2021: Release of an updated version of Raspberry Pi OS (formerly Raspbian), the official operating system.
- February 2022: A decade after its first shipment, it was reported that 46 million Raspberry Pi units had been sold, highlighting its widespread popularity and impact.

6. Image Processing

According to Britannica (2023), image processing involves a collection of computational techniques for analyzing, enhancing, compressing, and reconstructing images. Its primary phases encompass importing, where an image is acquired through scanning or digital photography. This process, essential in computer vision, includes tasks like image recognition and object detection. Typically treating images as two-dimensional signals, an Image Processing system applies established signal processing methods. Beyond its technical applications, image processing significantly influences various industries such as manufacturing, healthcare, and retail. For instance, it plays a crucial role in quality control in manufacturing, aids in medical imaging diagnostics in healthcare, and contributes to tasks like inventory management and customer analytics in the retail sector.

6.1 Label Image

In computer vision, data labeling involves adding tags to raw data such as images and videos. Each tag represents an object class associated with the data. Supervised machine learning models employ labels when learning to identify a specific object class in unclassified data. It helps these models associate meaning to data, which can help train a model. Image annotation is used to create datasets for computer vision models, which are split into training sets, used to initially train the model, and test/validation sets used to evaluate model performance. Data scientists use the dataset to train and evaluate their model, and then the model can automatically assign labels to unseen, unlabelled data. (*Image Labeling in Computer Vision: A Practical Guide*, 2023b) .

According to Boesch (2022), If one is seeking a straightforward, user-friendly, and lightweight image annotation software for tasks such as object detection and classification, LabelImg would be a suitable tool to consider. It proves particularly beneficial for student projects and small-scale prototypes due to its easy installation and operation on a local PC. (Boesch, 2022).

7. Sensor

As stated in Techslang (2022), A sensor is an electronic device that measures and monitors environmental conditions. The data recorded by these devices is usually collected by a computer, which then uses the information to act. Sensors measure physical qualities, such as speed, and built into many devices that you use regularly there are several types of sensors:

- **Active sensors** Also called "parametric sensors" require an external power source to operate. Examples include Global Positioning System (GPS) and radar sensors.
- **Passive sensors** Also known as "self-generated sensors," these generate their own electric signal and do not require an external power source. Examples include thermal and electric field sensors and metal detectors.
- **Contact sensors** Require physical contact with their stimulus. Examples include temperature and strain gauge sensors.
- **Noncontact sensors** Don't require physical contact, which include optical and magnetic sensors and infrared thermometers.
- **Absolute sensors** Got their name by providing absolute readings of their stimuli. An example would be a thermistor that always measures the exact or absolute temperature reading.
- **Relative sensors** Provide fixed or variable measurements, such as a thermocouple, which measures temperature differences, not the actual temperature.
- **Analog sensors** Produce continuous analog output signals that are proportional to measurements. Examples include accelerometers, pressure sensors, and light and sound sensors.

- **Digital sensors** Also go by "electronic or electrochemical sensors," these convert data transmission digitally. Examples include digital accelerometers and pressure and temperature sensors.
- **Miscellaneous sensors** All other sensors that don't fall under any of the categories belong here. These include electric, biological, chemical, radioactive, and other sensors.

7.1 Infrared Sensor

An infrared (IR) sensor is defined as an electronic device designed to detect and measure infrared radiation in its immediate environment, as stated in the YoungWonks (2021). To clarify, infrared radiation, sometimes known as infrared light, is defined as an electromagnetic radiation type that has wavelengths that are longer than visible light. It extends beyond the theoretical red edge of the visible spectrum, covering a range of wavelengths from around 1 millimeter to roughly 700 nanometers. According to scientific description, this type of radiation is invisible to the human eye, yet it leaves a palpable warm skin impression (YoungWonks, 2021).

7.2 Infrared Proximity Sensor

Proximity Sensor includes all sensors that perform non-contact detection in comparison to sensors, such as limit switches, that detect objects by physically contacting them. Proximity Sensors convert information on the movement or presence of an object into an electrical signal. Devices such as limit switches detect an object by contacting it, but Proximity Sensors can detect the presence of the object electrically, without having to touch it. Detection takes place with almost no effect from dirt, oil, or water on the object being detected. Models with fluororesin cases are also available for excellent chemical resistance (Overview of Proximity Sensors | OMRON Industrial Automation, n.d.-b).

7.3 Capacitive Sensor

According to Pepperl+Fuchs (2021), A capacitive sensor is a good choice when you need to detect objects made of materials like plastic, mineral, glass, wood, or paper. It's also effective for detecting liquids that are oily or aqueous, as well as granular or powdery substances. This type of sensor can identify both metallic and non-metallic objects, offering flexibility in various applications. The detection distance can be adjusted based on factors like the size and properties of the target object, the sensor's size, and how it's installed, ranging from 1 mm to 50 mm (Pepperl+Fuchs, 2021).

Capacitive proximity sensors use the variation of capacitance between the sensor and the object being detected. When the object is at a preset distance from the sensitive side of the sensor, an electronic circuit inside the sensor begins to oscillate. The threshold circuit then recognizes the rise or fall in this oscillation, activating an amplifier connected to an external load. By adjusting a screw on the back of the sensor, the operating distance can be regulated. This sensitivity control proves beneficial in various applications, such as distinguishing between full and empty containers during detection processes (*Capacitive Sensors*, n.d.).

8. School Community

Addressing plastic bottle waste management is important in the school environment to promote sustainability and instill eco-conscious practices. Schools are important places that influence future behavior, therefore they are essential for effectively addressing plastic bottle waste. To create a greener campus and raise a generation of students dedicated to responsible waste management, it is essential to put in place efficient disposal systems, support recycling programs, and educate students about the environmental effects of plastic bottles. This strategy fits well with the goals of global sustainability and strengthens the overall effort to address environmental issues.

> As per Kusumaningrum (2018), Environmental literacy is a conscious attitude to protect the environment. This literacy is not only being knowledgeable about the environment but also being responsive and able to provide solutions to environmental issues. Students as part of society are prepared as the next generation and agents of change in society need to be equipped with environmental literacy skills. In the UK, educational institutions, including schools, colleges, and universities, are obligated by law to establish and maintain an effective waste management system focused on minimizing, repurposing, and recycling waste. These entities serve as significant influencers for children nationwide, serving as crucial role models in molding waste habits for the younger generation. (*The Benefits of Waste Management in Schools*, 2022)

According to Rudiyanto, et. al (2021) The formation of individual behavior in managing waste properly needs to be instilled from an early age. The formation of behavior at this age is easier and more visible. The formation of waste management behavior from an early age can be started from the formation of the habit of sorting and placing waste in its place. It is hoped that the habit of sorting and placing garbage in its place from an early age will continue to adulthood, so that it will be able to contribute in creating a clean and healthy environment. This not only contributes to the well-being of both staff and students but also ensures compliance with legal standards. Additionally, it presents the school in a favorable manner to visitors and potential parents. (The Benefits of Waste Management in Schools, 2022).

Synthesis

This chapter provides a comprehensive review of relevant literature and research in the field of reverse vending machines, image processing, and their potential impact on promoting recycling and environmental awareness among elementary students. The synthesis of existing literature will help in understanding the context and the gap this project aims to address.

1. Reverse Vending Machines (RVMs)

Reverse vending machines are automated systems designed to encourage recycling by offering incentives in exchange for recyclable items such as plastic bottles, cans, or other containers. These machines have gained popularity in recent years due to their environmental benefits and the promotion of a circular economy. According to Zia (2022) the reverse vending machine can play a key role in reducing plastic bottle pollution. Along with an accurate bottle classification model, the cost of the RVM is also crucial if it is to be deployed on a mass scale. The machine discussed will also raise public awareness of plastic recycling by rewarding users for every piece of plastic.

2. Environmental Education

Elementary students are a crucial target audience for environmental education and awareness. Research has shown that early exposure to recycling and sustainable practices can have a lasting impact on children's behavior and attitudes toward the environment. Interactive and engaging educational tools, such as reverse vending machines, can play a significant role in fostering eco-consciousness among young learners. As stated by William (2018) that young children have a positive view of the environment and that they are concerned with its well-being. Students should be actively engaged in their education and informed about their role in the natural world. Since children have fewer negative environmental behaviors to unlearn and have a longer time through which their behaviors will impact the environment, they represent a key population for environmental education. In order to more effectively educate children about the environment, it is vital that the barriers to environmental education be identified and understood, so that they might be overcome. According to other findings, it was determined that activities or educational tools were effective in the development of students' skills to empathize with nature Yesilyurt (2020).

3.Educational Impact

Lazas (2020) highlighted that there are several advantages of using reverse vending machines. One benefit is that they help the environment by recycling material and reducing the need for raw materials to make new beverage containers. RVMs also are conveniently placed in public locations such as grocery stores, gas stations, schools, parks, etc., which make them easily accessible for users. They are easy to manage since the machine separates the recyclable materials (plastic, glass, aluminum) rather than having it manually done. Furthermore, RVMs can benefit businesses. Stores with RVMs can offer store-specific incentives (i.e. coupons) so that customers who enjoy recycling through the RVM will come back regularly to recycle and shop. Lastly, since RVMs are incentivized devices, not only is the environment benefitting, but the recycler is as well. The "Drop&Treat" project can contribute to this body of research by evaluating its impact on elementary students' knowledge, attitudes, and behaviors regarding recycling and sustainability.

4. Role of Youth in Environment Protection

The involvement of youth in environmental protection is crucial for fostering a sustainable and eco-conscious society. Young individuals, often characterized by their enthusiasm, passion, and openness to change, possess the potential to drive positive behaviors and attitudes towards the environment. As emphasized in the World Youth Report, the youth of today face the long-term consequences of environmental degradation, making them key stakeholders in shaping a more sustainable future.

One notable aspect of youth engagement in environmental protection is their unique position to leverage information and education. With increased exposure to environmental education in schools and access to information through various channels, young people are well-equipped to understand the intricacies of ecological challenges. This knowledge not only empowers them to make informed decisions but also positions them as advocates for change within their communities.

5. Image Processing

Image processing is a computational field focused on analyzing, enhancing, and reconstructing images, finding applications across diverse industries. In the realm of computer vision, data labeling is essential for training machine learning models, enabling them to recognize and classify objects in unclassified data. Tools like LabelImg play a crucial role in this process, facilitating the training of models for various applications. Moreover, image processing techniques are integral to tasks such as feature extraction, image segmentation, and pattern recognition, providing a foundation for advanced computer vision applications. The accurate labeling of data not only contributes to the training of machine learning models but also enhances the overall precision and reliability of systems that rely on image analysis for decision-making processes.

6. Sensors

As per Techslang (2022), sensors are electronic devices designed to measure and monitor environmental conditions, with the data they capture typically gathered by a computer for subsequent action. There exists a variety of sensor types, each tailored to specific functionalities, reflecting the diverse landscape of sensor technology that permeates various aspects of our routine activities. Sensors are indispensable tools in the realm of environmental monitoring, serving as key instruments for measuring and assessing various environmental conditions. These sensors come in diverse types, each tailored to specific functionalities and detection methods. Active sensors, requiring an external power source, and passive sensors, which generate their own electric signal, offer versatile options for different applications. Contact sensors necessitate physical interaction for detection, while noncontact sensors, such as infrared and proximity sensors, provide the advantage of detecting objects without direct physical contact. The distinction between absolute and relative sensors lies in their ability to provide fixed or variable measurements, catering to different precision requirements. Additionally, the categorization into analog and digital sensors reflects the diverse data output formats, offering flexibility in data acquisition and interpretation. Among these, infrared sensors prove valuable in detecting infrared radiation, while proximity sensors, including capacitive sensors, excel in non-contact detection applications. Their contributions extend across various industries, showcasing the significance of sensor technology in advancing environmental monitoring capabilities.

CONCEPTUAL FRAMEWORK

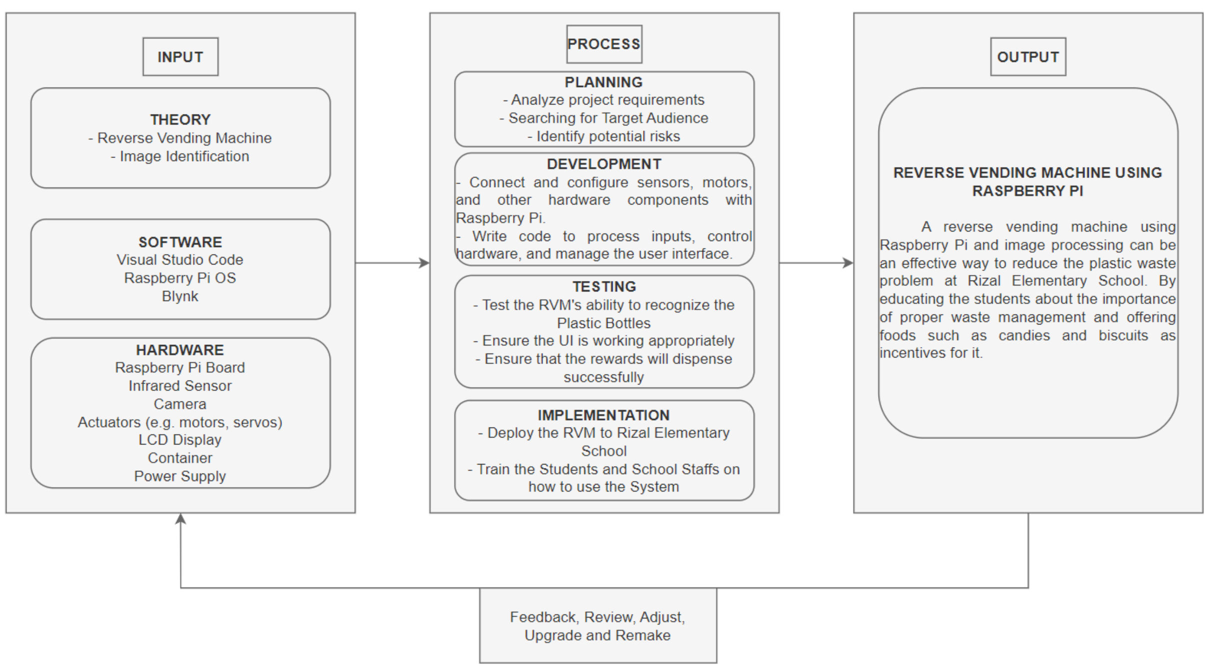

Figure 1. IPO Model Conceptual Framework of RVM

The figure shows the Input, Process, and Output of the Reverse Vendo Machine that dispenses candy when a plastic bottle is deposited, planned to be implemented at Barangay 800 zone 87 San Andres, Manila. The input focuses on theoretical aspects related to a project, specifically involving the concepts of a Reverse Vending Machine and Image Identification, While the software components include Visual Studio Code, Raspberry Pi OS, and Blynk. On the hardware side, the key components consist of a Raspberry Pi board, infrared sensor, camera, various actuators (such as motors and servos), an LCD display, a container, and a power supply. By that Input we can assure that the process will be organized. In the Process it explains how we plan the RVM by analyzing project requirements, searching for target audience which is the place where it will be implemented and identifying the risks. After planning, start the Development of the RVM by connecting and configuring the sensors, motors and other hardware components including the Raspberry Pi then after configuring write the code to process inputs, control hardware, and manage the user interface. Testing has a significant part in the process because this will be the time where the RVM will test the ability to recognize the Plastic Bottles then ensuring the UI is working appropriately and also testing if the rewards will dispense successfully. When the testing process is successful it can be implemented to its preferred location which is at Barangay 800 zone 87 San Andres, Manila. The output will be an effective way to reduce the plastic waste problem within the community. By educating the community within the barangay about the importance of proper waste management and offering foods such as candies and biscuits as incentives for it.

CHAPTER III

METHODOLOGY

A. Research Design

Participatory Action Research (PAR) emerged as a comprehensive and collaborative approach tailored for the implementation of a Reverse Vending Machine to address plastic waste in Barangay 800 zone 87 San Andres, Manila. PAR inherently values community engagement, integrating action and reflection throughout the research process. It fosters inclusive decision-making, actively involving residents, school authorities, and stakeholders in shaping the machine's design, placement, and incentive mechanisms. Through this approach, local insights and needs play a pivotal role in guiding the project's trajectory. The iterative nature of PAR allows for continual feedback collection, facilitating ongoing enhancements to the vending machine's functionality, as well as strategies for community involvement and waste reduction. Additionally, PAR's emphasis on empowerment and capacity building aligns harmoniously with the overarching objective of cultivating enduring practices in sustainable waste management, extending beyond the immediate scope of the vending machine and advocating for broader environmental responsibility within the community.

Figure 1 Agile Model (Harver, 2021)

Utilizing the Agile approach within the System Development Life Cycle (SDLC) streamlined the software and hardware development. This dynamic and progressive model was focused on continuously addressing goals until attaining the desired result (SDLC - Agile Model, n.d.). Employing this methodology allowed for agile responses to shifting project needs, milestones, and process refinements, contributing significantly to enhancing the final project output.

1. Program Flowchart

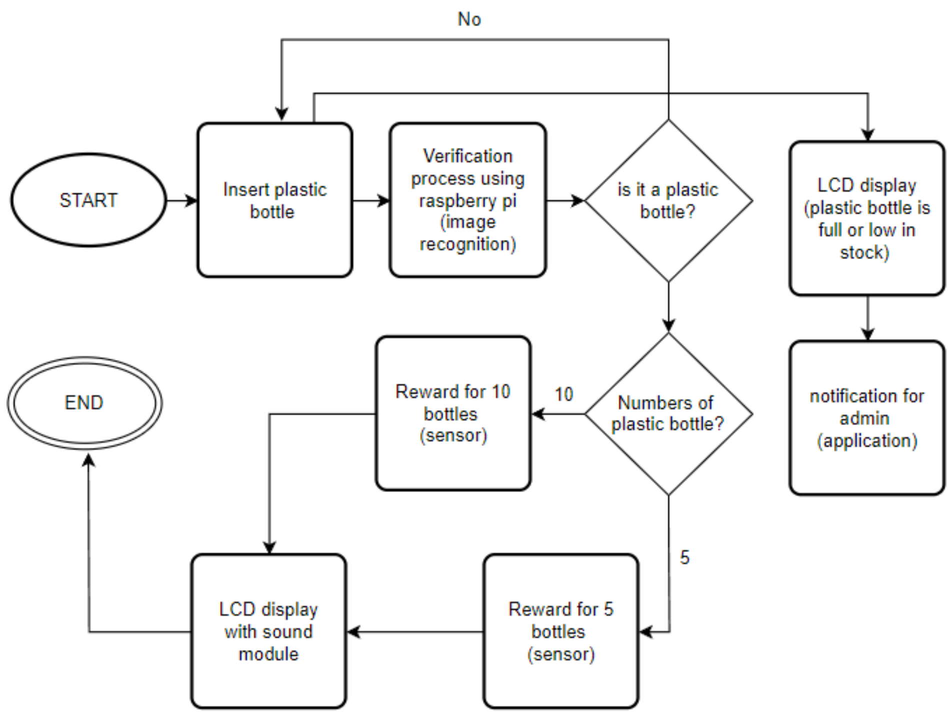

Figure 2. Program flowchart of Drop & Treat

The "Drop & Treat" system initiates when a user inserts a plastic bottle, followed by an image recognition verification process using Raspberry Pi to confirm the item's identity. Upon verification as a plastic bottle, the system tallies the quantity deposited; for instance, if 5 bottles are inserted, the user receives a corresponding reward. Subsequently, a "thank you" message is displayed on the LCD, signaling the completion of the user process. In cases of machine fullness or emptiness, an error prompt alerts the user, while concurrently notifying the admin via the application, ensuring real-time awareness of the RVM's status regarding plastic bottle capacity.

2. Hardware Components

The following were the hardware components needed for the Reverse Vendo Machine.

3.1 Raspberry Pi 4 Model B

Figure 3. Raspberry Pi 4B

The Raspberry Pi 4 Model B is the latest version of the low-cost Raspberry Pi computer. When it launched in 2019, the Raspberry Pi 4 took Pi to another level, with performance that’s good enough to use in a pinch as a desktop PC, plus the ability to output 4K video at 60 Hz or power dual monitors. More recently, the Raspberry Pi 4 (8GB) model came out, offering enough RAM for serious desktop computing, productivity and database hosting (Piltch 2020).

3.2 Capacitive Proximity Sensor

Figure 4. LJC30A3H-Z-A/Y Capacitive Proximity Sensor

There are many types of proximity sensors used in different applications, one of these is capacitive proximity sensor. A capacitive proximity sensor is a sensor that can detect an object using the electrical property, capacitance. They are widely used to detect and measure objects/fluids that have a higher dielectric constant than air. This includes anything that is conductive or non-conductive (OMCH, 2021).

3.3 Seven Segment Display

Figure 5. 7 Segment Display

Seven segment displays are the output display device that provides a way to display information in the form of images or text or decimal numbers which is an alternative to the more complex dot matrix displays. It is widely used in digital clocks, basic calculators, electronic meters, and other electronic devices that display numerical information. It consists of seven segments of light-emitting diodes (LEDs) which are assembled like numerical 8.

3.4 ESP32 Camera

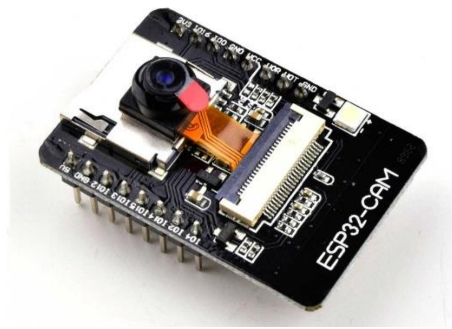

Figure 6. ESP32 Camera

ESP32-CAM is a low-cost ESP32-based development board with onboard camera, small in size. It is an ideal solution for IoT application, prototypes constructions and DIY projects. The board integrates WiFi, traditional Bluetooth and low power BLE , with 2 high performance 32-bit LX6 CPUs. It adopts 7-stage pipeline architecture, on-chip sensor, hall sensor, temperature sensor and so on, and its main frequency adjustment ranges from 80MHz to 240MHz (DroneBot, 2020).

3.5 Infrared Sensor

Figure 7. Infrared Sensor

An infrared sensor (IR sensor) is a radiation-sensitive optoelectronic component with a spectral sensitivity in the infrared wavelength range 780 nm … 50 µm. IR sensors are now widely used in motion detectors, which are used in building services to switch on lamps or in alarm systems to detect unwelcome guests. In a defined angle range, the sensor elements detect the heat radiation (infrared radiation) that changes over time and space due to the movement of people (Jost, 2019).

B. Research Locale

Barangay 800 is a barangay in the city of Manila, under the administrative district of Santa Ana. Its population as determined by the 2020 Census was 1,558. This represented 0.08% of the total population of Manila.

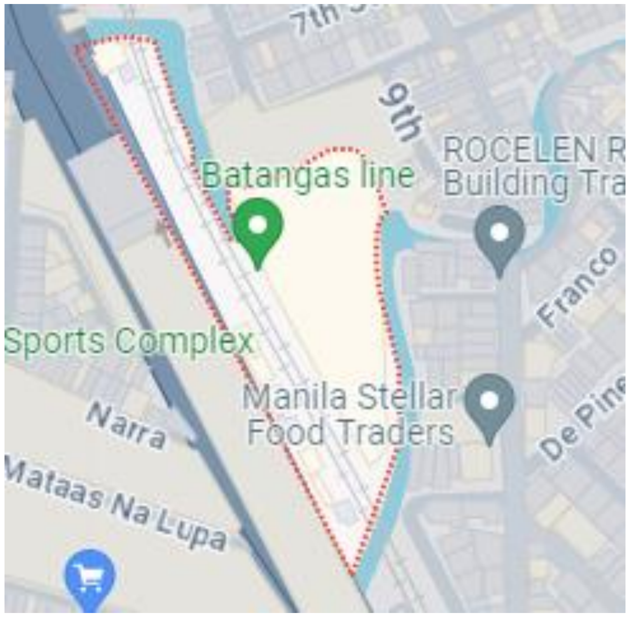

Figure 8. Map of the Barangay 800 San Andres Bukid Manila

Barangay 800 was chosen as the research locale of the study since it met the criteria set by the researchers, such as problems regarding plastic waste management, and allowed the researchers to deploy the proposed prototype in their vicinity.

C. Procedures

1. Development Procedures

The Reverse Vendo Machine is an unique idea made for Barangay 800 Zone 87 San Andres, Manila, that combines Raspberry Pi and image processing technologies. The project design was composed of 4 systems, Bottle Recognition System, Reward Dispensation System, Monitoring system, and Barangays graphical user interface. These systems were assembled to have a working RVM that dispenses hygiene materials when a plastic bottle is deposited.

1.1 Bottle Recognition System

The python programming language was used in Visual Code Studio to create the bottle recognition system. The phases of its development process are outlined below.

1.1.1 Data Acquisition

The Reverse Vendo Machine project's data collecting procedure includes gathering and analyzing information about deposited plastic bottles. The system uses a camera module to gather visual data using a Raspberry Pi and image processing technologies. Using complex algorithms, the bottle identification system analyzes the photos and detects and verifies the existence of plastic bottles instantly. The prize dispensing mechanism is activated by the system upon successful recognition of a bottle, and the necessary data, including the quantity of bottles gathered, is documented for further examination. Users may receive instant feedback via the interactive graphical user interface, which also shows important details regarding incentives and correct usage. This data acquisition approach not only ensures the accurate functioning of the machine but also allows for ongoing monitoring and optimization of the system's performance in promoting responsible waste disposal in Barangay.

1.1.2 Data Processing

OpenCV is a huge open-source library for computer vision, machine learning, and image processing (GeeksforGeeks, 2023), which is an essential part of the Bottle Recognition System in the Reverse Vendo Machine project (Open Source Computer Vision Library). OpenCV is an open-source image and video analysis toolkit that offers a wide range of functions and algorithms. It plays a major role in real-time operation which is very important in today's systems. By using it, one can process images and videos to identify objects (GeeksforGeeks, 2022) The method for processing images includes an assortment of OpenCV functions, including pattern recognition, imagine thresholding, and contour detection. The visual data that the Raspberry Pi camera module has gathered is subjected to these routines. The system can evaluate the photos in real-time because of OpenCV, which allows it to identify plastic bottles from the backdrop and initiate the relevant action, such as turning on the reward's dispensing mechanism.

Through the usage of OpenCV, the project gains access to a comprehensive and well-known computer vision library that provides effective tools for picture processing and analysis. This contributes to the overall effectiveness of the Reverse Vendo Machine in encouraging responsible garbage disposal in Barangay 800 Zone

87 San Andres, Manila, by guaranteeing the correctness and dependability of the data processing phase.

1.1.3 Training of the Bottle Recognition

In training the Bottle Recognition system using SSD MobileNet V2. The MobileNetSSDv2 Model essentially is a 2-part model. The first part consists of the base MobileNetV2 network with a SSD layer that classifies the detected image. In essence, the MobileNet base network acts as a feature extractor for the SSD layer which will then classify the object of interest (*MobileNet SSD V2 Object Detection Model*, n.d.). According to Majdalawieh et al, (2023) Classification accuracy ranged from 93% to 98% for the SSD Mobilenet v2 model. Making it the best model to use in this project.

The first step involved downloading the SSD MobileNet V2 repository by cloning it. Subsequently, the latest version of Python (Python 3.11.4) was installed as the programming language to seamlessly integrate the SSD MobileNet V2 model. TensorFlow, an important component for deep learning tasks, was installed to enable efficient model training and deployment. Additionally, other required dependencies and libraries were installed to support the overall development process. The trained model, configured for bottle recognition, was then seamlessly integrated into the Reverse Vendo Machine project, running on a Raspberry Pi. This comprehensive approach ensures that the system is well-equipped with the necessary tools, libraries, and dependencies for successful training, deployment, and operation in the intended environment of Barangay.

The most important component of the project was the Plastic Bottle Recognition dataset, which was downloaded from TensorFlow and used to train an advanced SSD Mobilenet v2 model. With the use of the "PlasticBot.py" command in the Python terminal, the training procedure produced an SSD Mobilenet v2 model that was proficient at identifying plastic bottles. The "bottle.py" command then made it easier to export the trained model in a more simplified way. Using the capabilities of the Raspberry Pi, this simplified model—which has been optimized for efficiency—is intended to be easily integrated into the project's suggested output. Through the use of innovative technology, the whole procedure guarantees the successful deployment of an effective plastic bottle identification system within the Reverse Vendo Machine, encouraging responsible waste disposal.

1.2 Reward Dispensation System

An essential part of the Reverse Vendo Machine is the incentive dispensing mechanism, which encourages users to dispose of plastic bottles responsibly. After a plastic bottle is successfully identified and deposited, the system does advanced image processing—probably with OpenCV—to verify the bottle's existence. This sets off a servo motor that has been carefully selected for dependability or an appropriate dispensing mechanism. Eco-friendly behavior is incentivized by the offering of a material reward, which provides immediate positive reinforcement. Strong technological integration, such as using Tkinter for the graphical user interface and Python for programming, is essential to connecting bottle detection and dispensing. For those actively participating in the Barangay's responsible disposal of waste, this generates an enjoyable and fulfilling experience.

1.3 Monitoring system

Specifically designed for exclusive administrative access, the mobile monitoring application for the Reverse Vendo Machine (RVM) provides strong safety together with simple functionality. Using the flexible frameworks used which are React Native, a mobile application was created to enable remote monitoring of RVM activities and give administrators access to real-time information. The solution makes use of a strong Flask-implemented backend to provide smooth communication between the RVM and the mobile app. Data integrity is preserved by means of safe database storage, with the use of SQL, ensuring the dependability and privacy of the gathered data. The most notable element of the program is the weekly reports it provides, which offer an in-depth analysis of the number of bottles gathered and awards given out. With the help of these reports' simple to comprehend method, administrators may quickly assess the RVM's effectiveness. This special mobile access not only makes things more convenient, but it also gives administrators the ability to monitor and assess RVM activities more effectively, which greatly helps in the success of waste management programs in the barangay.

1.4 Barangays graphical user interface

Effective communication between local officials and community members is made possible in a significant way by the Graphical User Interface (GUI) system created for the Reverse Vendo Machine (RVM) project in Barangay 800 Zone 87 San Andres, Manila. Constructed with Python and Tkinter, an effective graphical user interface toolkit, this system offers a visually attractive and user-friendly platform that can be accessed on the Raspberry Pi. Real-time data on important RVM duties, such the amount of incentives distributed, the continuous count of bottles collected, and the overall system status, is shown on the GUI. Community members may easily navigate the interface, get detailed information, and learn about the environmental effect of their donations through thoughtfully placed interactive components. The seamless integration of Tkinter with the RVM's backend ensures a cohesive user experience, fostering enhanced engagement and instilling a sense of community responsibility for promoting responsible waste disposal practices in Barangay

2. Testing Procedures

The system went to multiple tests to ensure that it will work correctly in every feature without any errors before its deployment.

2.1 Unit Testing

Using this method, components such as the incentive dispensing mechanism, graphical user interface (GUI), and bottle identification system are separated out for comprehensive evaluation. The main objective is to ensure that every single part functions as intended when it separates from the rest of the system, confirming its accuracy and functioning. Unit testing for the bottle identification system, for instance, would entail determining whether the system correctly recognizes and handles plastic bottles. Similar to that, the system for dispensing incentives would be examined to guarantee its accurate distribution according to predetermined standards, and the graphical user interface would be validated for appropriate presentation and functionality. Unit testing is an essential practice to identify and rectify any issues within specific components before they are integrated into the larger system, ensuring a solid foundation for subsequent testing phases and overall system functionality.

Table 1. Unit Testing Table

Test	Expected Result
Raspberry Pi 4 Model B	• The Raspberry pi 4 Model B will function once it's connected to a power source. • The Programs can be uploaded in raspberry pi 4 Model B without issue and can function properly • The raspberry pi 4 model B is successfully works with the ESP32 Camera
Capacitive Proximity Sensor	• to accurately detect the presence or absence of an object such as the plastic bottle within its sensing range. • Provide output signals corresponding to the proximity status of the detected plastic bottle
Seven Segment Display	• To accurately and clearly display numeric or alphanumeric characters based on the input it receives, when inputting a plastic bottle. • Each segment of the display should illuminate correctly depends on how many plastic bottles are deposited
ESP32 Camera	• The ESP32 Camera is to capture and transmit visual data effectively.

	• The camera integrates seamlessly with the Raspberry Pi, allowing for the transmission and processing of image data.
Infrared Sensor	• The Infrared Sensor is expected to accurately detect infrared radiation or reflections.

2.2 Integration Testing

The Reverse Vendo Machine (RVM) project's testing protocols heavily rely on integration testing. This stage assesses how well three separate parts—the graphical user interface (GUI), the incentive dispensing mechanism, and the bottle identification system—work together. Evaluating the interplay between these disparate components as they are incorporated into the broader system is the main goal. Integration testing joins the bottle identification, incentive dispensing, and GUI components to find and fix any possible problems that could occur when they work together. During this testing step, the cohesive operation of the entire system is verified, as well as the harmonic and efficient functioning of the integrated components. Data flow between them is verified. Integration testing is important to the overall dependability and functionality of the Reverse Vendo Machine because it finds and fixes any inconsistencies or compatibility problems that may arise when separate components are combined.

2.3 End-to-End Testing

In order to verify the system's general operation and user experience, end-to-end testing is an essential phase in the testing process for the Reverse Vendo Machine (RVM) project. Through careful testing, a whole user interaction scenario is simulated, including every step of the process—from inserting a bottle into the machine to using the Graphical User Interface (GUI) to get a reward. The main goal is to confirm that every element—bottle recognition system, reward dispenser, and graphical user interface—works together harmoniously to provide a comprehensive and useful user experience. End-to-end testing checks that the system operates as intended in a production-like environment by running real-world user scenarios. This helps to discover any possible problems that could occur across the whole user journey. This testing process is important for verifying that the workflow as intended by each component integration is followed, ensuring that the Reverse Vendo Machine functions properly and offers users in Barangay 800 Zone 87 San Andres, Manila, a positive experience.

2.4 Performance Testing

For the Reverse Vendo Machine (RVM) project, performance testing is a testing process that evaluates the system's resilience and effectiveness in various scenarios. This study assesses the RVM's performance in a range of settings, such as the number of plastic bottles, illumination, and user interactions. The main goal is to guarantee reliable and effective operation regardless of the particular circumstances the equipment faces when being used in the actual world. Performance testing assists in locating any bottlenecks, resource limitations, or areas of system deterioration by methodically exposing the RVM to a range of bottle pieces, and user interactions. This ensures that the machine can reliably and promptly process bottle recognition, reward dispensation, and GUI interactions, offering a seamless experience for users engaging with the system in Barangay 800 Zone 87 San Andres, Manila. Ultimately, performance testing is instrumental in guaranteeing that the RVM can consistently meet performance expectations and provide optimal functionality in a range of operational scenarios.

2.5 Error Handling and Recovery Testing

Error Handling and Recovery Testing is one of the important phases in the testing procedures for the Reverse Vendo Machine (RVM) project, specifically focused on assessing the system's resilience and responsiveness in the face of errors. This testing evaluates how effectively the RVM identifies, manages, and recovers from errors, ensuring a graceful and user-friendly response in the event of unexpected issues. The procedure involves intentionally introducing errors into the system, such as simulating sensor failures or other potential glitches. This deliberate introduction of errors helps evaluate the RVM's response mechanisms, including its ability to detect errors, provide meaningful error messages to users, and initiate a recovery process to maintain system stability. The overarching goal is to identify weaknesses in error handling, fortify the system against potential disruptions, and enhance the overall robustness of the RVM. Through this testing, the project team can ensure that the Reverse Vendo Machine not only operates seamlessly under normal conditions but also exhibits resilience and reliability when faced with unforeseen challenges in the waste disposal process in Barangay 800 Zone 87 San Andres, Manila.

2.6 Load Testing

In order to evaluate the system's stability and performance at different usage levels, load testing is the method of the testing processes for the Reverse Vendo Machine (RVM) project. The purpose of this testing is to see how effectively the system manages the anticipated loads by simulating situations when several consumers drop bottles into the machine at once. The principal aim is to guarantee that the RVM maintains its responsiveness, stability, and ability to continue its functionality even during periods of high usage. Load testing assists in locating any bottlenecks, resource constraints, or locations where performance degrades by putting the system under higher loads. The project team can adjust the system's design and settings to meet the anticipated usage patterns in Barangay 800 Zone 87 San andres, Manila because of this proactive approach.

2.7 System Testing

Table 2. System test table

Tests	**Expected Result**
Plastic Bottle Recognition System	• The object recognition can recognize the plastic bottle • The system can identify if it is a plastic bottle
Reward Dispensation System	• System ensures that users receive tangible rewards upon successful deposit of a plastic bottle.
Monitoring System	• Application for Reports and for Monitoring the RVM • The application feature is the weekly report, containing how many plastic bottles are deposited and how many rewards are dispensed in every week or every day.
Barangays GUI	• The continuous count of bottles collected, and the overall system status, is shown on the GUI. • System offers a visually attractive and user-friendly platform that can be accessed on the Raspberry Pi.

Table 2 presents the system test table which is divided into four parts, the Plastic Bottle Recognition System, Reward Dispensation System, Monitoring System, and Barangays GUI. The Plastic Bottle Recognition system test focused on how the plastic bottle will recognize accurately if it is a plastic bottle. The Reward Dispensation System test is ensuring that users receive their rewards which are the hygiene materials successfully when they deposit a plastic bottle. The Monitoring System test is focused on application where it contains an accurate weekly report such as how many plastic bottles are dropped in a week or how many rewards it dispenses in a week. Lastly the Barangay GUI where it focused on overall status such as continuous count of bottles collected.